EARLY
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Key competencies in early cognitive development

Things, people, numbers and words

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Summary

Aims and objectives

The Early Intervention Foundation (EIF) champions and supports the use of effective early intervention to improve the lives of children and young people at risk of experiencing poor outcomes. Two recent EIF reviews, *Foundations for Life* and *Language as a child wellbeing indicator*, have both identified early language development as a competency critically associated with children's overall wellbeing. This review expands upon these previous publications by summarising further evidence highlighting the importance of children's early language development, as well as three other competencies associated with their future success: children's understanding of objects, people and numbers. These four competencies were chosen because they draw from perceptual capabilities that are already present at birth and are viewed by many to represent the building blocks for children's later learning.[1]

We provide this information with the ultimate aim of improving the effectiveness of early years services and reducing pervasive learning gaps associated with family income. In doing so, we:

- Provide a comprehensive summary of the most recent evidence involving the development of children's knowledge of objects, people, numbers and language. We intend this information to be used by early years providers and practitioners to strengthen current programmes and practices, as well as develop new ones.
- Identify factors which support the development of early competencies or place them at risk. We believe this knowledge will be particularly useful to commissioners of early years services, so that effective early interventions can be made available to children who need them the most.
- Translate the implications of this evidence for improving the quality of early years services, particularly those aimed at reducing income-related differences in children's cognitive performance at school. We believe this information is particularly useful for the development of policies aimed at increasing social mobility, as well as supporting children's cognitive development more generally.

Methodology

This review provides a comprehensive summary of the development of four important competencies during the first five years of life by systematically answering the following seven questions:

1. What is the competency?
2. In what ways is the competency supported by other child competencies?
3. How does the competency impact children's development over time?
4. What is typical development during the periods of infancy, toddlerhood and preschool?

[1] Spelke, E. S. (2017). Core knowledge, language, and number. *Language Learning and Development*, *13*(2), 147–170.

5. Which factors support or hinder typical competency development?
6. What methods are most appropriate to assess typical and atypical development?
7. What are the implications for early intervention?

Hand search methods involving indexed journals were used to identify the most recent research on early cognitive development to answer questions 1–4. Systematic methods were used to identify large-scale cohort studies to answer question 5 (as described in appendix A). Findings from this second exercise were then augmented with relevant, smaller-scale studies identified through the hand search methods used for questions 1–4. The assessment tools identified for question 6 were obtained by collating information described in previous EIF reports and consultation with experts in the field. We answer question 7 by summarising the information reviewed in questions 1–6 in terms of its implications for early intervention commissioning and practice.

Principles underpinning early cognitive development

This review begins with an overview of many of the principles and assumptions that underpin the evidence we describe:

- Cognitive development is *never* the result of only nature or nurture. Cognitive development is the result of interdependent processes involving the child's genetic make-up, age and environment.
- Children are born with a set of competencies which facilitate their early learning, but learning is also shaped by the family, community, culture and society.
- Children play an active role in their own cognitive development, informed by their current level of cognitive understanding.
- There is an age-related progression in children's thought processes, whereby early capabilities lay the foundation for later capabilities.
- Cognitive development involves both general and specific processes.
- Cognitive capabilities are typically stable within individuals. Cognitive capabilities at earlier points of development are predictive of capabilities at later points, and the strength of these associations increase over time.
- Cognitive development is nevertheless malleable. Stable individual trajectories can and do change when the child's circumstances change. Changes in circumstances can include the availability of effective interventions.

Findings: Children's understanding of things

What is it?

Children's knowledge of objects involves their understanding of the physical properties of objects, object categories and the relationship between objects and their ability to use objects as tools.

What other competencies are associated with children's object knowledge?

- Children's knowledge of objects is supported by their memory and other perceptual capabilities, the executive functions (for example, their working memory, attention inhibition, cognitive flexibility and information processing speed) and language development.

- Children's knowledge of objects is also supported by their ability to share attention with and gain information from others. Studies show that joint attention activities are particularly associated with the learning of object names and the functionality of objects.
- Children's object knowledge is also supported by their motor capabilities. Studies show that gross motor skills involving the ability to sit up and crawl can accelerate children's interaction with objects, as do small motor skills which allow children to explore objects in terms of their critical features.

How does children's knowledge of objects impact their cognitive development over time?

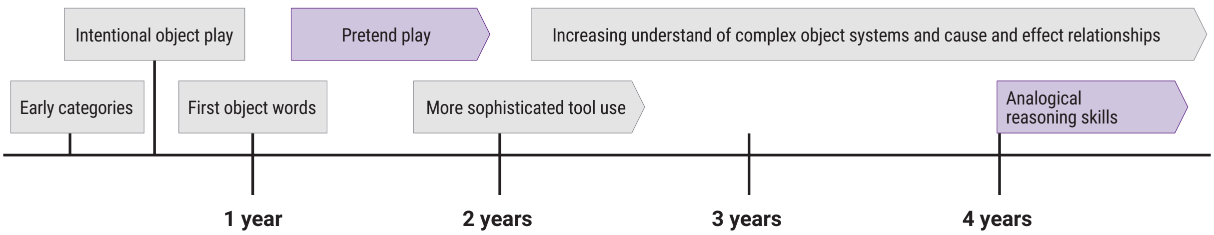
Children's knowledge of objects and object relationships is identified as a core component of children's intelligence, as measured by various scales (such as picture similarities) on IQ tests. Studies show that the manipulation of objects in infancy and knowledge of object relationships in preschool play a critical role in the development of problem-solving skils as children grow older. Studies show that children's object knowledge in preschool is predictive of their intelligence test scores in primary school and academic performance in secondary school.

How do children's theories of objects develop during the first five years?

Figure S1 provides an overview of the key milestones in children's object knowledge occurring during the first five years.

FIGURE S1

Milestones in the development of children's object knowledge during the first five years



Source: EIF

- Antenatal brain development is supported by proper maternal nutrition, reductions in stress, avoidance of harmful substances such as alcohol and tobacco and a full-term birth.
- In infancy, children's object knowledge includes the ability to form object categories on the basis of their critical features, the intentional motor manipulation and exploration of objects and the rudimentary use of objects as tools (for example, using a blanket to pull an object closer).
- During the second year, many of children's first words involve objects familiar to them on a daily basis. Other milestones occurring during the second year include the ability to engage in pretend play and increasingly sophisticated object categories and tool use.
- During the third, fourth and fifth years, children come to understand increasingly complex object relationships and systems. This knowledge, in turn, supports the development of children's higher cognitive reasoning skills which are associated with their academic success during primary and secondary school.

What factors are associated with the development of children's understanding of objects during the first five years?

Factors found to support children's understanding of objects include:

- having a mother who gave birth to her first child between the ages of 30 and 39
- breastfeeding
- being read to
- family rules and routines
- learning opportunities outside of the home, including visits to parks, museums and other places of interests
- higher parental qualifications
- increased family income
- participation in high-quality childcare and preschool education.

Factors that pose risks to children's understanding of objects include:

- adolescent parenthood
- maternal mental health problems during the antenatal and postnatal period
- maternal use of drugs, alcohol and tobacco during the antenatal period
- a preterm birth
- exposure to lead during the antenatal and postnatal period
- low family income
- low parental qualifications.

How is children's object knowledge best assessed during the first five years?

Children's early object knowledge is predictive of their later object knowledge. Methods for assessing children's early object knowledge include:

- the problem-solving sections of the Ages and Stages Questionnaire between one month and three years
- the Bayley Scales of infant and toddler development for in-depth assessments of children's object knowledge and motor development during the first three years
- the Pictures Similarities subtest from the British Abilities Scale for understanding children's knowledge between the ages of three and six.

Details of further assessments are provided in the main report.

What are the implications for early intervention?

- During infancy, all caregivers should be made aware of the importance of object manipulation and exploration, and the value of caregiver and child object play.
- During toddlerhood, all caregivers should be made aware of the value of learning experiences outside of the home.
- During the later preschool years, all families can benefit from messages that highlight the importance of books for providing young children with information about object relationships, as well as toys and other learning materials, which support children's knowledge of object categories and the use of objects as tools.
- Opportunities to play with objects and gain information about them should be made available through children's centres and early childcare.

- Early years' curriculums should provide children with opportunities to learn about object characteristics, categories and systems.

Findings: Children's understanding of people (theory of mind)

What is it?

'Theory of mind' (ToM) involves the awareness that some objects are alive and conscious, that conscious beings have goal-directed intentions, and that individuals differ in what they know and understand. Children's ToM is typically understood through the child's ability to predict the thoughts of others based on others' knowledge, even if this knowledge happens to be different from what the child knows to be true.

What other competencies are associated with the development of children's theory of mind?

Children's ToM capabilities are associated with the development of the executive functions, children's early language capabilities and their ability to understand the causal relationship between their own thoughts and behaviours, and the thoughts and behaviours of others.

How does children's theory of mind impact their cognitive development over time?

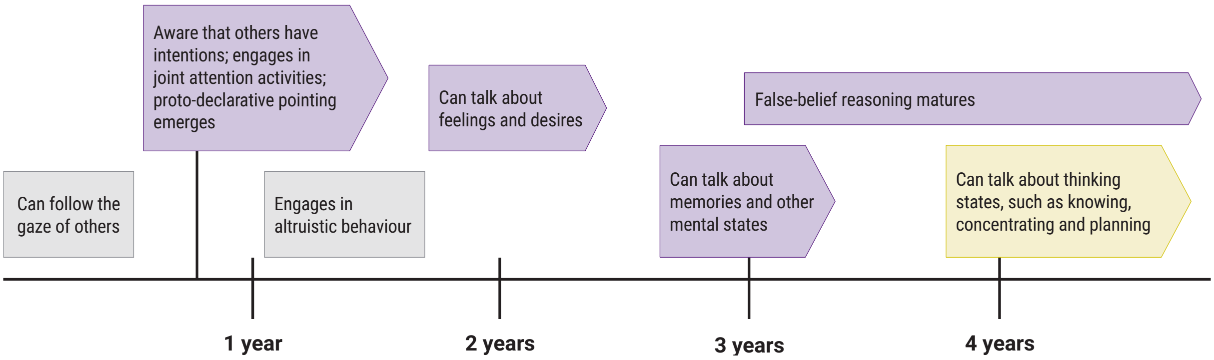
Children's ToM capabilities during preschool allow them to anticipate the thoughts and feelings of others and are believed to contribute to children's social skils. Studies show that ToM skills at age four predict children's popularity and friendships in primary and secondary school. ToM capabilities are also associated with children's sensitivity to teacher feedback, which in turn predicts their academic success.

How does children's ToM develop during the first five years?

Figure S2 provides an overview of the key milestones in children's ToM occurring during the first five years of life.

FIGURE S2

Milestones in the development of children's ToM during the first five years



Source: EIF

- Precursors to children's ToM understanding in infancy include a preference for human faces, higher-pitched vocal tones and the ability to track moving objects.
- At three months, most infants can follow the gaze of others.

- At nine months, most children are capable of sharing in joint attention activities with others. Joint attention reflects the understanding that others may have interests and knowledge that is worth understanding and sharing.
- The protodeclarative point (for example, pointing at an object or event), occurring at around 10 months, is also thought to be indicative of the infant's awareness that knowledge may be shared.
- Key ToM milestones occurring during the second year include spontaneous altruistic behaviours, as well as the use of 'mental-state' talk for sharing thoughts and feelings with others.
- By the end of the third year, most children can talk about past events and discuss events occurring in the future.
- Many four-year-olds are capable of manipulating the thoughts of others by telling sophisticated lies.
- During the fifth year, most children can fully predict the false beliefs of others. Children are also able to talk about more complex thinking states such as knowing, planning and concentrating.

What factors are associated with the development of children's understanding of theory of mind during the first five years?

Supportive factors associated with the development of ToM:

- treating the child as a valued member of the family through 'mind-minded' conversations during infancy and toddlerhood
- conversations about what people want, like and think – also referred to as 'mental state' talk
- having an older sibling within one and 12 years of the child's age.

Risk factors associated with the development of ToM:

- a genetic risk of autism
- speech and language delays
- low family income.

How is children's ToM best assessed during the first five years?

Methods for assessing children's ToM include items from the communication section of the Ages and Stages Questionnaire, as well as the Ages and Stages – Social, Emotional Questionnaire. In later preschool, a variety of other validated measures exist, including the Theory of Mind Inventory-2.

What are the implications for early intervention?

- Parents should be made aware of the value of mind-minded parenting behaviours throughout infancy and toddlerhood and mental-state talk, especially from the age of one onwards.
- Childcare providers should be encouraged to use mental-state talk with children.
- Preschool curriculums should be enhanced through content which increases children's awareness of others' feelings, intentions and perspectives.
- Targeted interventions should be made available to parents with a child identified as having an autism spectrum condition.

Findings: Children's understanding of number

What is it?

The development of children's numerical understanding involves their awareness of the concepts of more and less, the ability to count, basic addition and subtraction skills, and their understanding of the relationship between Arabic numerals and specific cardinal values. Children's understanding of number is thought to operate through two systems:

- an approximate number system (ANS) which allows them to discriminate differences in magnitude
- a precise number system (PNS) which allows them to understand the precise value of numerosities of four or less.

What other competencies are associated with the development of children's understanding of number?

Children's numerical understanding is supported by the executive functions, and working memory in particular. Early number capabilities are also associated with children's early language development and motor skills.

How does children's early understanding of number impact their development over time?

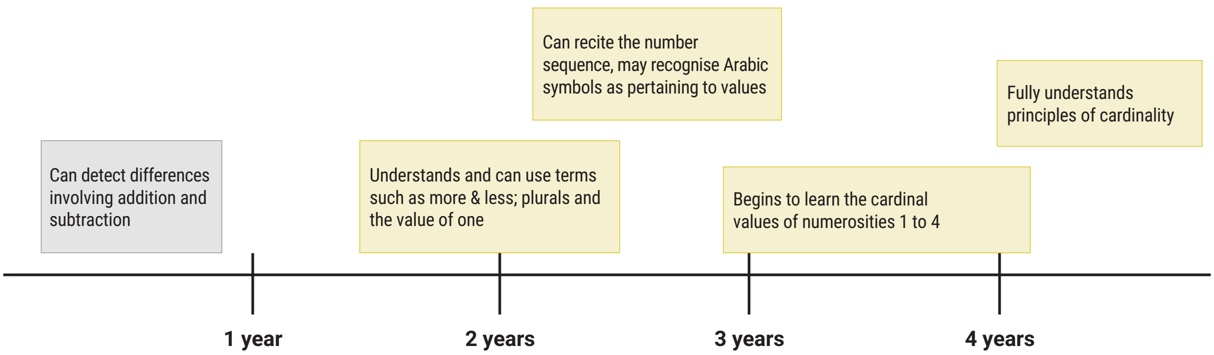
Children's understanding of number during preschool is consistently associated with their mathematical achievement in primary and secondary school. Mathematical achievement in turn is consistently found to be the strongest predictor of children's overall school achievement and their success in entering the workforce.

How does children's understanding of number develop during the first five years?

Figure S3 provides an overview of the key milestones in children's understanding of numbers occurring during the first five years.

FIGURE S3

Milestones in the development of children's understanding of number occurring during the first five years



Source: EIF

- Infants have been found to discriminate differences in magnitude at ratios of 1 to 3 within hours of birth. Magnitude discrimination capabilities continue to improve throughout early childhood.
- Infants can also discriminate differences in small numbers between one and three, and this is associated with their rudimentary understanding of addition and subtraction principles.

- By the end of the second year, many toddlers understand the word one, the use of plurals, and words involving values such as 'many', 'more' and 'less'.
- During the third year, many children learn to recite the number list.
- By end of the third year, many children will have begun to learn the cardinal values associated with the words two through four. This learning is gradual, and the cardinal values are learned one at a time. Once children learn the word five, however, most children will be able to accurately apply the appropriate number name to the cardinal values of all numbers.
- Children's understanding of the counting principles at the end of reception is highly predictive of their mathematical achievement for the remainder of primary school.

What factors are associated with the development of children's understanding of numbers during the first five years of life?

Supportive factors associated with children's understanding of number:

- 'number talk' conversations with caregivers about small and large numerical values
- the frequency with which caregivers emphasise large numerical values
- the availability of formal numerical activities in the home
- enriching early years education, which includes activities that support children's understanding of Arabic numerals, the counting principles, and concepts associated with addition and subtraction.

Risk factors associated with children's early understanding of numbers:

- a preterm birth
- speech and language delays
- low family income.

How is children's understanding of numbers best assessed during the first five years?

Most assessments of children's numerical understanding are validated for children aged four and older. These assessments include the Early Math Diagnostic Assessment (EMDA) and the Test of Early Mathematical Ability. The problem-solving section of the Ages and Stages Questionnaire also includes questions involving children's understanding of numbers from 30 months onwards. However, mathematical difficulties are not typically diagnosed with any reliability until children enter primary school.

What are the implications for early intervention?

- All families are likely to benefit from messages regarding the importance of large and small number-talk in the home, as well as number-related play.
- Income-related differences in children's counting capabilities have been identified by age four and increase throughout primary and secondary school. Studies show that low-income children nevertheless have an informal understanding of numerical concepts that supports their learning of the counting principles. The ages of three to five are therefore considered an ideal time to rectify income-related learning gaps in children's understanding of numbers.
- Enriching preschool and reception curriculums which include content aimed at supporting children's understanding of the counting principles have good evidence of improving children's numerical understanding.

- Income-related learning gaps might further be reduced through strategies aimed at increasing the frequency of informal and formal mathematics activities in the home. Formal activities include those that support children's understanding of the counting principles, and activities that increase children's knowledge of Arabic numerals and number signs.

Findings: Children's language development

What is it?

Language is traditionally defined as the systematic and conventional use of sounds, signs or written symbols for communication purposes and self-expression. Language provides children with an efficient means to represent and combine information from the environment in a way that can be communicated with others. Language initially develops as a result of children's understanding of objects, people and numbers, but then fundamentally transforms children's thought processes within each of these systems by providing children with words to describe and think about many of the core concepts fundamental to each cognitive system.

Language development is typically understood through four separate components:

- phonology involves the ability to perceive differences between sounds and words, as well as reproduce these sounds
- semantics refers to the knowledge of vocabulary
- pragmatics involves children's knowledge of the communicative functions of language
- grammar involves knowledge of the rules which govern the ways in which words are put together in sentences to convey specific meanings.

What other competencies are associated with the development of children's understanding of language?

Children's language development is supported by their ability to understand the intentions of others. Language development is also reliant on children's ability to detect patterns in human speech.

How does children's early understanding of language impact their development over time?

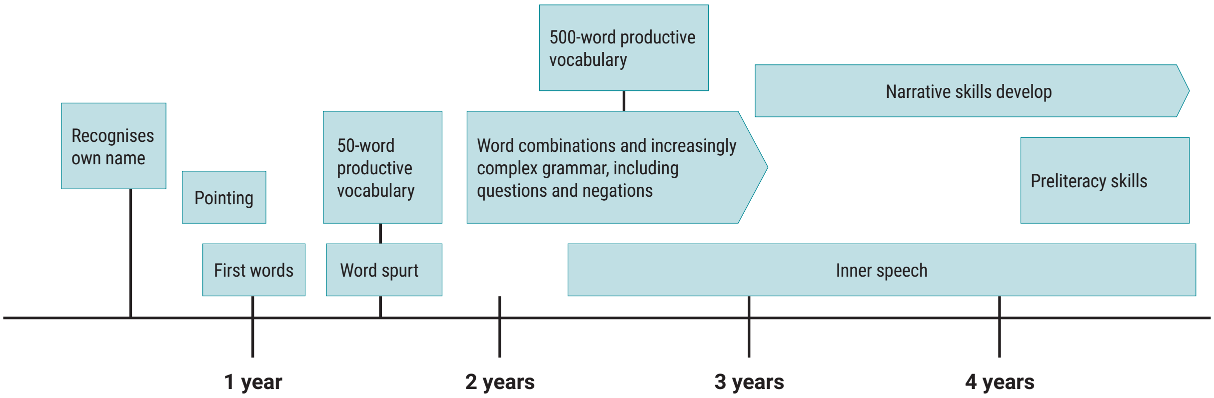
Children's language capabilities are strongly associated with a wide variety of important child outcomes – including the three previous cognitive competencies described in this review – as well as children's social, emotional and behavioural development. Once in school, children's language capabilities are highly associated with their academic achievement and entry into the workforce.

How does children's language develop during the first five years?

Figure S4 provides an overview of the key milestones in children's language development during the first five years.

FIGURE S4

Milestones in the language development occurring during the first five years



Source: EIF

- Key milestones in children's receptive understanding of language during the first year include the ability to recognise their own name. This typically occurs between four and six months.
- Key milestones in children's expressive capabilities include the occurrence of reduplicative babbling, which typically occurs at around six months.
- The protodeclarative point is believed to suggest that the infant understands that he or she can communicate with others to gain or share information. Protodeclarative pointing frequently occurs during joint attention activities involving objects at around the time infants are 10 months old.
- Most children can say one or two words at the time of their first birthday.
- Children's vocabulary grows dramatically during the second year. Children can typically say approximately 300 words by the time of their second birthday.
- By the age of two, many children are putting words together in sentences.
- From the beginning of the third year onwards, children's word combinations become increasingly more sophisticated as their vocabulary continues to grow.
- During the third year, children begin to use inner speech to practise language and monitor their own behaviour.
- During the fourth year, children begin to converse with others in structured narratives.
- During the fifth year, children begin to acquire preliteracy skills associated with their school readiness.

What factors are associated with the children's language development during the first five years?

Supportive factors associated with children's language development:

- the child's mother was between the ages of 30 and 39 at the time of her child's first birth
- being firstborn
- being a girl
- high levels of age-appropriate infant-directed speech that is responsive to the child's specific interests
- frequent joint attention activities

- the availability of books in the home and shared reading
- degree-educated parents
- high family income
- childcare from one adult in the first two years
- participation in childcare from age two onwards
- enriching preschool education.

Risks associated with children's early language development include:

- adolescent motherhood
- high levels of stress or the existence of maternal mental health problems during pregnancy and postnatally
- maternal use of harmful substances
- a preterm birth
- low parental qualifications
- higher number of siblings

How are children's language capabilities best assessed during the first five years?

Parental reports of their child's early communication behaviours are considered to provide reliable estimates of children's verbal abilities during the first 14 months. The most widely used measures during the second year involve adaptations of the MacArthur Bates Communicative Development Inventories. Later in development, direct testing by a trained practitioner is required. Tests with particularly good reliability include the New Reynell and the British Picture Vocabulary Scales.

What are the implications for early intervention?

- Caregivers should be provided with information about the importance of infant-directed speech which is developmentally appropriate and responsive to children's needs, in addition to information about the importance of book sharing activities.
- Children can grow in and out of language difficulties throughout development. This means that children's language should be monitored on an ongoing basis from the age of two onwards, so interventions can be made available as and when needed.
- Children's language development is highly associated with caregiver qualifications and family income. Early intervention activities can therefore be effectively targeted on the basis of family income.
- Income-related language gaps are present already by 18 months and entrenched by the age of three. Early intervention activities aimed a reducing income-related language gaps should therefore start well before the child's first birthday.

Summary of key findings

- Studies consistently show that early cognitive competencies are predictive of later school achievement. In particular, cognitive capabilities at age four are reliable predictors of children's academic success from reception onwards.
- Studies show that highly nurturing and stimulating environments in the early years potentially protect children from poor cognitive outcomes as they grow older, whereas early experiences of disadvantage may place children at a developmental risk.

- Nurturing home learning environments include positive and sensitive parent–child interaction, enriching learning materials that include age appropriate books and toys, and enriching learning experiences outside of the home, which may include high-quality childcare and early years education.
- Frequent, high-quality infant-directed speech and behaviours which are responsive to the child's developmental needs are found to make the greatest impact in supporting early cognitive and language outcomes.
- Income-related learning gaps are both wide and deep. These gaps are already present by the age of three (and in some cases even earlier) and then steadily increase as children grow older.
- Income-related learning gaps are not determined by one single factor, meaning that there is no single solution. Strategies for addressing income-related learning disparities must therefore be comprehensive and multifaceted.

A variety of factors other than family income are also associated with individual differences in children's early cognitive development, including preterm birth and maternal mental health problems during pregnancy and after the child is born. These factors should therefore be incorporated as part of comprehensive, system-wide strategies which aim to support children's cognitive development during the early years.

Recommendations

The earlier, the better

The evidence described in this review makes clear that individual differences in children's cognitive development are evident from the first year onwards. **Early years services should therefore be optimised to support children's cognitive development from the antenatal period onwards.**

- Activities that support children's cognitive development during the antenatal period include those that target risks associated with a preterm birth and increase mothers' access to effective mental health services.
- Activities with evidence of supporting cognitive outcomes during the first year include intensive home visiting interventions for families with pre-identified risks, including low family income.
- Activities found to support children's cognitive development during toddlerhood include continued intensive home visiting support, as well as enriching childcare from the age of two onwards.
- There is preliminary evidence to support the use of various speech and language interventions for children identified as having language delays from the age of two onwards.
- There is good evidence to increase the availability of enriching and high-quality early years education for disadvantaged children starting at age two. The research described in this review suggests that early years curriculums may be enhanced through content that supports children's understanding of the world and the relationships between objects, their ToM capabilities through stories and role play, their awareness of numbers through counting activities, and their understanding of language through activities which support preliteracy skills.

A comprehensive approach

Early learning gaps are multi-determined, meaning that there is no single solution. **Reducing income-related learning gaps therefore requires a comprehensive approach, providing age-appropriate support to all levels of need.** Family income should be a primary target of this support, although any comprehensive strategy should make use of individual assessments to further determine when and how early intervention services should be provided.

A role for everyone

The comprehensive approach described in the previous section identifies a prominent role for everyone involved in the delivery of early years services that support children's early cognitive development. This includes midwives, health visitors, GPs, speech and language therapists, educational psychologists, children's centres, childcare providers, nursery and preschool educators, intervention providers, academic researchers and early years' commissioners.

Strong support from central government is also crucial for supporting children's early learning needs, and efforts such as the recently announced 'Chat, Play and Read' behaviour change strategy for improving the quality of the home learning environment are warmly welcomed. However, the evidence described in this report tells us that behaviour change messages are simply not enough to improve the learning outcomes of the nation's most disadvantaged children. We therefore recommend that **central government increase its investment in health visiting so that the service can provide, alongside its universal offer, a package of intensive home visiting support for low-income families to support their young children's early learning needs.** The government's recent announcement to provide speech, language and communication training to health visitors is a welcome start.

We further believe that the 15-hour childcare offer for the most disadvantaged families represents a good opportunity to close income-related learning gaps. **We therefore recommend that the government considers enriching this offer through additional support for parents that is offered alongside and through the 15-hour childcare offer.** This support should be responsive to individual family needs and provide sufficient opportunities for parents to learn new skills for supporting the home learning environment. This support should also be augmented by evidence-based parenting interventions and other local family support services.

Moving forward

This review has summarised the most recent evidence regarding children's early cognitive development with the aim of improving the effectiveness of early years services and providing recommendations for reducing income-related learning gaps. This evidence suggests that there are no easy solutions, but there are some clear options for moving forward. These options include starting as early as possible, already during the antenatal period. We also emphasise the need for a strong commitment, both at the local and central level to make sure that sufficient resources are available so that these options are possible. While some of these options are clearly costly, they also stand the greatest chance of reducing income-related learning gaps in the short run, and increasing social mobility over time.

Full contents

Part 1: Overview

1. Introduction

1.1 Why this review?

There is no question that a strong and pervasive achievement gap exists between rich and poor children. It is already present by the time they enter reception and increases until they leave secondary school.[2,3] The achievement gap then follows children into adulthood where it determines their access to higher education, employment opportunities and earning potential.[4] Although results from the Early Years Foundation Stage Profile indicate that the gap may be narrowing, it is doing so at a very slow rate, suggesting that it will be over 40 years before it is closed if nothing else were to change.[5] It is thus likely that this gap will continue to influence many of the social inequalities existing in the UK today.[6]

The primary aim of this report is to consider the ways in which this gap can be prevented or reduced during the preschool years, with the best evidence suggesting that this means starting very early. In our recent review, *Language as a child wellbeing indicator*,[7] we reported that a substantial language gap already exists by the age of three, with middle and upper-income children having a vocabulary which is at least twice the size as their low-income peers.[8] Studies show that this gap is associated with the amount of verbal stimulation children receive in their homes[9] and is predictive of their performance in reading and maths in primary and secondary school.[10] Studies now also show that this gap is already present at 18 months, at a time when children are just starting to master their first words.[11,12]

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11 Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological science*, *24*(11), 2143–2152.

12 Fernald, A., Marchman, V., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science, 16*, 234–248.

Some have argued that the achievement gap can be closed by increasing young children's vocabulary, although the best evidence tells us that vocabulary is only part of the story.[13] While vocabulary is indeed indicative of what children know, many other factors contribute to children's understanding of words.[14] This means that closing the language gap involves much more than increasing the number of words disadvantaged children hear every day. It also means supporting their ability to master the concepts which lie beneath the words. Competencies known to contribute to children's early concept development include their understanding of objects and numbers, and their ability to accurately assess the intentions of others.[15] While these competencies are often highly correlated with children's language capabilities, they constitute additional skills which also contribute to the achievement gaps that become evident later in life.[16]

The primary aim of this review is to consider the nature of these cognitive competencies and the processes which support or place them at risk. We do this by summarising:

- the most recent evidence involving the development of early cognitive competencies identified as important for children's future learning
- the processes which support the development of these competencies, particularly those involving the young child's learning environments
- processes which support or undermine the development of these early learning competencies
- methods for measuring individual differences in the development of these competencies
- where and how early interventions might make a difference in supporting the development of these competencies.

1.2 How can this knowledge be used?

The Early Intervention Foundation (EIF) was established in 2013 with the aim of putting the most recent and robust research evidence regarding children's development into practice. Our mission is to ensure that effective early intervention is available and is used to improve the lives of children and young people at risk of poor outcomes.

We believe that the knowledge summarised in this report can usefully inform the development of policies and practices aimed at reducing the risks associated with the language gap and poor academic achievement. Specifically, we maintain that knowledge of early cognitive development can inform policies that aim to:

- increase the quality of the home learning environment during the first two years of life, including disadvantaged parents' ability to support their children's early learning
- increase the quality of the childcare made available through the 15-hour-per-week childcare offer for disadvantaged two-year-olds through more enriching learning opportunities
- increase the quality of the early years provision made available to disadvantaged preschool children.

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13 Marulis, L. M., & Neuman, S. B. (2010). The effects of vocabulary intervention on young children's word learning: A meta-analysis. *Review of educational research*, *80*(3), 300–335.

14 Waldfogal, J. & Washbrook, E. (2010). *Low income and early cognitive development in the U.K*. The Sutton Trust.

15 National Research Council. (2015). *Transforming the workforce for children birth through age 8: A unifying foundation*. National Academies Press.

16 Rittle-Johnson, B., Fyfe, E. R., Hofer, K. G., & Farran, D. C. (2017). Early Math Trajectories: Low-Income Children's Mathematics Knowledge from Ages 4 to 11. *Child development*, *88*(5), 1727–1742.

The information provided in this report is organised so that those commissioning and delivering early years services can make informed decisions about how and when to increase the support available to families who need it the most. Information that is likely to be particularly beneficial for the commissioning process includes knowledge about the specific risks associated with children's early cognitive development, as well as the validated measures for assessing these risks.

1.3 Methodology

This report provides information about children's early cognitive development through separate chapters covering the following four competencies:

- children's understanding of objects (that is, things)
- children's understanding of the thought processes of others (also referred to as children's 'theory of mind')
- children's understanding of numbers
- children's early language development.

Each chapter answers the following seven questions for each competency:

1. What is the competency?
2. In what ways is the competency supported by other child competencies?
3. How does the competency impact children's development over time?
4. What is typical development during the periods of infancy, toddlerhood and preschool?
5. Which factors support or hinder typical competency development?
6. What methods are most appropriate to assess typical and atypical development?
7. What are the implications for early intervention?

The primary aim of this review is to provide a concise and systematic synthesis of the most recent evidence regarding early cognitive development gained from both observational and experimental studies. A variety of methods were used to access diverse research literatures to answer the first six questions for each competency.

- **Questions 1–4:** Manual or 'hand search' methods involving indexed journals were used to identify the most recent research on early cognitive development. Citation forward and backward methods were also used to confirm key studies and theoretical frameworks.
- **Question 5:** Systematic methods were used to identify longitudinal observational studies involving large populations. These studies include national cohort studies taking place in developed countries around the world, including the UK, US, Canada, Australia and New Zealand. Further details about the search terms and strategy can be found in appendix A. Findings from this exercise were augmented with relevant, smaller-scale studies identified through the hand search methods used for questions one through four.
- **Question 6:** Valid methods for assessing early cognitive development were obtained from the studies identified through the manual and systematic search methods described above.

Each chapter concludes by considering the implications of questions 1–6 for early intervention. Where relevant, further recommendations are made for interventions and practices that might be offered on the basis of child and family need. We distinguish level of need in terms of the following four levels (see figure 1.1).

FIGURE 1.1
Levels of need

Source: EIF

- **Universal**: Practices/interventions which are available to all families, including immunisations, developmental reviews and antenatal care.
- **Targeted selective**: Practices or interventions that target or 'select' subgroups of the population with characteristics that place them at greater risk of experiencing problems. Selected characteristics include economic hardship, single parenthood, young parents and ethnic minorities. Examples of targeted-selective support include advice provided to teenage mothers or childcare that is available to families living in disadvantaged circumstances.
- **Targeted indicated**: Practices/interventions for specific families with a child or parent with a pre-identified issue or diagnosed problem requiring more intensive support. Examples of services/interventions falling into this category include support for antenatal depression and parenting advice for families with a pre-identified issue with their child's development.
- **Specialist**: Refers to interventions developed for high-need families, where there is an ongoing problem (such as illness or special needs) or serious child protection concerns.

It is worth noting that much of the research described in this review is gender-independent when describing the the parents' role in children's development. Fundamentally, all of the parenting behaviours apply to mothers, fathers and other non-biological caregivers, with the exception of pregnancy, when maternal behaviours may have direct bearing on child outcomes. We therefore use the terms parents and caregivers interchangeably to describe behaviours that apply to fathers or mothers. The term mother is reserved for behaviours specific to mothers, or studies that only included mothers in their sample.

2. Concepts, frameworks and theoretical assumptions

In this chapter, we provide an overview of some of the key theories, assumptions and principles that inform much of the research described in this review. It is worth noting that many of these theories are highly debated and it is not our intention to take sides. However, we believe that some discussion of the nature of these debates is necessary for contextualising the findings that are described in the following chapters.

2.1 What do we mean by cognitive development?

Cognitive development is traditionally understood as the emergence of children's ability to think and understand.[17] *Cognitive* processes include mental activities of all types that help children acquire, modify and communicate information. Definitions of cognitive processes include functional activities involving perception and memory that allow children to recognise and categorise various stimuli, as well as higher order capabilities that allow children to predict, plan and problem solve. Cognitive processes may encompass unconscious activities – that is, those occurring outside of an individual's active awareness – and conscious activities – for example, mental strategies used to plan, make comparisons and develop and test hypotheses. Cognitive *development* is closely related to that of learning, but with an important difference – as it fundamentally refers to the *changes* that occur in children's thought processes which are the result of learning – be it through adult instruction or child-driven behaviour.[18]

Much of cognitive development is not directly observable and can only be understood through the child's actions or explanations. Understanding the thought processes of babies is particularly challenging, as they have limited control over their motor skills and cannot yet explain their thinking to others. This means that our knowledge of early cognitive development must be inferred through systematic observation and experimentation. The result is a heterogeneous set of definitions, frameworks and taxonomies used by disciplines ranging from philosophy to the neurosciences. Some of these frameworks define cognition in terms of all conscious and unconscious mental activities, whereas others consider it more narrowly in terms of a specific set of skills which contribute to children's ability to learn at school.

For this review, we have taken a pragmatic approach in our definition of cognitive development by adopting the framework put forth by the US National Research Council's Committee (NRC) on the Science of Children Birth to Age 8. This committee was tasked to identify how the most recent scientific evidence from the fields of child development, health and education could be used to support those delivering services to young children.[19] Consensus building techniques were used to gain expert views from a wide range of disciplines about the competencies contributing to children's early development. The result was a framework linking 26 distinct competencies within four important developmental domains. Figure 2.1 provides an overview of the committee's framework and table 2.1 lists the individual competencies within each of the four domains.

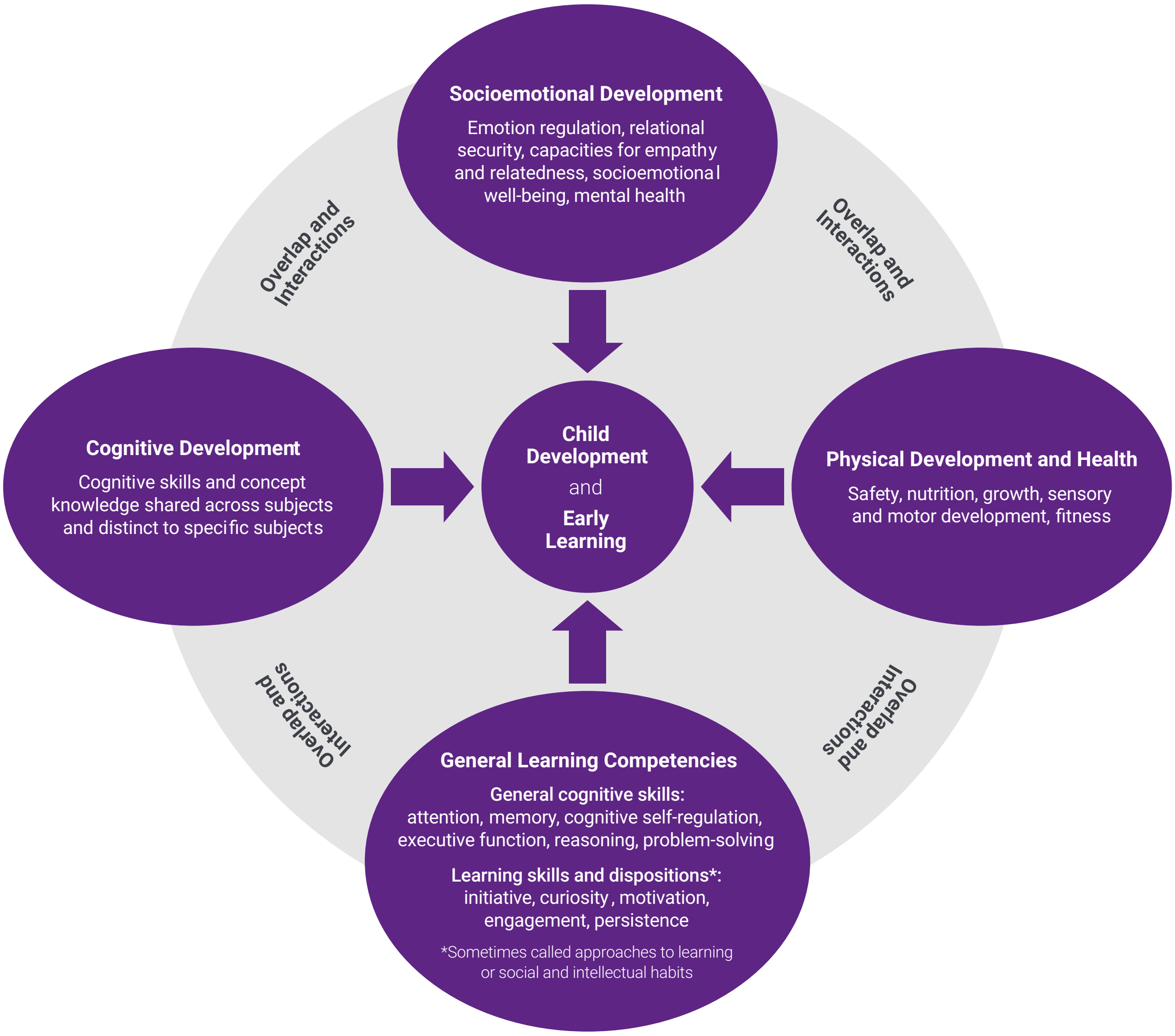
[17] Bjorklund, D. F., & Causey, K. B. (2018*). Children's thinking; Cognitive development and individual differences* (6th edition). London: Sage Publications.

[18] Newcombe, N. S. (2011). What is neoconstructivism? *Child Development Perspectives, 5*, 157–160.

[19] National Research Council. (2015). *Transforming the workforce for children birth through age 8: A unifying foundation*. National Academies Press.

FIGURE 2.1

Domains and subdomains key to children's development



Source: Reproduced from US National Research Council (2015). Transforming the workforce for children birth through age 8

TABLE 2.1

Child competencies across four important domains of early child development

Cognitive (6)	Social/emotional (7)	Learning competencies (9)	Physical health (4)
• Implicit theories • Objects • Living things (theory of mind) • Numbers • Conditional probability • Causal inference • Language	• Temperament • Self-awareness • Self-management • Attachment security • Social-awareness • Relationship skills • Responsible decision- making	• Memory • Attention control • Inhibitory control • Cognitive flexibility • Curiosity • Initiative • Mastery motivation • Persistence • Learning beliefs	• Physical growth • Child health • Nutrition • Physical activity

The four domains within the NRC framework are defined as follows:

- **Cognitive competencies** are those which support the learning of specific subjects, such as literacy and maths, and are the primary topic of this report.
- **Learning competencies** include mental and self-regulatory processes which allow children to regulate and control cognitive capabilities while learning. These include the executive functions, which help the child to manage their memory, attention and emotions in the completion of learning tasks, as well as 'noncognitive' skills (such as initiative, persistence) which influence the degree to which children engage and persist in learning tasks.
- **Social/emotional competencies** include the child's self-awareness and empathy for others, which are conceptually different from more purely intellectual thought processes, but also clearly contribute to children's academic success.
- **Physical competencies** include children's physical maturation, physical health, and small and large motor skills.

It is important to acknowledge that we do not view the NRC framework as the best or only system for understanding children's development, nor do we view these competencies as wholly discrete or separable. Nevertheless, the framework provides a useful starting point for identifying which competencies are important in early development and understanding how various factors impact their development over time.

Ideally, we would like to be able to summarise the most recent evidence involving all 26 competencies. However, this is not feasible or practical within a single report. We therefore begin with four competencies thought to form the basis of children's core knowledge about the world: children's understanding of objects, people, numbers and language.[20]

2.2 Theories, assumptions and frameworks of early cognitive development

Beyond nature vs nurture

Research in cognitive development has historically been preoccupied with understanding the contribution of nature – that is, the child's inherited characteristics, versus nurture – the child's external environment, in predicting children's cognitive capabilities. Evidence supporting the nature (also sometimes referred to as 'nativist') side include findings from studies involving twins (see below), which indicate that many cognitive processes likely have a genetic basis.[21] Evidence supporting the nurture side comes from studies linking environmental factors (such as family income) to children's early learning and school achievement.[22] It is not the aim of this report to resolve this debate, except to say that the science has moved beyond it to more dynamic models which recognise the interdependence of a variety of processes in predicting children's development.[23] These processes include epigenetic mechanisms which influence gene expression in response to biological and environmental stimuli.

[20] Spelke, E. S. (2017). Core knowledge, language, and number. *Language Learning and Development*, *13*(2), 147–170.

[21] Plomin, R., DeFries, J. C., Knopik, V. S. & Neiderheiser, J. (2013). *Behavioral genetics* (6th edition). New York, NY: Worth Publishers.

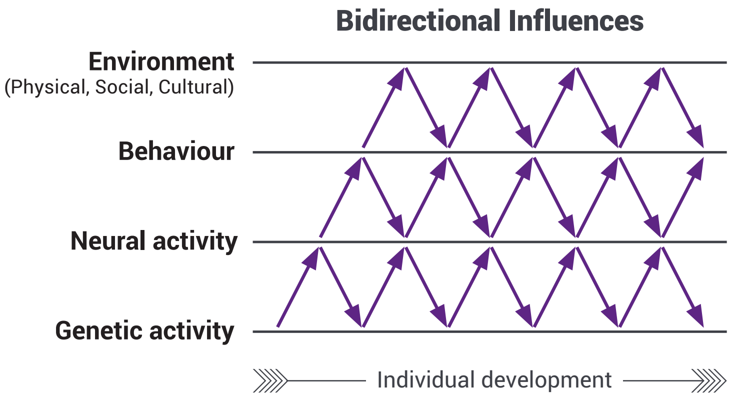
[22] Feinstein, L. (2003). Inequality in the early cognitive development of British children in the 1970 cohort. *Economica*, *70*(277), 73–97.

[23] van IJzendoorn, M. H., Bakermans-Kranenburg, M. J., & Ebstein, R. P. (2011). Methylation matters in child development: Toward developmental behavioral epigenetics. *Child Development Perspectives*, *5*(4), 305–310.

Studies involving identical twins provide one method of understanding how gene expression can change once environments begin to differ. While patterns of gene expression appear to be virtually identical in twins sharing the same environment at age three, they often diverge quite substantially by the time the twins are age 50 and have been living in separate environments for some time.[24] Hence, some studies show that as twins grow and age, differing life experiences lead to differences at the cellular level, which in turn, trigger differences in gene expression. Over time, differences in gene expression further alter the individual's interaction with the environment, again triggering changes at the cellular level, which in turn alter gene expression, and so on.[25] Figure 2.2 provides a model for considering how these bidirectional processes may occur.

FIGURE 2.2

The bidirectional nature of epigenetic processes



Source: Reproduced from Gottlieb, G. (2001). *Individual development and evolution: The genesis of novel behavior*. Psychology Press.

Heritability estimates

The relative contribution of genetic and environmental factors on children's development is frequently understood through a *heritability estimate*. Heritability estimates are derived from large-scale twin studies which compare the proportionate impact of inherited and environmental processes on development outcomes among identical and fraternal twins. Identical twins are the same sex and share 100% of their genes. Fraternal twins can be same- or opposite-sex and share, on average, 50% of their genes. Statistical comparisons between these two groups, as well as twins who have been placed in adoption, allow researchers to estimate the degree to which genetic factors influence specific behaviours or capabilities in comparison to environmental influences. Environmental influences include processes that occur in the twin's *shared environment* – that is, their family or school – and their *non-shared environment* – that is, the twin's non-shared experiences.

Heritability estimates range from 0.0 to 1.0, with 0.0 indicating zero heritability and 1.00 meaning the capability is entirely heritable. Heritability estimates are based on several assumptions which are important to consider when interpreting their value.

- Heritability estimates are most useful if there is sufficient variation in the capability being measured. If there is no variation, then the heritability estimate will result in a value of 1.00, which is not particularly meaningful for understanding differences in children's development.

[24] Fraga, M. F., Ballestar, E., Paz, M. F., Ropero, S., Setien, F., Ballestar, M. L., ... & Boix-Chornet, M. (2005). Epigenetic differences arise during the lifetime of monozygotic twins. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(30), 10604–10609.

[25] Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype environment effects. *Child development*, *54,* 424–435.

- Heritability estimates can mistakenly produce very high or low values if there is not sufficient variation within the population under investigation. Sample sizes must therefore be sufficiently large to detect variations in the capabilities being measured.
- It is important to recognise that heritability estimates are nothing more than population-wide snapshots. This means they can only provide information about a specific population at a specific point in time, thus providing no predictive value at the individual level.
- Heritability estimates may also measure factors *associated* with variations in the capability under investigation, and the extent to which they are genetically determined is unknown.[26] As a result, heritability estimates should never be interpreted as an indication of genetic determinism. For example, studies repeatedly show that political affiliation is passed down through generations, and therefore highly heritable, with estimates ranging in the .40 range.[27] Few would argue, however, that political affiliation is genetically inherited.
- Heritability estimates are thought to routinely overestimate the role of heritable factors, although the extent to which they do this is not fully understood.[28] This is because reciprocal gene and environment interactions also influence heritability, but the magnitude of this impact is difficult to determine. The example of Mozart (box 2.1) illustrates the ways gene-environment interactions could potentially magnify heritability estimates.
- The amplifying effects of gene-environment interactions can lead to dramatic changes in heritability estimates depending on children's age. In some instances, heritability estimates increase throughout development as heritable effects cumulate, whereas in others, heritability estimates decrease as children's unique interactions with the environment increase.
- Environmental contributions are often non-linear, as their proportional value tends to be higher in extreme circumstances. For example, environmental factors have been found to be more influential in highly deprived populations, although not in the UK.[29]
- Environmental factors (such as parenting, education) have also been found to contribute more strongly to outcomes among children with specific genetic risks. For example, studies show that parenting quality likely mediates the developmental outcomes for children with attention deficit hyperactivity disorder (ADHD). In this respect, studies show that high-quality parenting reduces the risk of developmental problems, whereas poor-quality parenting increases the risk of poor developmental outcomes.[30] Thus, the child's environment remains an important influence despite the presence of strong heritable factors.[31]

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26 Sauce, B., & Matzel, L. D. (2018). The paradox of intelligence: Heritability and malleability coexist in hidden gene-environment interplay. *Psychological Bulletin*, *144*(1), 26.

27 Hatemi, P. K., Medland, S. E., Klemmensen, R., Oskarsson, S., Littvay, L., Dawes, C. T., ... & Christensen, K. (2014). Genetic influences on political ideologies: Twin analyses of 19 measures of political ideologies from five democracies and genome-wide findings from three populations. *Behavior Genetics*, *44*(3), 282–294.

28 Bronfenbrenner, U., & Ceci, S. J. (1994). Nature-nurture reconceptualised in developmental perspective: A bioecological model. *Psychological Review, 101,* 568–586.

29 Tucker-Drob, E. M., Rhemtulla, M., Harden, K. P., Turkheimer, E., & Fask, D. (2011). Emergence of a gene× socioeconomic status interaction on infant mental ability between 10 months and 2 years. *Psychological Science*, *22*(1), 125–133.

30 Kaiser, N. M., McBurnett, K., & Pfiffner, L. J. (2011). Child ADHD severity and positive and negative parenting as predictors of child social functioning: Evaluation of three theoretical models. *Journal of Attention Disorders*, *15*(3), 193–203.

31 Plomin, R., DeFries, J. C., Knopik, V. S., & Neiderhiser, J. M. (2013). *Behavioral genetics* (6th edition). New York, NY: Worth.

Box 2.1: Reciprocal gene-environment interactions in the development of Mozart's musical genius

Reciprocal interactions between genes and the environment take place through *genotype-environment correlations* and *gene-environment interactions*.

Mozart's musical genius was likely influenced by both processes. While it is highly likely Mozart's musical talent was inherited, it is also true that he was raised by musical parents in a musical home.[32] So, his musical environment may have amplified the musical capabilities he genetically shared with other family members. In other words, there was a strong *genotype-environment correlation* between Mozart's genetic endowment and his upbringing. Heritability estimates can never differentiate the inherited and environmental components in these situations, potentially inflating the contribution of heritable effects.

Mozart's genius may also reflect *gene-environment interactions* which can *amplify* heritable effects. For example, Mozart's innate sensitivity to tonal values (perfect pitch) may have accelerated his ability to absorb information during his music lessons. This accelerated learning, in turn, may have enhanced his understanding of tonal relationships and chord structures, which subsequently contributed to his ability to compose piano minuets by the age of five, gain the attention of better teachers, and so on. It is unlikely that he would have been able to compose these pieces without the music lessons, but the environmental value of these lessons would be lost in most heritability estimates.

Developmental systems

Heritability estimates are useful for illustrating the fundamental interdependence of inherited and environmental processes in determining children's development. Acknowledging this reciprocity thus shifts the debate from one of nature versus nurture to the articulation of more detailed models identifying mechanisms which unite various interdependent processes. The bioecological model (figure 2.3) is particularly useful for understanding the interdependence of inherited and environmental processes within multiple, developmental systems.[33,34,35]

A core assumption of the bioecological model is that all genetic and biological components of the child (genes, cells, issues, organs, and so on) interact dynamically within the contexts within which the child's development takes place. As figure 2.3 shows, there are multiple contexts within the child and his or her environment. The model further illustrates key processes taking place within the contexts involving the child's immediate family, community and society. Further details about processes specific to the early years are provided in table 2.2.

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32 Hambrick, D. Z. (2015). What makes a prodigy? Insights from psychology into the origins of extreme ability. *Scientific American, 315.*

33 Gottlieb, G. (1991). Experiential canalization of behavioral development: Theory. *Developmental Psychology, 27*, 4–13.

34 Lerner, R. M. (1991). Changing organism-context relations as the basic process of development: A developmental contextual perspective. *Developmental Psychology, 27*, 27–32.

35 Bronfenbrenner, U. (1994). Ecological models of human development. *International encyclopedia of education*, *3*(2), 37–43.

FIGURE 2.3

The bioecological model

Source: EIF (based on the concepts in Bronfenbrenner, 1994)

TABLE 2.2

Factors observed to contribute to variations in children's early development

Child
- Genetic variability
- Physical growth and maturation
- Physical health
- Fine motor skills
- Large motor skills
- Gender

Antenatal/birth
- Maternal physical health, diet & nutrition
- Fertility assistance
- Alcohol or substance misuse during pregnancy
- Tobacco use during pregnancy
- Maternal mental illness during pregnancy
- Gestational age
- Birth weight
- Birth trauma or other antenatal complications

Family
- Socioeconomic
- Parental age
- Parental education
- Marital status
- Family income
- Language spoken
- Ethnicity/race
- Religion
- Quality of the couple relationship
- History of family violence
- Parental mental illness
- Parental stress
- Social isolation

Parenting
- Warmth and sensitivity
- Quality of the home learning environment
- Visits to community activities; e.g. parks, drop-ins, libraries
- Makes use of childcare or nursery
- Reads to child
- Family routines
- Child discipline

Community
- Accessible healthcare
- Accessible resources
- Safety
- Housing
- Relative disadvantage

Culture/Society
- Employment
- Social-media
- Values

Source: McDonald, S., Kehler, H., Bayrampour, H., Fraser-Lee, N., & Tough, S. (2016). Risk and protective factors in early child development: Results from the All Our Babies (AOB) pregnancy cohort. Research in Developmental Disabilities, 58, 20–30.

As we make clear in the following chapters, all aspects of the child's genetic, biological and environmental contexts reciprocally influence the course of development in a *cascading* fashion over time.[36] In this respect, outcomes observed during later points in children's development reflect the culmination of reciprocal interactions taking place at earlier points. A primary aim of this report is to describe how these reciprocal interactions, and the processes which contribute to them, influence the development of key cognitive competencies during the first five years of life.

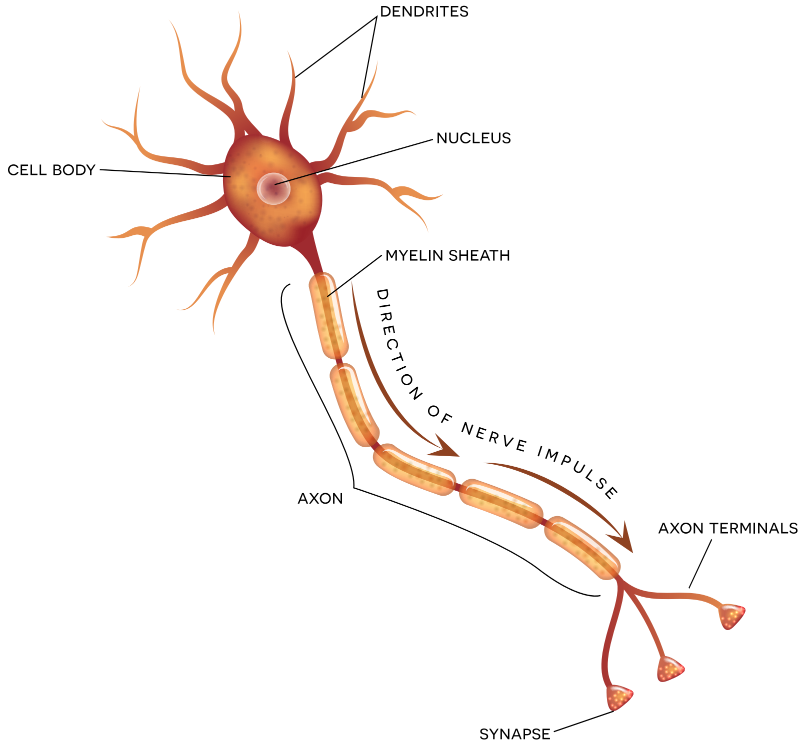
36 Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Developmental Psychopathology, 22*(3), 491–495.

Early brain development

The interdependence between inherited and environmental processes in supporting early cognitive development is evident from the moment of conception.[37] Genetically-based mechanisms contributing to early brain development include those which determine the formation of brain cells (also referred to as neurogenesis) that occurs between 6 and 18 weeks of gestation, involving the generation of approximately 225,000 cortical neurons per minute. As they are formed, the neurons migrate to their respective regions within the brain where they differentiate to perform separate mental functions. By week 26, most neurons will have reached their final destination and their dendritic branches – that is, the part of the brain cell which connects one cell to another (see figure 2.4) – will have started to grow. Neurogenesis then continues throughout infancy at rates faster than those which occurred during the antenatal period, until the child reaches his or her second birthday.

FIGURE 2.4

The anatomy of a brain cell



The antenatal formation and migration of neurons are believed to be *activity-independent*, meaning that they occur naturally through genetic mechanisms in the absence of environmental input. Their success is nevertheless determined by the quality of the child's foetal environment, which can threaten genetic processes through the introduction of toxic substances such as nicotine, alcohol and the chemicals found in various drugs. There is now good evidence showing that toxic substances, as well as the hormone cortisol (introduced through high levels of maternal stress), interfere with the organisation and programming of the developing brain.[38]

37 Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist*, *56*(1), 5.

38 Van den Bergh, B. R., Mulder, E. J., Mennes, M., & Glover, V. (2005). Antenatal maternal anxiety and stress and the neurobehavioural development of the fetus and child: links and possible mechanisms. A review. *Neuroscience & Biobehavioral Reviews*, *29*(2), 237–258.

Environmental processes are essential for establishing many of the early neural pathways contributing to all mental thought processes. These pathways are made up of trillions of connections (such as the synapses identified in figure 2.4) which rely on both *experience-expectant* and *experience-dependent* processes which involve input from the child's environment to occur. *Experience-expectant* processes are those triggered by species-specific stimuli existing in the child's environment, with the term 'expectant' meaning that the brain is prewired to expect the stimuli.[39] For example, when light hits the infant's eye for the first time, it activates a chain of genetic events that determine the development of important neural pathways, including those that process light and other visual information. Experience expectant processes are ubiquitous and necessary for normal development in all human infants.[40]

Experience-dependent (or adaptive) processes, by comparison, require more than species-specific environmental stimuli to take place. While environmental inputs actively contribute to the development of the brain's structure, experiences are not predetermined or anticipated by the synapses at any particular stage. Instead, experience-dependent processes rely on an individual's interaction with his or her environment to take place.[41] For example, the neural areas that govern finger movements in the hand are more highly developed in individuals who play stringed instruments than they are for the rest of the population.[42] Experience-dependent processes thus reflect a process of learning, whereby information is deliberately processed and stored by the brain.[43]

Experience-expectant and experience-dependent processes take place during separate but overlapping time periods in children's early development. During the antenatal period and at birth, genetically-based, experience-expectant processes trigger a period of synaptic overproduction that continues throughout the first three years of life.[44] By the age of two, the infant will have over 1,000 trillion connections, which is twice as many as his or her parents have. Although the brain will continue to make connections throughout the child's lifetime, they will have reached their highest density by the age of three with 15,000 synapses per neuron.[45] Figure 2.5 provides a comparison of the brain's dendritic growth and connectivity during the child's first three years.

From an evolutionary standpoint, synaptic overproduction is viewed as highly adaptive, as it enables young children to learn a wide variety of concepts. Synaptic connectivity is ultimately influenced, however, by the extent to which synapses are used through *experience-dependent* processes. Neural pathways that are frequently used (through experience) become stronger and more efficient. This process is further reinforced through neural myelination, whereby a protective layer of fatty myelin grows around the neuron's axon to insulate it. Myelination further improves the efficiency of synaptic connections by increasing the axon's conductivity, serving a purpose similar to the plastic coating surrounding an electrical wire.

39 Black, J. E., Jones, T. A., Nelson, C. A., & Greenough, W. T. (1998). Neuronal plasticity and the developing brain. *Handbook of child and adolescent psychiatry*, *6*, 31–53.

40 Phillips, D. A., & Shonkoff, J. P. (eds) (2000). *From neurons to neighborhoods: The science of early childhood development*. National Academies Press.

41 Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child development*, 539–559.

42 Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B., & Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science*, *270*(5234), 305.

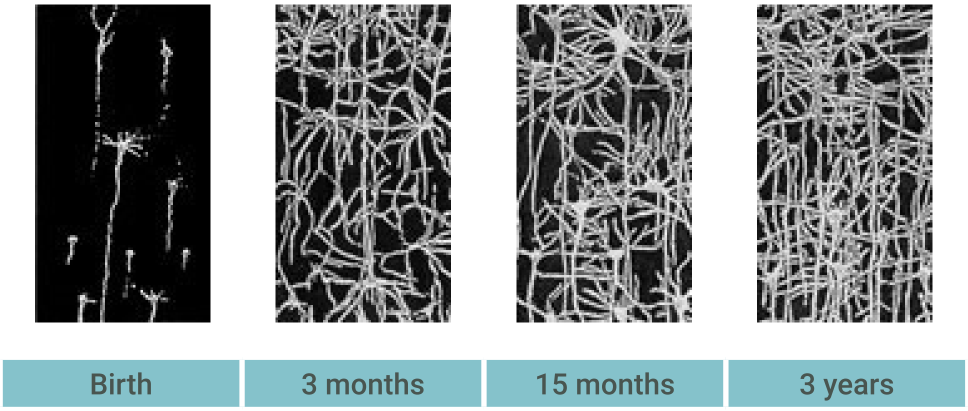
43 Rovee-Collier, C., & Giles, A. (2010). Why a neuromaturational model of memory fails: Exuberant learning in early infancy. *Behavioural processes*, *83*(2), 197–206.

44 Tierney, A. L., & Nelson III, C. A. (2009). Brain development and the role of experience in the early years. *Zero to three*, *30*(2), 9.

45 Tau, G. Z., & Peterson, B. S. (2010). Normal development of brain circuits. *Neuropsychopharmacology*, *35*(1), 147.

FIGURE 2.5

Dendritic growth during the first three years



Source: US National Institute on Drug Abuse

While synaptic overproduction increases the brain's potential for learning, it also reduces its efficiency.[46] Redundant and unnecessary synaptic connections frequently interfere with the young child's ability to effectively process information. For this reason, connections that are not used eventually die off through processes involving synaptic pruning and cell death which take place throughout children's development. By the time a child reaches adulthood, it has far fewer synaptic connections than it did in infancy, but they are more specialised and far more efficient. While this 'use it or lose it' feature of brain development allows humans to become uniquely attuned to their environment, it does not mean that connections are lost forever. Experience-dependent processes allow the brain to form new connections, as required, throughout child development and adulthood, thus increasing the brain's efficiency and adaptability as it matures.[47]

The social construction of cognitive thought

Environmental stimulation is essential for cognitive development to take place and there is clear evidence that the brain is prewired to prioritise some forms of stimulation over others. Already in the hours following birth, infants show greater interest in visual stimuli that moves and are more likely to track 'face-like' over non-face-like patterns.[48,49,50] Newborn infants also pay greater attention to high-pitched sounds[51] and demonstrate a clear preference for their mother's voice within the first week of life.[52]

46 Rovee-Collier, C., & Giles, A. (2010). Why a neuromaturational model of memory fails: Exuberant learning in early infancy. *Behavioural processes*, *83*(2), 197–206.

47 Phillips, D. A., & Shonkoff, J. P. (eds) (2000). *From neurons to neighborhoods: The science of early childhood development*. National Academies Press.

48 Haith, M. M. (1966). The response of the human newborn to visual movement. *Journal of Experimental Child Psychology*, *3*(3), 235–243.

49 Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, *40*(1), 1–19.

50 Easterbrook, M. A., Kisilevsky, B. S., Hains, S. M. J., & Muir, D. W. (1999). Faceness or complexity: Evidence from newborn visual tracking of facelike stimuli. *Infant Behavior and Development*, *22*(1), 17–35.

51 Saffran, J. R., Werker, J. F., & Werner, L. A. (2006). The infant's auditory world: Hearing, speech, and the beginnings of language. In W. Damon and R.M. Lerner (Series Editor 0. & D. Kuhn and R. S. Siegler (eds), *Handbook of child psychology, Vol. 2. Cognition, perception and language* (6th edition pp. 58–106). New York: Wiley.

52 DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science*, *208*(4448), 1174–1176.

Infants' preference for human-related stimuli continues as they develop and is actively reinforced by their parents and caregivers. This is exemplified through the exaggerated speech adults use when interacting with infants.[53,54] This 'baby talk' (also known as Infant Directed Speech (IDS) or 'motherese') occurs universally across cultures and is viewed by some as evidence of an innate language acquisition support system existing within humans.[55,56,57] Infants appear to be instinctively attuned to IDS, demonstrating a clear preference for it over other forms of adult speech already within the first month of life.[58,59]

The example of IDS is useful for understanding the essential role the environment plays in shaping early thought processes. Environmental stimulation in the form of adult guidance both facilitates and directs early cognitive development. To be effective, however, adult guidance must (1) account for the child's current capabilities, and (2) provide instruction which is slightly beyond these capabilities, but still within the child's reach. Russian psychologist Lev Vygotsky described this 'gap' between what the child knows and can learn through adult guidance as the *zone of proximal development (ZPD)*, maintaining that this was where cognitive growth most often occurs.[60] In the example of IDS, caregivers and other adults are sensitive to the kinds of sounds which infants prefer and then use this knowledge to help infants further differentiate sounds and match them to specific words, emotions and activities.[61,62]

While appropriate adult guidance within the ZPD (also described as *guided participation*[63] or *scaffolding*[64]) often occurs naturally, it is strongly influenced by processes taking place within developmental systems described previously, involving the child's family, community and society (see figure 2.3).[65,66]

- **Family-level** processes include caregiver characteristics, such as their level of education, physical health and mental wellbeing, as well as family support systems, such as the quality of the interparental relationship and family income.
- **Community-level** factors include the availability of community resources, such as libraries, play groups high-quality childcare and nursery school provision.
- **Societal-level** factors include the availability of various forms of technology, fluctuations in the availability of work or the presence of war.
- **Cultural-level** factors include beliefs about the value and prioritisation of various forms of knowledge over others and the timing and quality of educational experiences.

53 Snow, C. E. (1972). Mothers' speech to children learning language. *Child development*, 549–565.

54 Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental psychology*, *27*(2), 209.

55 Bruner, J. (1985). Child's talk: Learning to use language. *Child Language Teaching and Therapy*, *1*(1), 111–114.

56 Hoff, E. (2006). How social contexts support and shape language development. *Developmental review*, *26*(1), 55–88.

57 Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., ... & Lacerda, F. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science*, *277*(5326), 684–686.

58 Vouloumanos, A., & Waxman, S. R. (2014). Listen up! Speech is for thinking during infancy. *Trends in cognitive sciences*, *18*(12), 642–646.

59 Cooper, R. P., & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child development*, *61*(5), 1584–1595.

60 Vygotsky, L. (1962). *Thought and Language.* Cambridge, MA: MIT Press.

61 Moore, D. S., Spence, M. J., & Katz, G. S. (1997). Six-month-olds' categorization of natural infant-directed utterances. *Developmental Psychology*, *33*(6), 980–988.

62 Ma, W., Golinkoff, R. M., Houston, D. M., & Hirsh-Pasek, K. (2011). Word learning in infant-and adult-directed speech. *Language Learning and Development*, *7*(3), 185–201.

63 Rogoff, B., Ellis, S., & Gardner, W. (1984). Adjustment of adult–child instruction according to child's age and task. *Developmental Psychology*, *20*(2), 193.

64 Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child psychology and psychiatry*, *17*(2), 89–100.

65 Rogoff, B. (2003). *The cultural nature of human development*. Oxford University Press.

66 Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. *Handbook of child psychology*.

Vygotsky argued that these environmental contexts, driven by cultural factors, not only determine *what* children learn, but *how* they learn it. While most children are equipped with a set of elementary mental functions that allow them to perceive, pay attention and remember – cultural processes transform these basic functions into higher-order mental activities that allow children to problem-solve and understand abstract concepts.

Vygotsky's thinking is consistent with evolutionary frameworks (see table 2.3) which differentiate biologically primary and biologically secondary abilities.[67] Biologically primary skills are those which appear to be universal to all human beings, with the exception of those born with severe disabilities or raised in highly deprived circumstances. The universality of these primary skills has led evolutionary theorists to conclude that human beings are thus biologically *prepared* to learn them as a result of natural selection processes.[68,69,70] While cultural factors also influence the development of biologically primary skills (see below), learning is relatively spontaneous as it occurs alongside other maturational processes.

TABLE 2.3

Examples of biologically primary and secondary abilities

Biologically primary abilities
• have undergone evolutionary selection through processes of environmental adaptation
• are acquired universally by children in all but the most deprived environments
• children are intrinsically motivated to exercise abilities and do so spontaneously
• the majority of children learn these abilities effortlessly, without explicit practice.
Biologically secondary abilities
• do not have an evolutionary history, but build upon biological primary abilities
• are culturally dependent, reflecting cognitive activities that are important to the culture (such as reading)
• children require instruction to master these skills
• children do not acquire abilities spontaneously and tedious practice is sometimes required to master them.

Source: Geary, D. C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist, 50*(1)

Examples of biologically primary abilities include the basic spatial processing skills which permit habitat navigation, as well as the 'skeletal principles' underpinning children's knowledge of objects, living things and numerical values.[71,72] Many have also argued that

67 Geary, D. C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist*, *50*(1), 24.

68 Bjorklund, D. F., Ellis, B. J., & Rosenberg, J. S. (2007). Evolved probabilistic cognitive mechanisms: An evolutionary approach to gene× environment× development interactions. In R.V. Kail (Ed.), *Advances in child development and behaviour* (Vol. 35, pp. 1 – 39). Oxford, UK: Elsevier.

69 Gould, S. J. & Vrba, E. S. (1982). Exaptation–A missing term in the science of form. *Paleobiology, 8*, 4–15.

70 Bjorklund, D. F., & Ellis, B. J. (2014). Children, childhood, and development in evolutionary perspective. *Developmental Review*, *34*(3), 225–264.

71 Cheng, K. & Gallistel, C. R. (1984). Testing the geometric power of an animal's spatial representation. In H. L. Roitblat, T. G. Bever, & H. S. Terrace (eds), *Animal cognition*, pp. 409—423. Hillsdale, NJ: Erlbaum.

72 Gelman, R. (1990). First principles organize attention to and learning about relevant data: Number and the animate–inanimate distinction as examples. *Cognitive Science, 14*, 79–106.

children's ability to process and use language is a biologically primary skill[73,74] although its primacy in comparison to other early skills remains highly debated.[75,76,77,78]

There are, nevertheless, cognitive skills which cannot be learned spontaneously. Evolutionary theorists argue that these biologically secondary skills, which often have strong cultural value, are rarely learned without instruction and practice. Examples of biologically secondary abilities include the ability to read, write and perform complex mathematical operations.[79,80]

The distinction between biologically primary and secondary abilities is helpful for understanding the role of instruction and culture in children's early learning. However, this should not be taken to mean that culture is not influential in children's ability to master biologically primary skills. It would also be inaccurate to assume that that acquisition of biologically secondary skills is wholly determined by instructional processes. Rather, the distinction between biologically primary and secondary abilities is useful for understanding when and how cultural processes are likely to have the greatest impact.

The child's active construction of thought

For much of the 20th century, developmental psychologists conceptualised children's cognitive development as the progression of a series of age-related stages.[81] This was largely due to the work of Jean Piaget, who originally theorised that cognitive growth was the result of the reorganisation of mental processes which occurred through biological maturation and the child's active interaction with his or her environment.

Piaget's views were based on thousands of hours of systematic observation of children at all ages in natural and experimental situations. Piaget concluded from these observations that cognitive development could be described in terms of four successive stages (table 2.4) which reflect structural changes in the ways in which the child organises and accesses information.[82,83,84] While some aspects of Piaget's stage theory has since been challenged (as we describe in the following chapters), these stages are worth reviewing as they have informed much of the research described in this report.

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73 Pinker, S. & Bloom, P. (1990). Natural language and natural selection. *Behavioral and Brain Sciences, 13*, 707–784.

74 Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: what is it, who has it, and how did it evolve? *Science*, *298*(5598), 1569–1579.

75 Tomasello, M. (2003). *Constructing a language: A usage-based account of language acquisition*. Cambridge, MA: Harvard University Press.

76 Herrmann, E., Call, J., Hernández-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science*, *317*(5843), 1360–1366.

77 Tomasello, M. (2016). Cultural learning redux. *Child development*, *87*(3), 643–653.

78 Karmiloff-Smith, A. (2006). The tortuous route from genes to behavior: A neuroconstructivist approach, *Cognitive, Affective, & Behavioral Neuroscience, 6,* 9–17.

79 Ceci, S. J. (1991). How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Developmental Psychology, 27*, 703–722.

80 Ginsburg, H. P., Posner, J. K. & Russell, R. L. (1981). The development of mental addition as a function of schooling and culture. *Journal of Cross-Cultural Psychology, 12*, 163–178.

81 Miller, P. (2014). Piaget's theory: Past, present, and future. In U. Goswami (ed.), *The Wiley-Blackwell handbook of childhood cognitive development* (2nd edition). Chichester, West Sussex: Blackwell Publishing.

82 Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

83 Piaget, J. (1954). *The construction of reality in the child*. New York: Basic Books.

84 Piaget, J. (1962). *Play, dreams, and imitation in childhood*. New York: Norton.

TABLE 2.4

Piaget's stages of cognitive development

Stage	Cognitive capabilities
Sensorimotor (birth to 2 years)	Learning takes place primarily through the infant's senses and motor activity. By the end of this stage, the toddler can conceptualise objects and others as separate and distinct from themselves. This ability is known as 'object permanence' in recognition of the child's ability to understand that objects continue to exist when he or she cannot see, hear or feel them.
Pre-operational (2 to 7 years)	Children can understand and communicate through symbols. This symbol acquisition is observed through the child's use of language, which also permits him or her to imagine and anticipate a variety of realistic and unrealistic possibilities. However, complex and abstract thought is difficult and marked by consistent errors in children's logical reasoning.
Concrete operations (7 to 11 years)	Children understand the logical concepts underpinning arithmetic and cause and effect problem solving. This reasoning is readily applied to concrete phenomenon, but more abstract and hypothetical problem-solving skills have not yet been developed.
Formal operations (11 years to adulthood)	The child is capable of abstract reasoning, hypothesis testing through both deductive and inductive reasoning capabilities.

Source: Piaget 1952, 1954, 1962

Throughout his career, Piaget was primarily interested in the development of logical thought processes used by scientists.[85] Like Vygotsky, Piaget believed that environmental processes were essential for learning to take place. However, Piaget was less interested in the contribution of instruction and culture to children's knowledge acquisition and more interested in the ways in which children actively acquired and constructed their own thought processes.[86,87,88] Piaget maintained that this took place through a process of cognitive 'equilibration' (box 2.2) which he described in his 'four factor formulae':

Cognitive development = Physical maturation + Direct experience with the physical environment + Social experience + Equilibration

Box 2.2: Equilibration as the engine of cognitive development

Piaget viewed *equilibration* as a primary mechanism of cognitive development. Piaget defined equilibration as the intrinsic need to balance and integrate new information with old knowledge. Equilibration occurs as a result of the child's adaptation to the environment through ongoing processes of *assimilation* and *accommodation*. New information is successfully assimilated (that is, integrated) when it is compatible (in equilibrium) with the child's current cognitive schemas. It is not assimilated, however, if it is beyond what the child's current schemas can take in. Over time, an event will occur that forces a restructuring of the schema to accommodate the new information. This new, restructured schema is typically more advanced than previous schemas and will remain in a state of equilibration until another disruption occurs.

85 Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review, 96*, 675–689.

86 Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

87 Piaget, J. (1954). *The construction of reality in the child*. New York: Basic Books.

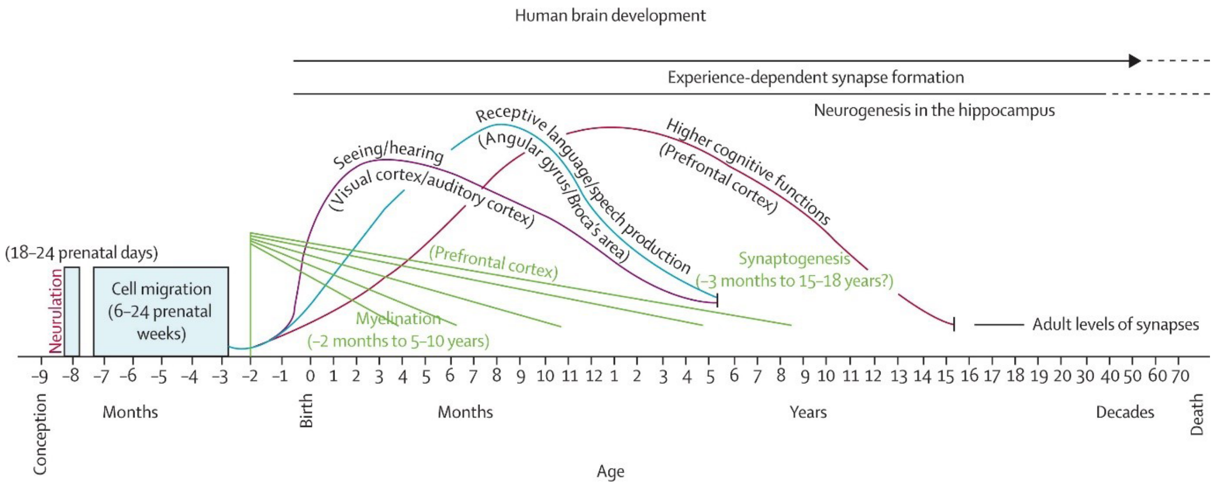
88 Piaget, J. (1962). *Play, dreams, and imitation in childhood*. New York: Norton.

Piaget proposed that early learning begins with the infant's initial reflexes and perceptual capabilities (such as the ability to perceive edges and dimensionality) that permit the infant to accumulate knowledge about the world through instinctual, 'sensorimotor' interactions. Knowledge gained from these interactions is then gradually organised into mental structures, which Piaget defined as 'schemas' (see description in chapter 3). By the end of the second year, many sensorimotor schemas are then replaced by more abstract and representational thought processes. Piaget assumed these changes reflected a substantial reorganisation of thinking which was qualitatively different and more advanced than what had occurred previously. Piaget thus argued that pre-operational thought constituted a new 'stage' in children's cognitive development. Piaget further maintained that advancement from sensorimotor to pre-operational thinking was virtually universal during the second year, occurring without any explicit instruction from adults.

While the details of some of these assumptions have been challenged, neuroscientific studies have since verified that early neurological development does undergo a number of stage-like shifts. For example, the periods of synaptic overproduction and pruning taking place during the first three years (see figure 2.6) parallel the transition from sensorimotor to pre-operational thought, as Piaget first described. Additional periods of neurological restructuring include the period between the ages of three and five when the executive functions are thought to mature (figure 2.7), and then again during adolescence, when the brain undergoes a second period of synaptic pruning and myelination.[89,90] These shifts not only suggest that cognitive development occurs through predictable, qualitative changes, but also show how maturation can constrain what a child is capable of learning at any given point in time.[91,92]

FIGURE 2.6

Synaptic production during child development



Source: Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist, 56*(1).

89 Center on the Developing Child at Harvard University (2011). *Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function: Working Paper No. 11*. Retrieved from www.developingchild.harvard.edu.

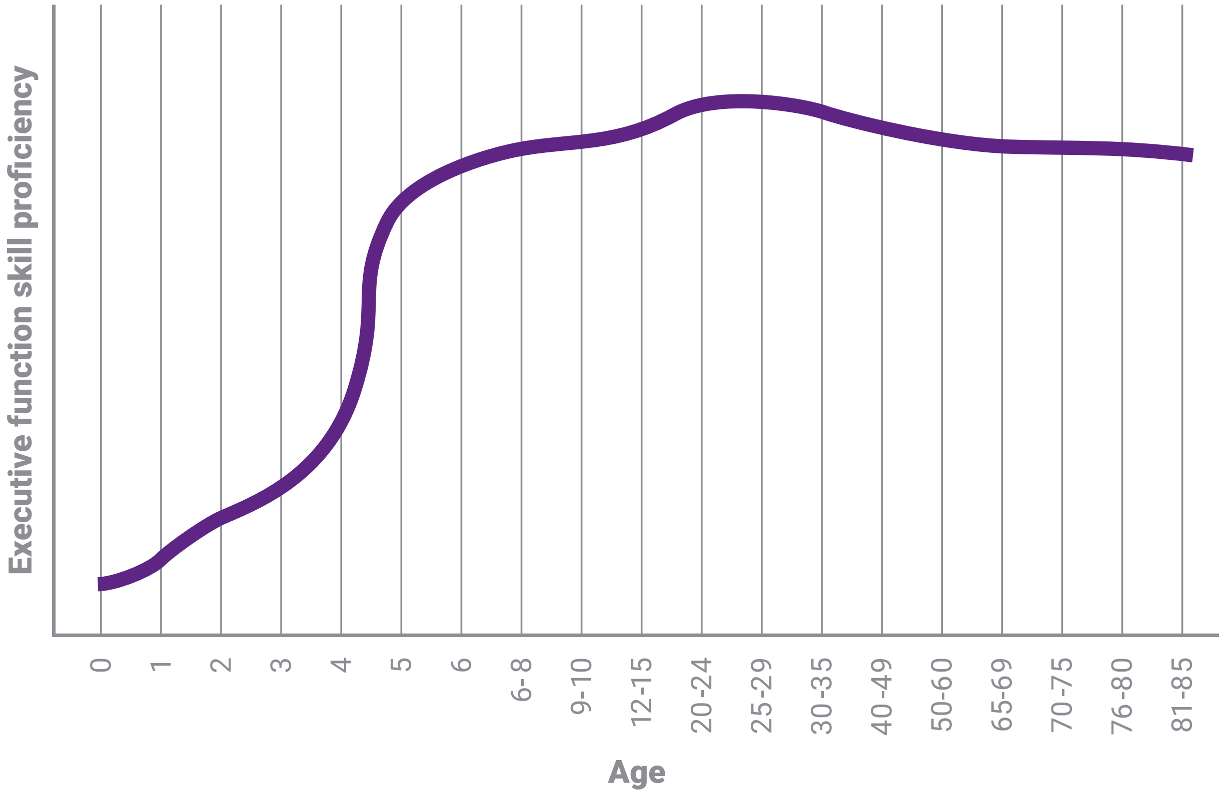
90 Sowell, E. R., Thompson, P. M., Leonard, C. M., Welcome, S. E., Kan, E., & Toga, A. W. (2004). Longitudinal mapping of cortical thickness and brain growth in normal children. *Journal of Neuroscience*, *24*(38), 8223–8231.

91 Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist*, *56*(1), 5–15.

92 Karmiloff-Smith, A. (1992). Beyond modularity: A developmental approach to cognitive science. Cambridge, MA: MIT Press.

FIGURE 2.7

Executive function skills build into the early adult years



Source: Reproduced from Center on the Developing Child (2012). *Executive Function* (InBrief). Retrieved from www.developingchild.harvard.edu.

Box 2.3: What are the executive functions?

The executive functions are processes which help children control their feelings, thoughts and behaviour. The executive functions thus help regulate domain-general processes involving perception and long-term memory, as well as inhibit children's response to various stimuli. The executive functions have been defined in various ways, but are typically understood to include the following three processes:[93]

- **Working memory:** involves that amount of information one can hold in his or her short-term memory and manipulate this information when problem solving.
- **Inhibition control:** involves the extent to which one can inhibit their response to information and regulate impulses. Also used to regulate or deploy one's attention.
- **Cognitive flexibility:** refers to the extent to which one can easily shift thought and attention from one set of rules or tasks to another. Cognitive flexibility also involves the ability to think creatively – that is, 'outside of the box'.

Some also consider the speed and efficiency which information is processed as an executive function, although this occurs as a result of maturation within the other three domains, as well as increased efficiency in children's perceptual and long-term memory. This report does not specifically consider the development of the executive functions but does describe their contribution to children's understanding of objects, people, numbers and language.

[93] Diamond, Adele. (2013). Executive functions. *Annual Review of Psychology, 64*, 135–168.

It is worth noting that the cognitive shifts described by Piaget are thought to involve general cognitive processes that underpin a wide variety of mental activities. Researchers define these processes as *domain-general* processes which include perceptual and memory capabilities, as well as the executive functions, as described in box 2.3. However, cognitive development is also thought to involve *domain-specific* processes involving more specialised knowledge structures, including the understanding of objects, human thought, number and language as described in this report.[94] Many researchers now assume that children are born with a set of domain-general capabilities that become increasingly more specific, as neural pathways are reinforced through the child's interactions with his or her environment.[95,96] This corresponds with Piaget's original belief that children come into the world with only a few general skills which are nevertheless adequate for them to learn a wide variety of environmentally-specific tasks. Karmiloff-Smith has since proposed that this lack of specificity is fundamentally adaptive, as it keeps children from learning things which may not be necessary, while allowing them to master new ideas that their parents may not yet understand.[97]

A word about measurement

A key aim of this report is to describe how individual differences in children's cognitive development are measured. As discussed in the previous section, much of what we know about children's cognitive development comes from observational studies whereby researchers systematically watch and code children's behaviour. These methods often provide rich information about the thought processes of small samples of children, although the methodologies used are often not practical for measuring individual differences in large populations. When such information is required, researchers rely on psychometric instruments that are developed specifically to measure children's *intelligence* as opposed to their cognitive ability. While there is a high degree of overlap between these two concepts, intelligence tests were not originally developed to measure many of the competencies we describe in this review.

Modern conceptualisations of human intelligence are rooted in the work of British statistician Charles Spearman, who proposed that mental activities involved both domain-general and specific processes.[98] Domain-general, also referred to as 'g-factor' processes, are those shared by a range intellectual tasks, such as memory, perceptual capabilities and the executive functions, as described above. 'S-factor' processes, by contrast, apply to domain-specific activities which are nevertheless necessary for all children to function well at school and in society. Reading, for example, is considered to be an s-factor process.

Spearman showed that g-factor capabilities are highly correlated and stable within individuals, whereas s-factor competencies vary from measure to measure. Others have since argued that intelligence is best described as a set of modular and more domain-specific capabilities. These capabilities include the child's verbal ability, perceptual capabilities, inductive and deductive reasoning skills, numeric understanding, rote memory and spatial awareness. However, modern theorists recognise that even these capabilities are highly correlated – thus acknowledging that a common factor may nevertheless underpin them all.[99]

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94 Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental Science*, *10*(1), 89–96.

95 Karmiloff-Smith, A. (2006). The tortuous route from genes to behavior: a neuroconstructivist approach. *Cognitive, Affective, & Behavioral Neuroscience*, *6*(1), 9–17.

96 Johnson, M. H. (2011). Interactive specialization: a domain-general framework for human functional brain development? *Developmental Cognitive Neuroscience*, *1*(1), 7–21.

97 Karmiloff-Smith, A. (1995). *Beyond Modularity: A Developmental Perspective on Cognitive Science*. Cambridge, MA: MIT Press.

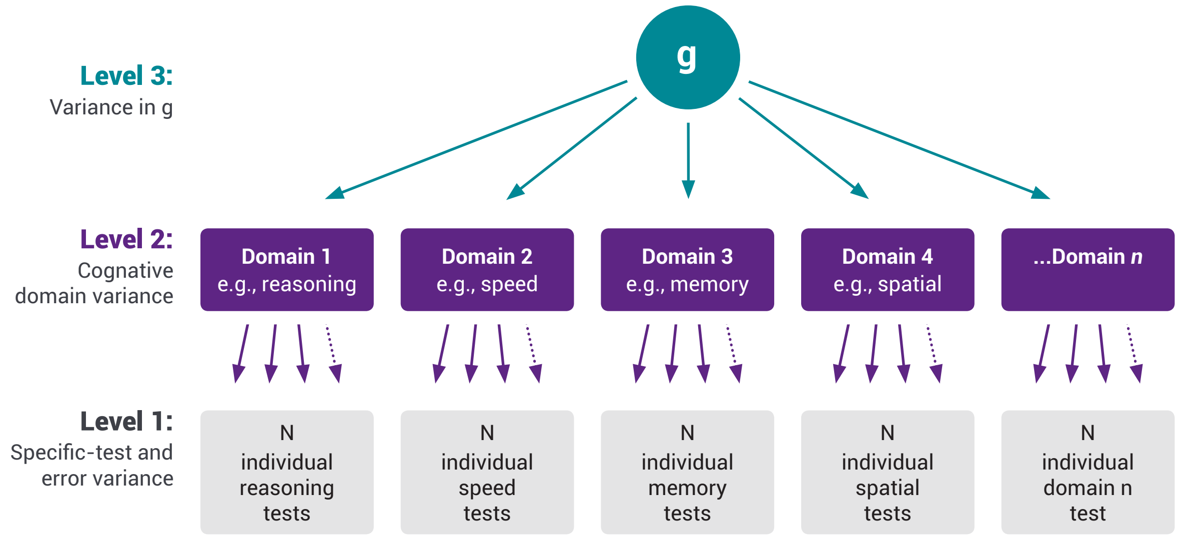
98 Spearman, C. (1904). 'General Intelligence', Objectively Determined and Measured. *The American Journal of Psychology*, *15*(2), 201–292.

99 Thurstone, J. R. (1938). Primary mental abilities. *Psychometric monographs, No. 1.*

Current psychometric theories having skirted the domain-general/specific debate by conceptualising intelligence in terms of three levels which correspond with differences in individual performance (figure 2.8): (1) some individuals perform well on all measures; (2) others are more proficient on some sets of tasks over others (such as verbal comprehension over spatial reasoning); and (3) some are proficient only on specific tests.[100] This view is consistent with neuroscientific evidence which confirms that some domain-specificity in cognitive functioning exists, which is enhanced by increased cortical thickness (that is, more dendritic connections and greater myelination).[101,102]

FIGURE 2.8

A hierarchical model of cognitive capabilities



Source: Reproduced from Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies.* Cambridge: Cambridge University Press.

The domains tested in most intelligence tests have been identified through decades of research considering individual differences, developmental change and the degree to which intelligence is related to children's performance once they enter school. These studies confirm:

- the existence of universal changes in children's thinking which are associated with age and maturation
- a correspondence with the executive functions[103,104]
- individual differences in intellectual functioning which remain stable over time
- a stable correlation between children's performance on intelligence tests and their academic achievement once they enter school.[105,106,107]

[100] Deary, I. J. (2013). Intelligence. *Current Biology, 23*, R673–R676.

[101] Karama, S., Colom, R., Johnson, W., Deary, I. J., Haier, R., Waber, D. P., ... & Brain Development Cooperative Group. (2011). Cortical thickness correlates of specific cognitive performance accounted for by the general factor of intelligence in healthy children aged 6 to 18. *Neuroimage*, *55*(4), 1443–1453.

[102] Sowell, E. R., Thompson, P. M., Leonard, C. M., Welcome, S. E., Kan, E., & Toga, A. W. (2004). Longitudinal mapping of cortical thickness and brain growth in normal children. *Journal of Neuroscience*, *24*(38), 8223–8231.

[103] Ardila, A., Pineda, D., & Rosselli, M. (2000). Correlation between intelligence test scores and executive function measures. *Archives of clinical neuropsychology*, *15*(1), 31–36.

[104] Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of experimental child psychology*, *106*(1), 20–29.

[105] Kaufman, A. S. (2009). *IQ testing 101*. Springer Publishing Company.

[106] Watkins, M. W., Lee, P., & Canivez, G L. (2007). Psychometric intelligence and achievement: A cross-lagged panel analysis. *Intelligence, 35*, 59–68.

[107] Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence*, *35*(1), 13–21.

A key feature of most intelligence tests is that they provide norm-referenced scores, which enable individual differences on the basis of children's age. Intelligence tests thus facilitate a face-value assessment of a child's capabilities as being below average, average or above average – as long as the child is from the same culture in which the tests were normed. For this reason, it is important to recognise that intelligence tests contain a cultural bias.

The following chapters include information about how subscales from the various IQ tests developed for young children map on to these levels with respect to the four competencies covered in this review. These tests include the fourth edition of the Wechsler Preschool and Primary Scales of Intelligence (WPPSI-IV; summarised in table 2.5),[108] Differential Abilities Scale, the British Abilities Scale and the Kaufman ABC.

TABLE 2.5

Cognitive competencies measured with the Wechsler Preschool and Primary Scale of Intelligence, Fourth edition (WPPSI-IV)

Verbal comprehension		
Subtest	**Activity**	**Competencies**
Information	Child answers questions about general knowledge; responses are made through pictures and verbally	Long-term memory and acquired knowledge.
Similarities	Two similar but different objects or concepts are presented, and the child is asked to tell how they are alike or different.	Logical thinking, verbal concept formation and verbal abstract reasoning. This involves auditory comprehension, memory, distinguishing between nonessential and essential features, and verbal expression.
Vocabulary	There is a picture and verbal section. The picture section requires child to name pictures in a book. The verbal section requires the child to provide definitions for words that the examiner reads aloud.	Knowledge of and the ability to express the meaning of words, requiring verbal fluency and concept formation, word knowledge, word usage.
Comprehension	The child answers questions involving general principles, social conventions and moral reasoning.	Common-sense knowledge, practical judgment and level of social maturation, moral reasoning.
Visual-spatial		
Block design	Child is presented with a picture of an abstract design and then asked to reproduce it with a set of blocks.	Spatial visualisation and analysis (e.g. mental rotation), simultaneous processing, visual-motor coordination, dexterity, and nonverbal concept formation. Some logical reasoning also required.
Object assembly	Child is asked to complete a puzzle involving abstract shapes into a standard arrangement (such as a face) within 90 seconds.	Visual-perceptual organisation, integration and synthesis of part–whole relationships, nonverbal reasoning, and trial-and-error learning; spatial visualisation and analysis, visual-motor coordination, cognitive flexibility, and persistence.
Fluid reasoning		
Matrix reasoning	Child is given an incomplete matrix and selects the missing portion from four or five options.	Visual processing and abstract, spatial perception; may be influenced by concentration, attention and persistence.
Picture concepts	Child looks at two (or three) rows of pictured objects and points to the single picture from each row that shares a common characteristic with the single picture(s) from the other row(s). Items become increasingly difficult.	Categorical, abstract reasoning.

[108] Wechsler, D. (2012). *Wechsler Preschool and Primary Scale of Intelligence* — Fourth Edition. San Antonio, TX: Psychological Corporation.

Working memory		
Picture memory	Child is shown images on a card and then asked to pick them out from a new set of images.	Short-term memory.
Zoo locations	Child is shown a 2x8 grid with animals placed within various squares and are asked to replicate their placement on a blank grid.	Short-term memory; spatial orientation.
Processing speed		
Bug search (symbol coding)	Rapid matching task, where child is asked to match images as quickly as possible with a stamp.	Processing speed; planning; metacognition; visual-motor dexterity, associative nonverbal learning, and nonverbal short-term memory.
Cancellation	Child is presented with an image that has an assortment of objects and is asked to stamp out all objects within a given category, such as clothes or animals.	Processing speed; ability to distinguish small perceptual differences.
Animal coding	Speed task where the child is provided with a matched set involving an animal and shape and is asked to match the animal to the shape as quickly as possible.	Processing speed.

It is worth noting that intelligence tests are designed to reliably detect differences between individual children and are also useful for diagnosing specific cognitive differences. However, they often require specific expertise training to administer and are therefore not practical for population screening purposes. Population screening, by contrast, aims to detect the potential for cognitive problems, but is seldom sufficient for verifying the presence or absence of a specific problem (see table 2.6 for an overview of the difference between screening and diagnostic activities). Case finding is a third method of identifying individuals who may be at risk on the basis of characteristics (for example, low income, young parenthood, geographic isolation) but not manifesting any specific difficulty. Case finding does not necessarily make use of any assessment tool, but targets families on the basis of demographic risks.

TABLE 2.6

Overview of the uses and administration of screening and diagnostic measures

	Screening tests	Diagnostic tests
Purpose	To detect potential disease indicators.	To establish presence/absence of condition.
Target population	Large numbers of asymptomatic but potentially at-risk individuals.	Symptomatic individuals to establish diagnosis, or asymptomatic individuals with a positive screening test.
Test method	Simple, acceptable to patients and staff.	Maybe invasive, expensive but justifiable as necessary to establish diagnosis.
Positive result threshold	Generally chosen towards high sensitivity not to miss potential disease.	Chosen towards high specificity (true negatives). More weight given to accuracy and precision than to patient acceptability.
Positive result	Essentially indicates suspicion of disease (often used in combination with other risk factors) that warrants confirmation.	Result provides a definite diagnosis.
Cost	Cheap, benefits should justify the costs since large numbers of people will need to be screened to identify a small number of potential cases.	Higher costs associated with diagnostic test may be justified to establish diagnosis.

Source: Ruf, M., Morgan, O. & Mackenzie, K. (2008, 2017) Public Health Textbook, 2c - Diagnosis and Screening, Differences between screening and diagnostic tests and case finding. Available at: https://www.healthknowledge.org.uk/public-health-textbook/disease-causation-diagnostic/2c-diagnosis-screening/screening-diagnostic-case-finding

In this review, we identify measures that are useful for screening for potential problems and those that that are better suited for diagnosis. We also make recommendations about when case finding methods might be used to identify risks at the level of the family, child and community in the absence of any specific assessment measure.

Cognitive development is both a stable and flexible process

Studies involving intelligence testing consistently observe a high degree of variability in young children's cognitive development, particularly during the first several years of life.[109] Case in point is the time at which children speak their first words. While the average age of first words is 12 months, the normal range lies between 8 and 16 months, thus representing a 100% difference in age.[110]

During the first few years of life, individual differences in the onset of developmental milestones are not particularly strong predictors of later development. By the age of three, however, individual differences in cognitive capabilities become increasingly reliable.[111] This stability is due, in part, to greater maturation of neurological structures, but also due to *cascading* processes in children's development. In this respect, skills beget skills, and early failures tend to accumulate over time.[112]

This is not to say that early deficits cannot be rectified, particularly when processes are influenced by the child's environment. For example, studies consistently show that children raised in highly deprived environments can and do show dramatic cognitive improvements when subsequently reared in warm and nurturing homes. However, the duration of negative circumstances and the timing and quality of environmental factors appears to be crucial.[113] For example, the deleterious effects of institutional care appear to be minimal for children placed in stable homes prior to six months of age. However, negative outcomes become increasingly likely for children who remain in deprived institutional care for substantial periods of time after the age of 6 months.[114]

Such findings have led to protracted debates surrounding the existence of sensitive or 'critical' periods in children's development, as well as the degree to which early intervention is uniformly more effective than late intervention.[115] This review will not resolve these debates, but it will be informed by them. While there is consistent evidence in support of critical periods occurring during the child's first five years– many researchers view them to be few and atypical throughout the course of children's development.[116] By and large, research confirms that the young brain is highly malleable and resilient, suggesting that while the effects of early deprivation can be negative, they are by no means universal, nor irreversible.[117] Indeed, evidence from the neurosciences suggests that learning, in the form of experience-dependent processes, continues throughout the entirety of child and adult development.[118]

109 Bornstein, M. H. (2014). Human infancy... and the rest of the lifespan. *Annual Review of Psychology*, *65*, 121–158.

110 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

111 Kaufman, A. S. (2009). *IQ testing 101*. Springer Publishing Company.

112 Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Development and psychopathology*, *22*(3), 491–495.

113 Skeels, H. M. (1966). Adult status of children with contrasting early life experiences: A follow-up study. *Monographs of the Society for Research in Child Development*, *31*(3), 1–65.

114 Pollak, S. D., Nelson, C. A., Schlaak, M. F., Roeber, B. J., Wewerka, S. S., Wiik, K. L., ... & Gunnar, M. R. (2010). Neurodevelopmental effects of early deprivation in postinstitutionalized children. *Child development*, *81*(1), 224–236.

115 Doyle, O., Harmon, C. P., Heckman, J. J., & Tremblay, R. E. (2009). Investing in early human development: timing and economic efficiency. *Economics & Human Biology*, *7*(1), 1–6.

116 Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist*, *56*(1), 5–15.

117 Rutter, M., Sonuga-Barke, E. J., Beckett, C., Castle, J., Kreppner, J., Kumsta, R., ... & Gunnar, M. R. (2010). Deprivation-specific psychological patterns: Effects of institutional deprivation. *Monographs of the Society for Research in Child Development*, i–253.

118 Blakemore, S. J., & Choudhury, S. (2006). Development of the adolescent brain: implications for executive function and social cognition. *Journal of child psychology and psychiatry*, *47*(3-4), 296–312.

2.3 Summary of key principles

In this chapter, we have described many of the core theories, frameworks and debates informing current research in early cognitive development. This is by no means an exhaustive summary of all theories of cognitive development, but it underpins much of the research described in the following chapters. The principles informed by these theories are worth keeping in mind when reading these chapters.

- Cognitive development is the ongoing restructuring of thought processes that allow children to think and understand.
- Cognitive development is *never* the product of just nature or nurture. Cognitive development is the result of interdependent processes involving the child's genetic make-up, age and environment.
- Children are born with a set of competencies that facilitate their development, but chidlren's development is also shaped by their family, community and society.
- Children play an active role in their own cognitive development, informed by their current level of cognitive understanding.
- There is an age-related progression in children's thought processes, whereby early capabilities lay the foundation for later capabilities.
- Cognitive development involves both general and specific processes.
- Children's measures of intelligence are designed to consider mental activities which are general across multiple domains of thought.
- Cognitive capabilities are highly stable within individuals. Cognitive capabilities at one point in time are predictive of cognitive capabilities at another.
- Cognitive development is nevertheless malleable. Stable individual trajectories can and do change if the child's circumstances change. These circumstances can include the availability of effective interventions.

Part 2: Implicit theories

Infants come into the world with relatively few capabilities. The few that they do have are nevertheless sufficient for them to master a variety of progressively complex tasks during the first year. While Piaget originally maintained that newborns had only a handful of non-intentional reflexes, more recent studies suggest they reflect biases which privilege some forms of information over others. Some believe these biases constitute the infant's 'core knowledge' – that is, cognitive structures which are in place already at the time of birth (see box below).[119,120,121] Others maintain that knowledge structures develop more gradually through domain-general processes involving the infant's perception and memory. This latter point of view – also referred to as the neoconstructivist or 'theory theory' perspective of cognitive development – assumes that the basic skills present at birth rapidly develop into implicit theories which are then actively tested and revised by the infant over time.[122,123,124]

Regardless of the mechanism, both core knowledge and theory theorists agree that virtually all young children spontaneously generate common-sense theories within the following core domains.

1. **Theories of inanimate objects and the physical word:** These theories are informed by the child's awareness that 1) objects exist independently of the child in space and time, 2) that objects interact according to universal physical laws, and 3) that objects can be grouped by conceptual similarities.
2. **Theories of mind** (also referred to as theories of intentions, psychological reasoning, mindreading or naïve psychology): Such theories are rooted in the child's awareness that some objects are alive and conscious, that conscious beings have goal-directed intentions, and that individuals differ in what they know and understand.
3. **Theories about number:** These theories include a basic understanding of magnitude and concepts of more and less, number symbols and their correspondence with cardinality, the ability to count and an understanding of the principles of addition and subtraction.

The following three chapters consider children's development within each of these domains and the processes which contribute to it.

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119 Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental Science*, *10*(1), 89–96.

120 Geary, D. C., & Bjorklund, D. F. (2000). Evolutionary developmental psychology. *Child development*, *71*(1), 57–65.

121 Gelman, R., & Williams, E. M. (1998). Enabling constraints for cognitive development and learning: Domain specificity and epigenesis. In W. Damon (Ed.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (pp. 575–630). Hoboken, NJ: John Wiley.

122 Wellman, H. M., & Gelman, S. A. (1992). Cognitive development: Foundational theories of core domains. *Annual review of psychology*, *43*(1), 337–375.

123 Gopnik, A. (2011). The theory theory 2.0: probabilistic models and cognitive development. *Child Development Perspectives*, *5*(3), 161–163.

124 Newcombe, N. S. (2011). What is neoconstructivism?. *Child Development Perspectives*, *5*(3), 157–160.

Core-knowledge systems and their characteristics

Core-knowledge system 1: Inanimate objects and the physical world

- Cohesion (objects have boundaries with connected components)
- Continuity (objects move along unobstructed paths and cannot be in the same place at the same time)
- Contact (one object must contact another to make it move)
- Number limitation (infants cannot mentally represent more than three objects at the same time).

Core-knowledge system 2: The psychological intentions of living things

- Goal directedness (Intentional human actions are directed towards goals)
- Efficiency (goals are achieved through effective and efficient means)
- Contingency (means are not applied rigidly, but flexible towards conditions)
- Reciprocity (turn taking in interaction)
- Gaze direction (gaze direction is used to interpret social and non-social interactions).

Core-knowledge system 3: Numbers representation

- Abstractness (numbers are abstract ideas which apply objects, events, concepts)
- Comparability and combinability (number representations are comparable and can be combined by addition and subtraction.

3. Children's theories of objects and the physical world

3.1 What is it?

The child's theory of objects (also referred to as naïve physics) pertains to the child's common-sense understanding of objects and their physical and mechanical characteristics.[125] This includes an awareness that objects exist independently in space and time and that they adhere to specific physical laws.[126] Children's object knowledge includes their understanding of *object permanence*, as originally described by Piaget, as well as their knowledge of *object constancy* and *object cohesion* (see box 3.1).

Box 3.1: Early object knowledge

- **Object permanence** refers to the child's awareness that objects exist in space and time independently from the child, even when they are out of sight. Piaget maintained that children do not fully master object permanence until they are between 14 and 18 months old,[127] although more recent studies suggest that this may occur earlier, as described in the sections that follow.
- **Object constancy** refers to the fact that objects do not change their shape and size, depending on how they are viewed. Object constancy is informed by the child's spatial awareness, which may be sufficient to perceive objects as constant already at birth.[128]
- **Object cohesion** refers to the infant's ability to perceive objects as cohesive wholes with distinctive boundaries. Some believe that this capacity is present in newborns, whereas others have found that object cohesion is not stable until six months.[129,130,131]

Children's knowledge of objects also includes an understanding of their basic properties and potential use as tools.[132] Tool use begins already in infancy, when babies spontaneously use objects to retrieve other objects, or learn through instruction how to feed themselves.[133] Tool use continues to develop throughout the preschool years, as children actively discover the properties of objects by hitting, dropping, throwing or stacking them. This active

125 Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental science, 10*(1), 89–96.

126 Baillergeon, R. (2008). Innate ideas revisited: For a principle of persistence in infants' physical reasoning. *Perspectives on Psychological Science, 3*, 2–13.

127 Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

128 Slater, A.M., Mattock, A., Brown, E., & Bremner, G.J. (1991). Form perception at birth: Cohen and Younger (1984) revisited. *Journal of Experimental Child Psychology, 49*, 314–322.

129 Spelke, E. S. (1990). Principles of object perception. *Cognitive science*, *14*(1), 29–56.

130 Johnson, S. P. & Aslin, R. N. (1995). Perception of obioject unity in 2-month-old infants: The roles of motion, depth, and orientation. *Cognitive Development, 11*, 161–180.

131 Slater, A. M., Mattock, A., & Brown, E. (1990). Size constancy at birth: Nowborn infants' responses to retinal and real size. *Journal of Experimental Child Psychology, 49*, 314–322.

132 Bjorklund, D. F. & Gardiner, A. K. (2011). Object play and tool use: Developmental and evolutionary perspectives. In A. D. Pellegrini (ed.), *The Oxford handbook of the development of play* (pp. 153–171). Oxford, UK: Oxford University Press.

133 Connolly, K., & Dalgleish, M. (1989). The emergence of a tool-using skill in infancy. *Developmental Psychology*, *25*(6), 894.

manipulation allows children to understand objects' potential utility, as well as the adherence to basic physical laws (e.g. gravity, velocity) and simple relations between objects in terms of cause and effect. Children's understanding of object constancy – that is, the awareness that objects remain fundamentally the same despite transformations in their appearance – deepens throughout the early years.

Object theories are also informed by children's ability to appreciate similarities and differences between objects and form object categories.[134] Object categories are initially based on appearance and purpose, but become increasingly more complex and hierarchical as children develop.[135] Examples of advanced and overlapping categorical systems mastered during the preschool years include natural versus manmade, animate versus inanimate and conscious versus unconscious.

By the time children enter primary school, children are actively testing and revising their theories about the properties of objects and the ways in which they interact. These theories typically include notions about complex biological processes (such as 'Where do babies come from?' or 'How does the heart beat?') and abstract notions of life and death.[136] Children often generate these theories spontaneously, but these theories are also informed by explicit instruction.[137]

3.2 What other competencies are associated with the development of children's object knowledge?

Children's object knowledge is informed by their perceptual capabilities (such as spatial awareness, selective attention, memory and information processing speed) that allow them to recognise objects on the basis of their critical features.[138,139,140] These mental capabilities mature throughout infancy and toddlerhood, eventually developing into the executive functions (involving the working memory, attention control, cognitive flexibility and information processing speed) between the ages of three and five. Object knowledge is further informed by children's motor development, which determines their ability to grasp, hold, explore and manipulate objects.[141]

Object knowledge is also contingent upon the infant's ability to form mental representations.[142] Mental representations allow children to imagine objects under different circumstances and test assumptions about their function and use. Evidence suggests that the ability to form mental representations gradually increases during the first year and then expands rapidly with the acquisition of language.[143] While infants demonstrate some understanding of objects and their physical properties prior to acquiring language, it is assumed that having the words to describe these properties substantially deepens this knowledge.[144]

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134 Xu, F., Carey, S., & Welch, J. (1999). Infants' ability to use object kind information for object individuation. *Cognition*, *70*(2), 137–166.

135 Quinn, P. C. (2011). Born to categorize. In. U. Goswami (ed.) *The Wiley-Black Handbook of Cognitive Development*. 2nd edition (pp. 129–152), Chicester, West Sussex: Wiley-Blackwell Publishing.

136 Carey, S. (2009). *The origin of concepts.* New York: Oxford University Press.

137 Sloutsky, V. (2015). Conceptual Development. In R. M. Lerner, L. S. Liben & U. Muller (eds.) *Handbook of Child Psychology and Developmental Science*, 7th edition (pp. 469–518). Hoboken, N.J.: John Wiley and Sons.

138 Leslie, A. M., & Kaldy, Z. (2001). Indexing individual objects in infant working memory. *Journal of Experimental Child Psychology*, *78*(1), 61–74.

139 Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition*, *80*(1), 1–46.

140 Pelli, D. G., & Tillman, K. A. (2008). The uncrowded window of object recognition. *Nature neuroscience*, *11*(10), 1129.

141 Tamis-Lemonda, C. S., & Bornstein, M. H. (1993). Antecedents of exploratory competence at one year. *Infant Behavior and Development*, *16*(4), 423–439.

142 Tremoulet, P. D., Leslie, A. M., & Hall, D. G. (2000). Infant individuation and identification of objects. *Cognitive Development*, *15*(4), 499–522.

143 Perszyk, D. R., & Waxman, S. R. (2018). Linking Language and Cognition in Infancy. *Annual review of psychology*, *69*.

144 Gelman, S. A., & Meyer, M. (2011). Child categorization. *Wiley Interdisciplinary Reviews: Cognitive Science*, *2*(1), 95–105.

Children's object knowledge is particularly enhanced through the learning of object labels, which usually occurs between 9 and 24 months.[145,146] Label learning, which often takes place during shared attention activities with adults and older children (see below), serves multiple purposes:

- The naming process often includes pointing and demonstrations which focus the child's attention towards the object's salient features.
- Naming processes frequently include information about the function of objects.[147]
- A label conveys the idea that objects contain generic features which can be shared with other objects.[148] An awareness of these features, in turn, increases the toddler's understanding that objects may contain deeper, more essential properties which are not readily seen. Knowledge of unseen object properties encourages children to learn more about the nature of objects, as well as develop more complex and abstract concepts about them.

Children's object knowledge is also influenced by their ability to share attention with others. This ability develops during the first year and is a primary skill underpinning children's theory of mind (see chapter 4).[149] Adults facilitate joint attention by attracting and maintaining the infant's attention through verbal and visual cues.[150] As described in chapter 2, most adults do this naturally within the first few weeks of the child's life and there is good evidence that infants appreciate this behaviour. However, there is no clear evidence that infants are aware that others have intentions and that something can be learned from others, until the second half of the first year.[151] Attention sharing is typically evident at nine months, when most infants can actively follow the gaze of their parents during *triadic interactions* – that is, interactions involving the parent, child and an object. Initially, attention sharing is parent-led, but by 12 months, many infants are deliberately catching and directing their parents' attention towards objects and actions.[152]

Curiosity and motivation also clearly contribute to young children's understanding of objects. For example, studies have found that a significant proportion of young children develop a fascination of various categories of objects already by the age of two.[153] Common examples of early object 'obsessions' include balls, trains, other vehicles and dinosaurs.[154] When these interests are nurtured, children can develop a level of expertise about object categories that rivals that of an adult expert in terms of object facts. Although research in this area is sparse, studies find that intense interests during childhood often fuel the learning of other transferable cognitive skills, including an appreciation for complex processes (e.g. the principles underpinning combustion) and the use of sophisticated taxonomies.[155]

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145 Balaban, M., & Waxman, S. (1997). Words may facilitate categorisation in 9-month-old infants. *Journal of Experimental Child Psychology, 64*, 3–26.

146 Waxman, S. R. (1999). Specifying the scope of 13-month-olds' expectations for novel words. *Cognition, 70*, B35–B50.

147 Futó, J., Téglás, E., Csibra, G., & Gergely, G. (2010). Communicative function demonstration induces kind-based artifact representation in preverbal infants. *Cognition*, *117*(1), 1–8.

148 Gelman, S. A. (2003). The essential child: Origins of essentialism in everyday thought. *Oxford Series in Cognitive Development*. Oxford: Oxford University Press.

149 Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive development*, *15*(4), 481–498.

150 Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development, 78*, 938–954.

151 Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental science*, *10*(1), 121–125.

152 Carpenter, M. (2014). Social cognition and social motivations in infancy. In U. Goswami (eds), *The Wiley-Blackwell handbook of childhood cognitive development* (pp. 106–128). West Sussex, UK: Blackwell Publishing Ltd

153 DeLoache, J. S., Simcock, G., & Macari, S. (2007). Planes, trains, automobiles – and tea sets: Extremely intense interests in very young children. *Developmental psychology*, *43*(6), 1579.

154 Chi, M. T. H., Hutchinson, J. E. & Robin, A. F. (1989). How inferences about novel domain-related concepts can be constrained by structured knowledge. *Merrill-Palmer Quarterly, 35,* 2–62.

155 Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in cognitive sciences*, *6*(6), 248–254.

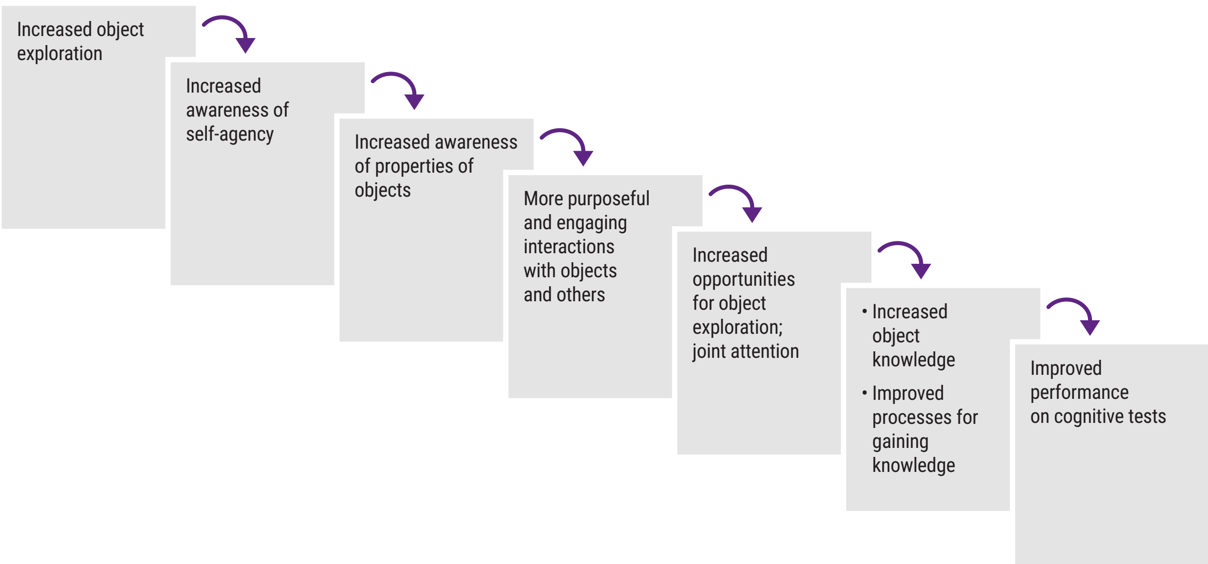
3.3 How does children's knowledge of objects impact their development over time?

Piaget assumed that active object exploration during infancy provided the starting point for children's knowledge of the external world.[156] As described in the previous chapter, basic motor and perceptual capabilities observed in infancy are thought to pave the way for more sophisticated cognitive skills as children develop. This assumption has recently been tested in several longitudinal studies conducted in the UK and US. For example, an analysis involving the Avon Longitudinal Study of Parents and Children (ALSPAC) cohort study observed that the infant's processing of object information at four months (through habituation tasks, see box 3.2 below) predicted their school achievement at age 14 indepdendently of their mothers' education and other environmental influences.[157] Similar results were observed in a more recent US cohort study, showing that infants' object exploration and motor maturation at five months predicted their intelligence at ages 4 and 10 and achievement at age 14.[158]

What processes link object manipulation in infancy to children's achievement at school? A simple explanation assumes that the same domain-general processes involving memory, perception and information processing that support object exploration in infancy also support children's intelligence and achievement in school. Researchers maintain, however, that the continuity observed in these behaviours is best understood through the metaphor of developmental 'cascades' which are rooted in the infant's emerging object processing skills. Figure 3.1 illustrates one potential cascade linking children's early object exploration to enhanced interactions with objects and the environment, which, in turn, increases their object knowledge and performance on validated measures when they grow older.[159]

FIGURE 3.1

Potential developmental cascades in children's theories of objects



Source: EIF

[156] Ginsburg, H. P., & Opper, S. (1988). *Piaget's theory of intellectual development*. Prentice-Hall, Inc.

[157] Bornstein, M. H., Hahn, C. S., & Wolke, D. (2013). Systems and cascades in cognitive development and academic achievement. *Child Development*, *84*(1), 154–162.

[158] Bornstein, M. H., Hahn, C. S., & Suwalsky, J. T. (2013). Physically developed and exploratory young infants contribute to their own long-term academic achievement. *Psychological science*, *24*(10), 1906–1917.

[159] Soska, K. C., Adolph, K. E., & Johnson, S. P. (2010). Systems in development: motor skill acquisition facilitates three-dimensional object completion. *Developmental psychology*, *46*(1), 129.

3.4 How do children's theories of objects develop during the first five years?

Children's understanding of the physical characteristics of objects – in other words, their permanence, constancy and cohesion – are thought to be biologically primary capabilities. This means that they are believed to be 1) acquired universally through processes which are 2) fundamentally innate and 3) require relatively little instruction or effort. Secondary processes, supported by adult guidance, are thought to support children's deeper awareness of objects' unseen characteristics, object relationships (wheel/vehicle) and object systems (world/universe). This section describes how these processes develop and interact with each another during the first five years.

0–12 months

Sensorimotor object interactions

Piaget originally maintained that the newborn's cognitive competences were restricted to a few innate reflexes, such as sucking, looking, listening and grasping. Piaget thus viewed the infant's knowledge as *sensorimotor*, as he believed it to be limited to the infant's basic sensory perceptions and motor movements. Table 3.1 provides an overview of the progression of the infant's sensorimotor capabilities during the first two years.

TABLE 3.1

The six substages of sensorimotor development

Stage	Age	Description	Example
Substage 1: Simple reflexes	1 month	The new born responds to external stimulation with innate reflexes.	The baby will grasp an object automatically if placed in the hand. Object knowledge is primarily reflexive.
Substage 2: Primary circular reactions	1–4 months	The baby intentionally repeats pleasurable physical actions.	The baby repeatedly kicks feet, wriggles fingers, sucks objects, etc. with intention. Babies may accommodate their actions towards objects but appear not to understand that objects exist outside the context of these interactions.
Substage 3: Secondary circular reactions	4–8 months	Babies explore objects and their properties through repetitive and increasingly sophisticated interactions.	The baby may intentionally shake a rattle or bang a table and make use of the feedback to modify behaviour. For example, the baby will alter the way s/he shakes a rattle to make different kinds of sounds. Babies explore objects and their properties through repetitive interactions.
Substage 4: Secondary circular reactions	8–12 months	The baby combines motor behaviour in pursuit of a goal.	The baby demonstrates simple tool use – for example, may use a blanket to pull an object to him or herself. The baby may search for a hidden object, but not persistently and not efficiently. For example, babies will search for objects where they were last found (location A), even when they can see they were hidden somewhere else (location B). This is known as the 'A not B' error.
Substage 5: Tertiary circular reactions	12–18 months	The toddler is capable of manipulating objects to test assumptions.	The toddler may dump a set of nesting boxes, just to put them back together, or drop objects from different heights to see how they fall. The toddler will search for objects when hidden, but not persistently, especially in the absence of visual cues.
Substage 6: The beginning of symbolic thought	18–24 months	The toddler can form mental representations of objects independently of being in their presence.	The toddler will search for object persistently if hidden and difficult to find. Can also anticipate where objects might be if out of sight – e.g. accurately identifying where a ball rolled under a piece of furniture.

Object manipulation in the weeks following birth is limited to reflexive behaviours and is thus primarily sporadic and non-intentional. For example, a rattle placed in a newborn's hand may be shaken, but only as the result of spontaneous arm movements – not because of any intentional behaviour or curiosity towards the rattle. By the time the infant is 12 months old, however, most of the infant's interactions with objects are explicitly intentional, reflecting some knowledge of the object's use and function.[160] From nine months onwards, infants also exhibit the beginnings of tool use, typically by using some objects (such as a blanket or stick) to retrieve others.[161]

Piaget proposed that a primary achievement of the sensorimotor stage was object permanence – in other words, the awareness that objects exist independently from the infant in space and time, even when they cannot be seen.[162] Piaget maintained that infants lacked full object permanence until 18 or so months, when the ability to mentally represent objects is fully mature. Piaget based this assumption on consistent searching errors made by infants and younger toddlers when desired objects were placed out of view (see table 3.1).

Piaget's assumptions about the age at which object permanence occurs have since been challenged on the basis that search errors may, in fact, be due to limitations in the infant's memory and motor coordination. Once these barriers are removed, studies show that infants as young as two months old demonstrate some understanding of object permanence by expressing surprise during violation of expectation tasks when objects disappear and then reappear in impossible places (see box 3.2). Researchers have thus argued that even very young infants have an expectation of object *persistence*, meaning that they understand that objects exist continuously and cannot vanish, break apart or turn into something else without something explicitly causing them to do so.[163]

While most researchers now assume that some expectation of persistence is present at birth, they differ on the extent to which they assume it is influenced by experience. Some argue that it is an innate capability which simply unfolds when infants receive the appropriate stimulation,[164] while others believe that experience is necessary for it to be efficiently and accurately applied.[165] This experience includes being able to watch objects moving in space and time and having opportunities to physically manipulate and explore objects.

160 Belsky, J., & Most, R. K. (1981). From exploration to play: A cross-sectional study of infant free play behavior. *Developmental psychology*, *17*(5), 630.

161 Bates, E., Carlson-Luden, V., & Bretherton, I. (1980). Perceptual aspects of tool using in infancy. *Infant Behavior and Development*, *3*, 127–140.

162 Piaget, J. (1952). *The origins of intelligence in children*. New York: International Universities Press.

163 Baillargeon, R. (2008). Innate ideas revisited: For a principle of persistence in infants' physical reasoning. *Perspectives on Psychological Science*, *3*(1), 2–13.

164 Spelke, E. S. (1998). Nativism, empiricism, and the origins of knowledge. *Infant Behavior and Development, 21*, 181–200.

165 Baillargeon, R., Li, J., Gertner, Y., & Wu, D. (2011). How Do Infants Reason About Physical Events? In. U. Goswami (ed.) *The Wiley-Black Handbook of Cognitive Development*. 2nd edition. (pp. 11–48), Chichester, West Sussex: Wiley Blackwell.

Box 3.2: How do we know what infants know?

Studying infant cognition can be challenging, since infants cannot tell you what they are thinking. However, when they are awake and alert, infants behave in ways which provide insight into their thoughts. One of these behaviours involves the length of time infants spend actively paying attention to something through looking, listening or sucking. Infants are easily bored and thus spend less time looking at things which they understand or are familiar with and more time looking at things that are novel and unfamiliar. Very young infants also suck faster when they are interested or see something new. Researchers thus use *habituation* paradigms to measure the time in which it takes infants to become familiar with or 'habituate' to stimuli and *dishabituate* to stimuli which they find boring. Habituation paradigms are commonly used to assess a wide range of infant capabilities, including memory and sensitivity to similarities between objects.[166]

Infants also demonstrate surprise when something extraordinary happens, regardless of whether they have habituated to it. This surprise is often expressed through increased looking times, but also by measuring overt changes in facial expression. Studies which aim to surprise infants are commonly known as violation of expectation (VOE) paradigms, measuring both looking times and changes in infant's facial expression.[167]

Although these research methods are widely used to study infants, they are not without controversy.[168] Criticisms include the fact that some infants may be too sleepy or fussy to participate in these paradigms, thus limiting the representativeness of the findings. Many also believe that researchers read too much into the infant behaviours. Nevertheless, many of the findings reported in habituation and VOE studies are frequently replicated by multiple research groups, thus increasing their credibility.

Infant looking times during a habituation task.

Extreme surprise during a VOE task.

Object categories

During the first 12 months of life, infants increasingly come to recognise that objects can be grouped into categories. Studies show that already at two months, infants make distinctions between objects on the basis of their physical appearance. Some maintain that infants accomplish this through innate perceptual capabilities which allow them to recognise similarities in object features (such as feathers). Over time, infants come to understand that

166 Oakes, L. M. (2010). Using habituation of looking time to assess mental processes in infancy. *Journal of Cognition and Development*, *11*(3), 255–268.

167 Baillargeon, R., Spelke, E. S., & Wasserman, S. (1985). Object permanence in five-month-old infants. *Cognition*, *20*(3), 191–208.

168 Munakata, Y. (2000). Challenges to the violation-of-expectation paradigm: Throwing the conceptual baby out with the perceptual processing bathwater? *Infancy, 1*(4), 471–477.

some features frequently co-occur (for instance, feathers often co-occur with two legs) and thus begin to form mental representations of object categories.[169,170]

Early object categories are initially inclusive and based on a relatively constrained set of physical characteristics. For example, already at three months, infants can form categorical representations of dogs and cats which exclude birds, and categorical representations of cats which exclude dogs.[171,172] However, infants only form these categories in instances where there is relatively little within-category variation. Thus, young infants cannot readily form categories of dogs which exclude cats – unless the variability of dog type is limited to a relatively small number of physical features which are substantially different from cat features. For example, the category 'cat' is visually more straightforward, as all cats have a short snout and pointy ears. Dogs, by contrast, vary more dramatically in appearance and thus the category 'dog' requires more experience to be mastered.

Up until nine months, infant categorisation is fundamentally implicit, based on similarities in objects' physical appearance and movement.[173] By nine months, however, studies show that infants recognise similarities between objects on the basis of their function and use.[174] For example, most ten-month-olds can recognise the word cup and apply it correctly to a wide variety of cups, despite differences in appearance. Some researchers argue that this ability reflects a deeper and more conceptual understanding of objects, rooted in the awareness that all objects have 'essential' characteristics.[175] Over time, the infant's understanding of an object's essential nature is tested and revised as infants gain experience with them – leading to the production of words, which we describe in greater detail in chapter 6.[176,177,178,179]

12–36 months

Object names

During the second year, children's vocabulary rapidly increases. At 12 months, most infants can say only five or so words. By 24 months, the average toddler can say over 300.[180] The majority of first words are nouns[181] learned both through observation and active object labelling by caregivers and other adults.[182] Children typically first learn the names of specific people and animals (such as mummy, daddy, dog's name), and the generic label for objects

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169 Quinn, P.C. (2011). Born to categorize. In. U. Goswami (ed.) *The Wiley-Black Handbook of Cognitive Development*. 2nd edition (pp. 129–152), Chichester, West Sussex: Wiley Blackwell.

170 Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M, & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive psychology, 8*(3) 382–439.

171 Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception*, *22*(4), 463–475.

172 Eimas, P. D., & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child development*, *65*(3), 903–917.

173 Mandler, J. M. (2000). Perceptual and conceptual processes in infancy. *Journal of cognition and development*, *1*(1), 3–36.

174 Horst, J. S., Oakes, L. M. and Madole, K. L. (2005). What does it look like and what can it do? Category structure influence how infants categorise. *Child Development, 76*, 614–631.

175 Gelman, S. A. (2003). The essential child: Origins of essentialism in everyday thought. *Oxford Series in Cognitive Development*. Oxford: Oxford University Press.

176 Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate–inanimate distinction. *Psychological bulletin*, *127*(2), 209.

177 Oakes, L. M. & Madole, K. L. (2003). Principles of developmental change in infants' category formation. In D.H. Rakison and L.M. Oakes (eds) *Early category and concept development*. (pp. 131–158). New York, NY: Oxford University Press.

178 Younger, B., & Gottlieb, S. (1988). Development of categorization skills: Changes in the nature or structure of infant form categories? *Developmental Psychology, 24*, 611–619.

179 Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological review*, *92*(3), 289.

180 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

181 Waxman, S., Fu, X., Arunachalam, S., Leddon, E., Geraghty, K., & Song, H. J. (2013). Are Nouns Learned Before Verbs? Infants Provide Insight Into a Long-Standing Debate. *Child development perspectives*, *7*(3), 155–159.

182 Althaus, N., & Westermann, G. (2016). Labels constructively shape object categories in 10-month-old infants. *Journal of experimental child psychology*, *151*, 5–17.

shortly thereafter.[183] For example, any ball (big, small, soft hard) is labelled a ball, all non-familiar dogs are labelled as dogs, all cups are labelled as cups, and so on. It is assumed that the generic labelling of objects solidifies children's understanding of objects' essential characteristics and the ways in which they are similar or different from each other.[184]

Once children master nouns, they quickly learn their associated verbs and adjectives. This further refines their understanding of the essential features of objects and object categories.[185] For example, dogs can move, drink water, have fur and can bark. Cats can also move, drink water, have fur, but do not bark. Cars also move, but don't drink water and do honk, and so forth. By 18 months, most toddlers reliably categorise animate objects based on their biological and mechanical features.[186] Many can also recognise hierarchical relationships within categories and this capability appears to be directly linked to the size of their vocabulary.[187]

Between the ages of two and three, children's understanding of objects becomes increasingly more sophisticated as their language and motor skills continue to develop. At 30 months, the typical child's vocabulary will have expanded to just under 600 words, allowing them to describe objects in terms of their shape, size and function.[188] Two-year-olds are also starting to develop theories about the relationship between objects. These theories continue to be informed by objects' physical characteristics, but also reflect a deeper understanding of how objects work and what they do, as well as children's ability to understand more complex and hierarchical object categories.[189,190] For example, many two-year-olds will have a fundamental understanding of vehicles and their various moving parts, the function ad purpose of various body parts and associations between animals and their habitats.

Object play

During the second year, children's ability to manipulate and interact with objects becomes progressively more sophisticated. Prior to nine months, children's approach towards objects is primarily exploratory and often quite serious.[191] For example, studies have found that during the first year, infants are not easily distracted, and their heart rate increases when they are given a new object to play with.[192] Throughout the second year, children's interactions with objects become more playful and less exploratory.[193]

Pretend play can be seen in children as young as ten months old, who may pretend to eat invisible food with a spoon and a plate or pretend to talk on a toy phone. At first, the infant directs this play towards real or replica objects in the way the object was intended to be used, as a form of imitation. By 18 months, however, toddlers actively use objects to represent something they are not. Hence, a block can become a car, a clothespin can become a doll,

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183 Nelson, K. (1973). Structure and strategy in learning to talk. *Monographs of the society for research in child development*, 1–135.

184 Perszyk, D. R., & Waxman, S. R. (2018). Linking Language and Cognition in Infancy. *Annual review of psychology*, *69*.

185 Carey, S. (2010). Beyond fast mapping. *Language Learning and Development*, *6*(3), 184–205.

186 Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate–inanimate distinction. *Psychological bulletin*, *127*(2), 209.

187 Gopnik, A., & Meltzoff, A. N. (1992). Categorization and naming: Basic-level sorting in eighteen-month-olds and its relation to language. *Child Development*, *63*(5), 1091–1103.

188 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

189 Quinn, P.C. (2011). Born to categorize. In. U. Goswami (ed.) *The Wiley-Black Handbook of Cognitive Development*. 2nd edition (pp. 129–152), Chichester, West Sussex: Wiley Blackwell.

190 Gopnik, A., & Nazzi, T. (2003). Words, kinds and causal powers: A theory theory perspective on early naming and categorization. *Early category and concept development: Making sense of the blooming, buzzing confusion*, *303–329*.

191 Pellegrini, A. D. (2016). Object use in childhood: Development and possible functions. In *Evolutionary Perspectives on Child Development and Education* (pp. 95–115). Springer International Publishing.

192 Hutt, C. (1966). Exploration and play in children. In *Symposia of the Zoological Society of London*, *18*,61–81.

193 Belsky, J., & Most, R. K. (1981). From exploration to play: A cross-sectional study of infant free play behavior. *Developmental psychology*, *17*(5), 630.

and so on. Piaget maintained that this level of substitution suggests that the child's thought processes have become essentially symbolic, meaning that they can no longer be described as sensorimotor.[194]

Initially, children's pretend play is directed at the self, but by 15 months the infant can engage in pretend play with others. It is thought that pretend play serves multiple purposes.[195] First, it enriches children's understanding of objects by providing them with opportunities to imagine them in various circumstances and gain familiarity with their function and use. This includes objects that children do not have direct experience with. For example, a child cannot actually drive a car, but pretending to drive one provides an opportunity to imagine its functionality. Pretend play also allows children to adopt the perspective of others, which is a necessary skill in the development of theory of mind (see chapter 4).

Objects as tools

During the second year, children also start to engage with objects constructively – in other words, they can now use objects to make other objects.[196] For example, nested bowls can be stacked to form a tower, a lump of sand can become a cake and blocks can be lined sequentially to form a train. Children also demonstrate a more sophisticated understanding of objects as tools, although this is frequently after seeing the tool's use demonstrated (such as when a parent uses a tool for sweeping) rather than spontaneously using the object as a tool.[197,198]

Three to five years

Object relationships

Between the ages of three and five, children's understanding of objects reflects a deeper awareness of abstract object relationships: adult–child, whole–part, cause–effect, occupation–tool, opposites, matches, and so on. This awareness of object relationships allows preschoolers to engage in *relational mapping*, which is a form of analogical thinking that allows children to draw an analogy between what is known about one set of objects (the relationship between A and B) to another.[199] Children between the ages of three and five are thus actively using what they know about one set of object relationships to form theories about other object relationships.[200] Initially, this mapping is based on physical or thematic similarities. However, by the time children reach the age of five, a *relational shift* is evident, whereby relational mapping is informed by the child's deeper knowledge of object systems.[201]

For example, a three-year-old might assume that a squirrel lays eggs because of a thematic similarity with birds – that is, both birds and squirrels live in trees. By contrast, a five-year-old who is aware of a more fundamental biological difference between mammals and birds will understand that squirrels cannot lay eggs because they are mammals. In other words, the five-year-old will not need to be told that a squirrel cannot lay eggs, as he or she will be able to accurately predict this with knowledge of the class relationship between squirrels and mammals.

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194 Piaget, J. (2013). *Play, dreams and imitation in childhood* (Vol. 25). Routledge.

195 Pellegrini, A. (2013). Play. In Masten, A. S., & Zelazo, P. D. *The Oxford Handbook of Developmental Psychology, Vol. 2: Self and Other* (pp. 276–299). Oxford: Oxford University Press.

196 Pellegrini, A. D. (2016). Object use in childhood: Development and possible functions. In *Evolutionary Perspectives on Child Development and Education* (pp. 95–115). Springer International Publishing

197 Chen, Z., Siegler, R. S., & Daehler, M.W. (2000). Across the Great Divide: Bridging the Gap between Understanding of Toddlers' and Older Children's Thinking. *Monographs for the Society for Research in Child Development, 65.*

198 Pauen, S. & Bechtel-Kuehne, S. (2016). How toddlers acquire and transfer tool knowledge: Develpomoental changes and the role of executive functions. *Child Development, 87*, 1233–1249.

199 Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive science*, *7*(2), 155–170.

200 Gopnik, A., Meltzoff, A. N., & Bryant, P. (1997). *Words, thoughts, and theories* (Vol. 1). Cambridge, MA: Mit Press.

201 Gentner, D., & Hoyos, C. (2017). Analogy and abstraction. *Topics in Cognitive Science*.

This relational shift in children's understanding of objects and object systems is thought to support more advanced thought processes involving the abstract analogical and inductive reasoning skills used to solve problems during later childhood and adolescence (see box 3.3). Older preschoolers begin to engage in these processes, in part, because they know more about objects (that is, have more knowledge/facts) and have a greater vocabulary to describe them.[202] Studies also suggest, however, that analogical and inductive reasoning skills rely on the efficiency of the executive functions, which mature rapidly between the ages of three and five (see chapter 2).[203] Enhanced executive functions not only improve children's ability to remember important object facts, they also help children to focus their attention on the abstract similarities between objects. In this respect, studies confirm a longitudinal link between increased executive function efficiency in preschool and improved analogical reasoning capabilities in late adolescence.[204] Despite this link, researchers acknowledge that executive functions alone cannot support children's analogical reasoning skills. Children must also have a fairly sophisticated understanding of object properties and their relationship to each other, and this knowledge can only be gained through experience and instruction.[205]

Box 3.3: What do we mean by analogical problem-solving?

An *analogy* is a comparison between two or more objects, or systems of objects. Analogical problem-solving draws on the child's understanding of how one set of objects is similar or different to make a judgment or prediction about another set of objects. For example, a child will be able accurately answer the question 'moon is to sun, as black is to…?' as 'white' if he or she understands that the moon and sun are opposites, in the way the colours black and white are.

Analogical thinking underpins children's ability to understand the meaning of many idioms, jokes, poems and other forms of speech. As children grow older, analogical problem-solving capabilities also allow children to understand increasingly abstract relationships and engage in the inductive and deductive reasoning involved in solving algebra problems and various scientific experiments, as illustrated in figure 3.2.[206] Although analogical reasoning is often used in abstract problem solving (example B), initial analogical capabilities are rooted in children's understanding of object hierarchies and object relationships (example A).

202 Goswami, U. (1991). Analogical reasoning: What develops? A review of research and theory. *Child development*, *62*(1), 1–22.

203 Thibaut, J. P., French, R., & Vezneva, M. (2010). The development of analogy making in children: Cognitive load and executive functions. *Journal of experimental child psychology*, *106*(1), 1–19.

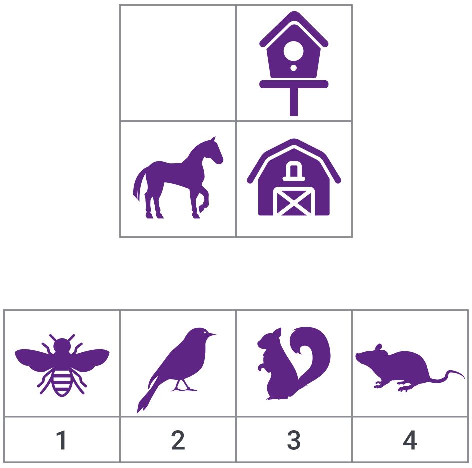
204 Richland, L. E., & Burchinal, M. R. (2013). Early executive function predicts reasoning development. *Psychological science*, *24*(1), 87–92.

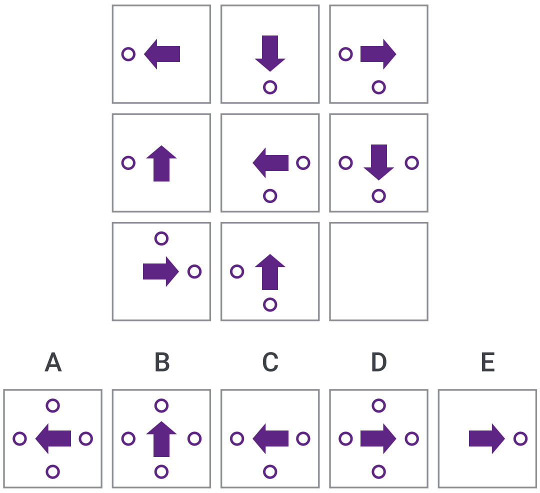
205 Goswami, U. (2010). Inductive and deductive reasoning. *The Wiley-Blackwell Handbook of Childhood Cognitive Development*, 2nd edition, 399–419.

206 Becker, N., Schmitz, F., Falk, A. M., Feldbrügge, J., Recktenwald, D. R., Wilhelm, O., … & Spinath, F. M. (2016). Preventing response elimination strategies improves the convergent validity of figural matrices. *Journal of Intelligence*, *4*(1), 2.

FIGURE 3.2

Examples illustrating analogical reasoning





Example A

Example of a problem-solving task from the WPPSI intelligence test which makes use of children's ability to draw analogies between animal relationships.

Example B

Analogical reasoning skills are necessary to determine which of the answers A through E complete the figural matrix.

Source: Reproduced from Becker et al. 2016. Preventing response elimination strategies improves the convergent validity of figural matrices. *Journal of Intelligence*, *4*(1), 2.

3.5 What factors influence the development of children's understanding of objects and the physical world during the first five years of life?

Overview

This chapter has taken a broad view of children's early object knowledge. During infancy, children use their senses and motor capabilities to process information about the features and functions of the objects existing in their everyday environments. By late preschool, children have abstract mental representations of complex object systems which allow them to accurately predict how objects will interact. This change in understanding occurs in virtually every child and is viewed as biologically primary by most researchers. However, a wide variety of inherited and environmental factors influence the course of this trajectory and thus contribute to individual differences that emerge during the preschool years.

Understanding individual differences in the development of children's object knowledge can be challenging. This is partially because there are relatively few pure measures of children's object knowledge. In infancy, object knowledge is assessed through children's manipulation of objects, which also measure early motor development. In late preschool, object knowledge is assessed through intelligence and achievement tests, which are highly reliant on children's language skills. This variation in measurement has contributed to differences in the ways in which studies define and measure children's object knowledge. Some studies rely solely on vocabulary measures, whereas others make use of more object-specific measures, including observations of children's object play. In this section, we will be drawing on evidence involving both sets of measures, depending on the study and the children's age.

A second challenge in this field is that studies vary in the factors they chose to investigate. While there is broad consensus that a common set of factors contribute to children's early cognitive development (see table 2.3 in chapter 2), their relative impact is rarely considered in a single study. While some studies focus primarily on 'proximal' factors occurring in the child's home, others also consider 'distal' factors involving the child's community and various other sociocultural factors. These differences, combined with differences in measurement and sample characteristics, can result in contradictory findings which limit our ability to draw conclusions about factors which matter the most.

In this section, we provide an overview of the factors found to impact children's early understanding of objects in instances where the literature provides a consistent set of messages. We do not view these factors to be the only or most important influences. However, we do believe they provide a useful starting point for understanding when and how to best support the development of children's object understanding during the early years.

Genetic factors

Few studies have directly considered the heritability of children's object knowledge, although quite a few have considered the development of intelligence more generally, through a battery of measures which include assessments of children's knowledge of objects and object relationship (see section 3.6). These studies consistently find that the heritability of intelligence during the preschool years is relatively low. Specifically, studies show virtually no heritability before the age of two, increasing to .20 in later preschool, rising above .40 in later primary school and above .60 in early adulthood.[207,208,209]

Given that the heritability of many capabilities often decreases over time (see chapter 2), heritability estimates involving young children's intelligence appear paradoxical. While some assume that the low heritability of intelligence at age two is related to a lack of precision in measurement,[210,211] others argue that the steady increase in heritability is potentially due to *innovations* in children's neurodevelopmental maturation and/or the *amplification* of gene-environment interplay.

Arguments involving *innovation* are based in the assumption that brain maturation is most likely genetically determined.[212] As described in chapter 2, the brain undergoes dramatic changes in early childhood, including changes in the amount of white matter (myelination) which increases the efficiency of neural connections. Some maintain that intelligence tests capture some of this efficiency in the variance (in other words g processes) that is shared across subtests. Twin studies have found that during early childhood white matter thickness is not associated with g, whereas in later childhood there is a modest positive association.[213,214]

207 Briley, D. A., & Tucker-Drob, E. M. (2013). Explaining the increasing heritability of cognitive ability across development: A meta-analysis of longitudinal twin and adoption studies. *Psychological Science*, *24*(9), 1704–1713.

208 Tucker-Drob, E. M., & Briley, D. A. (2014). Continuity of genetic and environmental influences on cognition across the life span: A meta-analysis of longitudinal twin and adoption studies. *Psychological bulletin*, *140*(4), 949.

209 Davis, O. S., Haworth, C. M., & Plomin, R. (2009). Dramatic increase in heritability of cognitive development from early to middle childhood: An 8-year longitudinal study of 8,700 pairs of twins. *Psychological Science*, *20*(10), 1301–1308.

210 Bayley, N. (1949). Consistency and variability in the growth of intelligence from birth to eighteen years. *The Pedagogical Seminary and Journal of Genetic Psychology, 75*(2) 165–196.

211 Tucker-Drob, E. M., & Briley, D. A. (2014). Continuity of genetic and environmental influences on cognition across the life span: A meta-analysis of longitudinal twin and adoption studies. *Psychological bulletin*, *140*(4), 949.

212 Plomin, R., DeFries, J. C., Knopik, V. S., & Neiderhiser, J. M. (2016). Top 10 replicated findings from behavioral genetics. *Perspectives on Psychological Science*, *11*(1), 3–23.

213 Wallace, G. L., Eric Schmitt, J., Lenroot, R., Viding, E., Ordaz, S., Rosenthal, M. A., ... & Giedd, J. N. (2006). A pediatric twin study of brain morphometry. *Journal of child psychology and psychiatry*, *47*(10), 987–993.

214 Shaw, P., Greenstein, D., Lerch, J., Clasen, L., Lenroot, R., Gogtay, N. E. E. A., ... & Giedd, J. (2006). Intellectual ability and cortical development in children and adolescents. *Nature*, *440*(7084), 676.

Arguments involving *amplification* are consistent with gene-environment interplay described in chapter 2.[215] Heritability estimates thus increase over time as children actively select, modify and create environments that are consistent with their genetic make-up.[216,217] Some speculate that once children enter school they evoke responses from their teachers that are consistent with their genetic propensities.[218] Teacher behaviours, in turn, reinforce the heritable aspects of cognitive thought processes and thus magnify the contribution of inherited effects, even though they contain an environmental component.[219,220]

Intellectual disabilities

Heritability estimates pertain to variation occurring in typically developing populations. Within these samples, intellectual disabilities are understood to represent the low-end of normal development and are thought to be caused by many genes which produce very small, but cumulative effects.[221] However, some intellectual disabilities are thought to involve a smaller set of genes involving non-heritable mutations, which are associated with more profound effects.[222] For example, various forms of autism spectrum conditions (ASCs) are assumed to fall into this latter category.[223,224] ASCs are frequently marked by delays in children's sensorimotor development, as well as unusual interactions with objects.[225] For example, infants at risk for ASCs are more likely to spin or rotate objects, or develop unusual object fixations.[226,227] Children at risk for ASCs also often have difficulty participating in joint attention activities with their parents, which in turn, negatively affects their ability to understand the features and functions of objects.[228]

Intellectual disabilities can also be caused by gene mutations which are not heritable but occur with some frequency. Down's Syndrome is an example of a genetic mutation which always has profound effects on children's intellectual functioning.[229] While most children with Down's Syndrome demonstrate the object permanence, constituency and cohesion described in the first part of this chapter, their progression through the sensorimotor

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215 Sauce, B., & Matzel, L. D. (2018). The paradox of intelligence: Heritability and malleability coexist in hidden gene-environment interplay. *Psychological bulletin*, *144*(1), 26.

216 Scarr, S., & McCartney, K. (1983). How people make their own environments: A theory of genotype environment effects. *Child Development*, *54*, 424–435.

217 Dickens, W. T., & Flynn, J. R. (2001). Heritability estimates versus large environmental effects: the IQ paradox resolved. *Psychological review*, *108*(2), 346.

218 Davis, O. S., Haworth, C. M., & Plomin, R. (2009). Dramatic increase in heritability of cognitive development from early to middle childhood: An 8-year longitudinal study of 8,700 pairs of twins. *Psychological Science*, *20*(10), 1301–1308.

219 Plomin, R., & Deary, I. J. (2015). Genetics and intelligence differences: five special findings. *Molecular psychiatry*, *20*(1), 98.

220 Haworth, C. M., Wright, M. J., Luciano, M., Martin, N. G., de Geus, E. J., van Beijsterveldt, C. E., ... & Kovas, Y. (2010). The heritability of general cognitive ability increases linearly from childhood to young adulthood. *Molecular psychiatry*, *15*(11), 1112.

221 Plomin, R., & Deary, I. J. (2015). Genetics and intelligence differences: five special findings. *Molecular psychiatry*, *20*(1), 98.

222 Reichenberg, A., Cederlöf, M., McMillan, A., Trzaskowski, M., Kapra, O., Fruchter, E., ... & Plomin, R. (2016). Discontinuity in the genetic and environmental causes of the intellectual disability spectrum. *Proceedings of the National Academy of sciences*, *113*(4), 1098–1103.

223 Chaste, P., & Leboyer, M. (2012). Autism risk factors: genes, environment, and gene-environment interactions. *Dialogues in clinical neuroscience*, *14*(3), 281.

224 Geschwind, D. H. (2011). Genetics of autism spectrum disorders. *Trends in cognitive sciences*, *15*(9), 409–416.

225 Kaur, M., Srinivasan, S. M., & Bhat, A. N. (2015). Atypical object exploration in infants at-risk for autism during the first year of life. *Frontiers in psychology*, *6*, 798.

226 Koterba, E. A., Leezenbaum, N. B., & Iverson, J. M. (2014). Object exploration at 6 and 9 months in infants with and without risk for autism. *Autism*, *18*(2), 97–105.

227 Ozonoff, S., Macari, S., Young, G. S., Goldring, S., Thompson, M., and Rogers, S. J. (2008). Atypical object exploration at 12 months of age is associated with autism in a prospective sample. *Autism* 12, 457–472.

228 Adamson, L. B., Bakeman, R., Deckner, D. F., & Romski, M. (2009). Joint engagement and the emergence of language in children with autism and Down's syndrome. *Journal of autism and developmental disorders*, *39*(1), 84.

229 Roizen, N. J., & Patterson, D. (2003). Down's syndrome. *The Lancet*, *361*(9365), 1281–1289.

sequence described in table 3.1 is frequently delayed.[230,231] Delays in the language and causal reasoning capabilities of children with Down's Syndrome can also negatively impact their ability to reason about object relationships, although the severity of these impacts can vary dramatically from child to child.[232]

Antenatal factors

The formation of brain cells and neuronal connectivity which takes place during the antenatal period lays the groundwork for optimal object exploration after the infant is born. Much of this work takes place during the third trimester, when over 50% of the initial neuro-connectivity occurs.[233] Studies show that a premature birth can significantly disrupt this process, placing the child's cognitive development at risk.[234] Factors that support optimal antenatal brain development include the mother's nutrition and diet, reduced levels of maternal stress and the restriction of harmful substances in the womb, such as nicotine, alcohol and illicit substances such as cocaine. This section summarises what is known about the impact of the antenatal environment on birth outcomes and children's later cognitive development.

Maternal nutrition

Sufficient levels of protein, iron, zinc, copper, and a variety of fatty acids support the brain cell growth that takes place during the antenatal period, especially during the third trimester.[235] Studies show that protein, iron and copper are particularly associated with improved object manipulation on the Bayley Scales in later infancy.[236] Supplemental use of the fatty acids provided by fish is also thought to support foetal development throughout pregnancy. Support for this assumption comes from the Avon Longitudinal Study of Parents and Children (ALSPAC), which observed that increased fish intake (three or more times per week) during pregnancy was associated with small, but significant increases in children's knowledge of object names and cognitive processing at 18 months.[237]

Maternal stress and mental illness

High levels of maternal stress during pregnancy are believed to introduce higher than optimal levels of cortisol in the womb that are thought to contribute to poor cognitive outcomes in children's later development.[238] While much of the initial research in this area has involved animals, a number of studies have recently verified a similar association in humans. For example, a recent US birth study observed that high levels of intrauterine cortisol during the first trimester was associated with reduced cognitive performance and motor manipulation in children at 12 months, independently of any other adverse parent or child factors.[239]

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230 Bruce, S., & Muhammad, Z. (2009). The development of object permanence in children with intellectual disability, physical disability, autism, and blindness. *International Journal of Disability, Development and Education*, *56*(3), 229–246.

231 Pasnak, C. F., & Pasnak, R. (1987). Accelerated development of object permanence in Down's syndrome infants. *Child: Care, Health and Development*, *13*(4), 247–255.

232 Roberts, J. E., Price, J., & Malkin C. (2007). Language and communication developing in Down syndrome. *Mental Retardation and Developmental Disabilities Research Reviews. 13*, 26–35.

233 Adams-Chapman, I. (2006). Neurodevelopmental outcome of the late preterm infant. *Clin. Perinatol, 33*, 947–964.

234 Davis, E. P., Buss, C., Muftuler, T., Head, K., Hasso, A., Wing, D., ... & Sandman, C. A. (2011). Children's brain development benefits from longer gestation. *Frontiers in psychology, 2*, 1.

235 Borge, T. C., Aase, H., Brantsæter, A. L., & Biele, G. (2017). The importance of maternal diet quality during pregnancy on cognitive and behavioural outcomes in children: a systematic review and meta-analysis. *BMJ open*, *7*(9), e016777.

236 Georgieff, M. K. (2007). Nutrition and the developing brain: nutrient priorities and measurement. *The American journal of clinical nutrition*, *85*(2), 614S–620S.

237 Daniels, J. L., Longnecker, M. P., Rowland, A. S., Golding, J., & ALSPAC Study Team. (2004). Fish intake during pregnancy and early cognitive development of offspring. *Epidemiology*, *15*(4), 394–402.

238 Glover, V. (2015). Prenatal stress and its effects on the fetus and the child: possible underlying biological mechanisms. In *Perinatal Programming of Neurodevelopment* (pp. 269–283). Springer New York.

239 Davis, E. P., & Sandman, C. A. (2010). The timing of prenatal exposure to maternal cortisol and psychosocial stress is associated with human infant cognitive development. *Child Development*, *81*(1), 131–148.

Sources of maternal stress measured in this study included pregnancy-specific anxiety, depression and general anxiety. Interestingly, these sources of anxiety and other forms of maternal stress were not significantly associated with the mothers' levels of intrauterine cortisol. Nevertheless, elevated levels of pregnancy-specific anxiety occurring during the second trimester were found to also contribute to negative child outcomes at 12 months, and this relationship was independent of any other family risk factors (including maternal stress) occurring during the postnatal period.

These findings are consistent with those previously reported for the ALSPAC cohort, which found that maternal depression occurring in pregnancy significantly predicted cognitive delays in infants at 12 months. Once again, this relationship was independent of any postnatal symptoms of depression or other family risk factors.[240] Similarly, a recent, large-scale Canadian study found that maternal depression during pregnancy rivalled a preterm birth in predicting cognitive delays at 12 months in comparison to a wide range of other family risk factors, including postnatal depression and family income.[241]

Exposure to harmful substances

Antenatal exposure to drugs and alcohol is consistently associated with impaired cognitive performance at later points in children's development, although the level at which exposure is harmful is strongly debated. At the extreme end, there is clear evidence that four or more units of alcohol a day during pregnancy is associated with reduced information processing speed during infancy,[242] impaired executive functioning in preschool, and reduced academic performance in adolescence.[243,244] At the less extreme end, studies find no association between occasional drinking and negative child outcomes, although findings from recent studies have been mixed. For example, a recent analysis involving the Millennium Cohort Study (MCS) found that one or two drinks per week during pregnancy predicted improved cognitive outcomes in children during middle childhood.[245] More recently, however, a meta-review found that even low levels of alcohol during the first trimester (less than two units per week) increased the risk of a premature or low birthweight baby.[246] Mothers are therefore advised to abstain from drinking entirely during their pregnancies.

Findings involving antenatal exposure to cigarette smoke on children's cognitive performance are also equivocal. For example, studies involving rats and other animals observe that any level of nicotine, in the absence of other harmful tobacco substances (such as carbon monoxide), disrupts early synaptogenetic processes thought to support later cognitive development.[247] Conversely, a recent large-scale Danish cohort study observed that while 10 or more cigarettes per day were strongly associated with cognitive deficits at age five, these deficits were no longer present once other associated family and environmental variables (such as income, parental education, ongoing exposure to cigarette smoke) were statistically

[240] Deave, T., Heron, J., Evans, J., & Emond, A. (2008). The impact of maternal depression in pregnancy on early child development. *BJOG: An International Journal of Obstetrics & Gynaecology*, *115*(8), 1043–1051.

[241] McDonald, S., Kehler, H., Bayrampour, H., Fraser-Lee, N., & Tough, S. (2016). Risk and protective factors in early child development: Results from the All Our Babies (AOB) pregnancy cohort. *Research in developmental disabilities*, *58*, 20–30.

[242] Mattson, S. N., Crocker, N., & Nguyen, T. T. (2011). Foetal alcohol spectrum disorders: neuropsychological and behavioral features. *Neuropsychology review*, *21*(2), 81–101.

[243] Jacobson, J. L., & Jacobson, S. W. (2002). Effects of prenatal alcohol exposure on child development. *Alcohol Research and Health*, *26*(4), 282–286.

[244] Alati, R., Smith, G. D., Lewis, S. J., Sayal, K., Draper, E. S., Golding, J., ... & Gray, R. (2013). Effect of prenatal alcohol exposure on childhood academic outcomes: contrasting maternal and paternal associations in the ALSPAC study. *PloS one*, *8*(10), e74844.

[245] Kelly, Y., Iacovou, M., Quigley, M. A., Gray, R., Wolke, D., Kelly, J., & Sacker, A. (2013). Light drinking versus abstinence in pregnancy–behavioural and cognitive outcomes in 7-year-old children: a longitudinal cohort study. *BJOG: An International Journal of Obstetrics & Gynaecology*, *120*(11), 1340–1347.

[246] Mamluk, L., Edwards, H. B., Savović, J., Leach, V., Jones, T., Moore, T. H., ... & Smith, G. D. (2017). Low alcohol consumption and pregnancy and childhood outcomes: time to change guidelines indicating apparently 'safe' levels of alcohol during pregnancy? A systematic review and meta-analyses. *BMJ open*, *7*(7), e015410.

[247] Wickstrom, R. (2007). Effects of nicotine during pregnancy: human and experimental evidence. *Current neuropharmacology*, *5*(3), 213–222.

taken into account.[248] Nevertheless, there is ample evidence that exposure to tobacco during the antenatal period is deleterious for other child health and development outcomes, so should therefore be avoided.

Studies also find that inadvertent exposure to lead during the antenatal and postnatal period may lead to significant cognitive deficits. Lead is a heavy metal which remains in the human body once it is absorbed. Studies show that lead can damage all body parts, but is particularly detrimental to the developing brain.[249] Studies observe that even small concentrations of lead in in the child's blood system potentially disrupt early synapse production and myelination leading to permanent mental impairment, thus leading to delays in children's motor development and an increased risk of attention deficit hyperactivity disorder (ADHD).[250,251,252,253,254]

Sources of lead during the antenatal period include traces of lead stored in the mother's bones which are then released into the womb through the mother's blood during pregnancy. Maternal smoking also increases concentrations of lead in the womb during the antenatal period. After birth, children may be exposed to lead through ingesting products with lead in them (paint, soil, water) or through leaded car fumes or household dust which settles on objects which are then ingested when children place them in their mouths. Risks associated with lead exposure after the child is born include maternal smoking, coal fire heating, being raised in urban settings or near an industrial estate.[255]

Preterm birth/obstetric complications

Studies consistently show that the presence of cigarette smoke in the womb indirectly impacts children's cognitive development through an increased risk of a premature birth, particularly impairing the cognitive function of children born before 32 weeks gestation.[256,257,258] It is believed that this is due to premature exposure to light and other stimuli, which substantially disrupts the neural migration, connectivity and myelination that occurs during the last trimester of the mother's pregnancy. Similar disruptions have been observed among infants experiencing birth trauma, either through oxygen restriction or direct cerebral injury.[259,260]

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248 Falgreen Eriksen, H. L., Kesmodel, U. S., Wimberley, T., Underbjerg, M., Kilburn, T. R., & Mortensen, E. L. (2012). Effects of tobacco smoking in pregnancy on offspring intelligence at the age of 5. *Journal of pregnancy*.

249 WHO (2016). Lead poisoning and health. http://www.who.int/mediacentre/factsheets/fs379/en/

250 Mycyk, M., Hryhorczuk, D., & Amitai, Y. (2005). *Lead*. In Erickson, T.B., Ahrens, W. R., Aks, S., & Ling, L. *Pediatric Toxicology: Diagnosis and Management of the Poisoned Child*. McGraw-Hill Professional.

251 Pearson H. A.; Schonfeld, D. J. (2003). *Lead*. In Rudolph, C. D. *Rudolph's Pediatrics* (21st edition). McGraw-Hill Professional.

252 Canfield, R. L., Henderson Jr, C. R., Cory-Slechta, D. A., Cox, C., Jusko, T. A., & Lanphear, B. P. (2003). Intellectual impairment in children with blood lead concentrations below 10 μg per deciliter. *New England Journal of Medicine*, *348*(16), 1517–1526.

253 Lanphear, B. P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D. C., ... & Rothenberg, S. J. (2005). Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environmental health perspectives*, *113*(7), 894.

254 Jusko, T. A., Henderson Jr, C. R., Lanphear, B. P., Cory-Slechta, D. A., Parsons, P. J., & Canfield, R. L. (2008). Blood lead concentrations< 10 μg/dL and child intelligence at 6 years of age. *Environmental health perspectives*, *116*(2), 243.

255 Taylor, C. M., Golding, J., Hibbeln, J., & Emond, A. M. (2013). Environmental factors predicting blood lead levels in pregnant women in the UK: the ALSPAC study. *PLoS One*, *8*(9), e72371.

256 Ruff, H. A., McCarton, C., Kurtzberg, D., & Vaughan Jr, H. G. (1984). Preterm infants' manipulative exploration of objects. *Child Development*, 1166–1173.

257 Zuccarini, M., Guarini, A., Savini, S., Iverson, J. M., Aureli, T., Alessandroni, R., ... & Sansavini, A. (2017). Object exploration in extremely preterm infants between 6 and 9 months and relation to cognitive and language development at 24 months. *Research in developmental disabilities*, *68*, 140–152.

258 McDonald, S., Kehler, H., Bayrampour, H., Fraser-Lee, N., & Tough, S. (2016). Risk and protective factors in early child development: Results from the All Our Babies (AOB) pregnancy cohort. *Research in developmental disabilities*, *58*, 20–30.

259 Rose-Jacobs, R., Cabral, H., Beeghly, M., Brown, E. R., & Frank, D. A. (2004). The Movement Assessment of Infants (MAI) as a predictor of two-year neurodevelopmental outcome for infants born at term who are at social risk. *Pediatric Physical Therapy*, *16*(4), 212–221.

260 Pavlova, M. A., & Krägeloh-Mann, I. (2013). Limitations on the developing preterm brain: impact of periventricular white matter lesions on brain connectivity and cognition. *Brain: a journal of neurology*, *136*(Pt 4), 998.

These disruptions, in turn, are thought to impede motor coordination and information processing speed throughout children's later development.[261]

Studies now also show that a preterm birth occurring after 32 weeks' gestation may also be associated with an increased risk of poor cognitive outcomes. For example, a recent analysis involving the MCS observed a graded relationship between gestational age and reduced cognitive competencies at ages three, five and seven after statistically controlling a wide variety of other family variables.[262]

Infancy (0–12 months)

During the first 12 months, a wide variety of processes are thought to support children's early understanding of objects, whereas others are believed to create specific risks. This section describes what these processes are and their impact on children's early development.

Breastfeeding

Studies consistently observe an association between breastfeeding during infancy and higher intelligence in later childhood.[263,264] It is thought that the fatty acids in breastmilk facilitate myelination, which in turn, support the synaptic connections implicated in early learning.[265] It is also likely that breastfeeding increases the opportunities for positive mother–child interaction, which additionally support children's early cognitive development.[266]

An association between breastfeeding and increased object knowledge was recently observed in a recent analysis involving the MCS sample.[267] Breastfeeding duration for term (> 37 week) and preterm (28–36 weeks gestation) infants was compared to children's performance on the picture similarities subtest of the British Abilities Scale (BAS3) at age five. The picture similarities subtest assesses children's conceptual understanding of object relationships by requiring children to match images of objects which are conceptually similar. The study observed that after statistically controlling for a wide variety of family variables (including income and maternal education), full-term infants who were breastfed for at least four months significantly outperformed those who were never breastfed on the picture similarities subtest by an average of three months at age five. Among preterm infants, the benefits of breastfeeding appeared to be even stronger. Preterm infants who were breastfed for a minimum two months outperformed those who were never breastfed on the picture similarities task by an average of six months at age five.

Further analyses involving this same cohort also observed an association between breastfeeding during infancy and children's achievement during their reception year, as assessed by their teachers through the Early Years Foundation Stage (EYFS). This association lost significance, however, once maternal education was statistically considered.[268] More recently, a robust correlation was observed between breastfeeding until

261 Mangin, K. S., Horwood, L. J., & Woodward, L. J. (2017). Cognitive Development Trajectories of Very Preterm and Typically Developing Children. *Child development*, *88*(1), 282–298.

262 Poulsen, G., Wolke, D., Kurinczuk, J. J., Boyle, E. M., Field, D., Alfirevic, Z., & Quigley, M. A. (2013). Gestational Age and Cognitive Ability in Early Childhood: A Population-based Cohort Study. *Paediatric and perinatal epidemiology*, *27*(4), 371–379.

263 Horta, B. L., Loret de Mola, C., & Victora, C. G. (2015). Breastfeeding and intelligence: a systematic review and meta-analysis. *Acta paediatrica*, *104*(S467), 14–19.

264 Victora, C. G., Bahl, R., Barros, A. J., França, G. V., Horton, S., Krasevec, J., ... & Group, T. L. B. S. (2016). Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. *The Lancet*, *387*(10017), 475–490.

265 Deoni, S. C., Dean, D. C., Piryatinsky, I., O'muircheartaigh, J., Waskiewicz, N., Lehman, K., ... & Dirks, H. (2013). Breastfeeding and early white matter development: a cross-sectional study. *Neuroimage*, *82*, 77–86.

266 Papp, L. M. (2014). Longitudinal associations between breastfeeding and observed mother–child interaction qualities in early childhood. *Child: care, health and development*, *40*(5), 740–746.

267 Quigley, M. A., Hockley, C., Carson, C., Kelly, Y., Renfrew, M. J., & Sacker, A. (2012). Breastfeeding is associated with improved child cognitive development: a population-based cohort study. *The Journal of Pediatrics*, *160*(1), 25–32.

268 Heikkilä, K., Kelly, Y., Renfrew, M. J., Sacker, A., & Quigley, M. A. (2014). Breastfeeding and educational achievement at age 5. *Maternal & child nutrition*, *10*(1), 92–101.

six months of age and later school achievement at ages seven and 11, which remained significant after all other demographics, including maternal education, were statistically controlled for.[269]

Individual differences in early motor skills and information processing capabilities

Piaget originally observed that early sensorimotor development unfolds in a predictable sequence. This sequence has since been confirmed in multiple studies, demonstrating a universal progression of object exploration occurring during the first 18 months of life (table 3.1).[270] These studies also find that children differ in the speed with which they progress through this sequence. While Piaget originally assumed that these differences were not particularly meaningful,[271] more recent studies have found that the quality of object exploration during the first few months is associated with children's cognitive competencies as they grow older.

As mentioned previously, a recent US longitudinal study observed that active object exploration at five months is positively associated with children's performance on intelligence tests at 4 and 10 years and school achievement tests at 10 and 14 years. Moreover, this consistency is independent of other family and environmental factors which also predict children's cognitive development and school achievement.[272] Similar results have been observed among the ALSPAC cohort, which also found that children's object processing speed at 4 months positively predicts their cognitive competence at 18 months, IQ at 8 years, and academic achievement at 14 years. Once again, these associations are independent of other important family variables, including parental education, which is also associated with children's cognitive development.[273]

Findings such as these have led some to speculate that children's early motor and information processing capabilities trigger a cascade of reciprocal interactions between themselves and their caregivers which further reinforce their conceptual understanding of objects.[274] Specifically, it is thought that the infant's awareness of objects elicits parental labelling behaviours during joint play activities. This increased verbal stimulation, in turn, is thought to support children's vocabulary at 12 months[275] and improved cognitive performance when children are in school.[276]

Family income, parenting behaviours and the quality of the home learning environment

Studies consistently confirm a strong and persistent link between family income and children's early cognitive development. Specifically, studies observe a gap in the cognitive capabilities of high- and low-income children at the time they enter reception, which then increases until they leave secondary school.[277] While the majority of these studies consider

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269 Borrell-Porta, M., Cooper, K., Costa Font, J., Orsini, C., Ozcan, B. and Platt, L. (2017). Children's wellbeing and development outcomes for ages 5, 7 and 11 and their predictors. The London School fo Economics (Department of Social Policy and LSE Enterprise).

270 Belsky, J., & Most, R. K. (1981). From exploration to play: A cross-sectional study of infant free play behavior. *Developmental psychology*, *17*(5), 630.

271 Ginsburg, H. P., & Opper, S. (1988). *Piaget's theory of intellectual development*. Prentice-Hall, Inc.

272 Bornstein, M. H., Hahn, C. S., & Suwalsky, J. T. (2013). Physically developed and exploratory young infants contribute to their own long-term academic achievement. *Psychological science*, *24*(10), 1906–1917.

273 Bornstein, M. H., Hahn, C. S., & Wolke, D. (2013). Systems and cascades in cognitive development and academic achievement. *Child development*, *84*(1), 154–162.

274 Needham, A. (2000). Improvements in object exploration skills may facilitate the development of object segregation in early infancy. *Journal of Cognition and Development*, *1*(2), 131–156.

275 Ruddy, M. G., & Bornstein, M. H. (1982). Cognitive correlates of infant attention and maternal stimulation over the first year of life. *Child Development*, 183–188.

276 Coates, D. L., & Lewis, M. (1984). Early mother–infant interaction and infant cognitive status as predictors of school performance and cognitive behavior in six-year-olds. *Child development*, 1219–1230.

277 Duncan, G. J., & Murnane, R. J. (Eds.). (2011). *Whither opportunity?: Rising inequality, schools, and children's life chances*. Russell Sage Foundation.

differences in children's pre-literacy and numeracy skills, several have also observed income-related differences in children's ability to reason about objects.

What are the processes that underpin this relationship and when are they first evident? First, it is thought that persistent family hardship impacts children's cognitive development in at least two ways: directly, by limiting their access to material goods and high-quality educational opportunities, and indirectly, through processes involving parental stress and reduced parenting capabilities associated with their level of education.[278] While relatively few studies have considered the comparative impact of direct and indirect processes on cognitive outcomes during the child's first year, those that have observe that family income appears to have the strongest effect on cognitive outcomes.

The relative value of family income on children's early cognitive development is exemplified through a series of analyses involving the MCS cohort.[279,280,281,282,283,284] Specifically, information about family income and maternal emotional distress was provided by approximately 15,000 families when the target child was nine months old and then again when the child was three. At age three, additional information about parenting behaviours, children's behaviour and school readiness was also collected. School readiness was assessed through the Bracken School Readiness Assessment (BSRA) which includes measures of children's vocabulary and knowledge of object categories. The studies made the following observations.

- Family income was the strongest predictor of children's vocabulary and understanding of objects at age three, even when a range of other family variables were statistically controlled for, including maternal education. This relationship became weaker after other mediating factors (such as parenting) were taken into account, but nevertheless remained.
- Family hardship at age three was highly associated with poor vocabulary and object knowledge outcomes. However, family hardship occurring during the child's first year significantly strengthened this relationship. In other words, persistent child poverty during the first three years of life was the strongest predictor of poor cognitive outcomes at age three, as well assubsequent points in children's development.
- The relationship between family hardship and child cognitive outcomes (that is, vocabulary and object categories) was stronger than it was for family hardship and child behavioural outcomes. This is consistent with findings throughout the literature.[285]
- While family hardship was directly related to children's cognitive outcomes, it was also indirectly implicated by reducing parents' ability to provide appropriate cognitive stimulation for their child.
- A number of important parenting characteristics were found to mitigate the negative impact of family hardship. These included greater maternal age, higher maternal education and breastfeeding duration during infancy.

278 Waldfogel, J., & Washbrook, E. (2010). Low income and early cognitive development in the UK. *Sutton Trust*, *60*.

279 Schoon, I., Hope, S., Ross, A., & Duckworth, K. (2010). Family hardship and children's development: the early years. *Longitudinal and Life Course Studies*, *1*(3), 209–222.

280 Kiernan, K. E., & Mensah, F. K. (2009). Poverty, maternal depression, family status and children's cognitive and behavioural development in early childhood: A longitudinal study. *Journal of Social Policy*, *38*(4), 569–588.

281 Kiernan, K. E., & Huerta, M. C. (2008). Economic deprivation, maternal depression, parenting and children's cognitive and emotional development in early childhood. *The British journal of sociology*, *59*(4), 783–806.

282 Dickerson, A., & Popli, G. K. (2016). Persistent poverty and children's cognitive development: evidence from the UK Millennium Cohort Study. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, *179*(2), 535–558.

283 Violato, M., Petrou, S., Gray, R., & Redshaw, M. (2011). Family income and child cognitive and behavioural development in the United Kingdom: does money matter? *Health economics*, *20*(10), 1201–1225.

284 Ermisch, J. (2008). Origins of social immobility and inequality: parenting and early child development. *National Institute Economic Review*, *205*(1), 62–71.

285 Aber, J. L., Jones, S., & Cohen, J. (2000). The impact of poverty on the mental health and development of very young children. In C. H. Zeanah (ed.), *Handbook of infant mental health* (2nd edition, pp. 113–128). New York: Guilford Press.

- The amount of cognitive stimulation in the home reported when the child was age three was also positively associated with improved child cognitive outcomes.
- A number of family characteristics were additionally found to amplify the impacts of family hardship. These included having a low birth weight and more siblings. The effects of family hardship were also significantly worse for boys than they were for girls.
- Maternal depression was found to negatively affect both behavioural and cognitive child outcomes. However, much of this relationship was explained by concurrent maternal depression, rather than any legacy from maternal depression occurring during the perinatal period. Moreover, the impact of depression on child cognitive outcomes virtually disappeared relative to family hardship. In other words, high levels of family income protected children from the negative impact of maternal depression, whereas maternal depression did not substantially worsen the cognitive outcomes of children experiencing high levels of family hardship.
- Family status (such as the extent to which the parents were together, and other factors pertaining to family structure) had relatively little impact on any child outcome in comparison to family income or other parenting characteristics.

In sum, these findings suggest that early experiences of family hardship predict poor cognitive outcomes throughout early development. These findings also resonate with the research literature more broadly, which consistently observes a strong association between child poverty and children's later cognitive development, particularly when it comes to children's language acquisition (see chapter 6).[286,287] These findings also support findings reported elsewhere that show that the negative effects of income are stronger among families experiencing greater economic disadvantage.[288]

The extent to which child poverty specifically impacts children's object knowledge is less well documented, although preliminary findings from a Canadian cohort study have verified a link between maternal education and increased object exploration during the child's first year.[289] Findings involving the ALSPAC cohort have similarly observed that maternal education predicts the frequency of parent–child interactions occurring during the first three years in life, which in turn, predicts children's fine and gross motor development.[290] Interestingly, a more fine-grained analysis involving a smaller US sample observed that while maternal education predicted infant's object exploration, no specific association was found between the quality of interaction during joint attention activities and children's later object knowledge.[291]

Toddlerhood (12–36 months)

Individual differences in children's motor development and object exploration continue to be observed during the second and third years. Factors thought to contribute to these differences include parenting behaviours and the quality of the home learning environment.

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286 Brooks-Gunn, J., Duncan, G. and Aber, J. (1997). *Neighborhood poverty, volume 1: Context and consequences for children* (Vol. 1). Russell Sage Foundation.

287 Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Paul H Brookes Publishing.

288 Mistry, R. S., Biesanz, J. C., Taylor, L. C., Burchinal, M., & Cox, M. J. (2004). Family income and its relation to preschool children's adjustment for families in the NICHD Study of Early Childcare. *Developmental psychology*, *40*(5), 727.

289 Institut de la statistique du Québec (2002). Québec Longitudinal Study of Child Development (Qlscd 1998–2002) Cognitive Development in Children Aged 17 to 29 Months. Quebec: Institut de la statistique du Québec

290 Gutman, L. M., & Feinstein, L. (2010). Parenting behaviours and children's development from infancy to early childhood: Changes, continuities and contributions. *Early Child Development and Care*, *180*(4), 535–556.

291 Tamis-Lemonda, C. S., & Bornstein, M. H. (1993). Antecedents of exploratory competence at one year. *Infant Behavior and Development*, *16*(4), 423–439.

For example, parental encouragement of diverse play options has been found to predict the quality of children's symbolic play at age four.[292]

The extent to which children are read to and are exposed to a greater range of different experiences during the second year are also found to be positively associated with children's understanding of objects throughout their preschool development. For example, an analysis involving the Growing Up in Scotland cohort observed that the frequency of being read to at 10 months and the variety of activities families engaged in at 22 months (such as going to parks, museums and libraries) positively predicted children's knowledge of object names at three years, independently of family income.[293] The variety of daily activities at 22 months also best predicted children's performance on the BAS3 pictures similarity subtest at age three, when the frequency of parental reading did not.

A similar pattern was observed in the Growing Up in Ireland Cohort, which reported a positive relationship between being read to at 10 months and children's performance on the BAS3 picture similarities and naming vocabulary subtests at age three.[294] This study also observed continuity in children's own behaviours, confirming a relationship between their problem-solving capabilities at nine months (as measured by the Ages and Stages Questionnaire) and their vocabulary and picture similarities scores at age three.

The Irish findings resonate with those reported in a landmark study involving over 2,000 Early Head Start participants in the United States.[295] Mother and infant pairs underwent assessments when the infants were 14, 24 and 36 months old, as summarised in figure 3.3. At each time point, information about family demographics, including the parents' relationship status, family income and parental education was collected. Parenting behaviours were also assessed through video-taped observations of parent–child interaction, and children's cognitive capabilities were measured via the Mental Development Index (MDI) of the Bayley Scale for Infant Development. The BSID assesses a wide variety of child cognitive skills, including their vocabulary and understanding of object categories (see section 3.6).

The study observed a reciprocal relationship between children's previous cognitive capabilities and concurrent parenting behaviours in predicting children's later cognitive outcomes. In particular, the quality of parenting behaviours at the second and third assessment points was independently associated with their child's previous capabilities, thus providing support for the developmental cascades described in previous sections of this chapter. Parenting behaviours were also predicted by family resources, which included income, parental education and paternal residency.

Interestingly, this study did not observe a direct relationship between family income and child cognitive outcomes, as was previously described with the MCS. Instead, the association between income and child outcomes was fully mediated by the reciprocal interactions between the parent and child. It is possible that the lack of a direct relationship between family income and child outcomes was related to the fact that all of the families participating in this study were living below the poverty line, meaning that there was unlikely sufficient variation in income to provide an independent, direct effect.

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292 Noll, L. M., & Harding, C. G. (2003). The relationship of mother–child interaction and the child's development of symbolic play. *Infant Mental Health Journal*, *24*(6), 557–570.

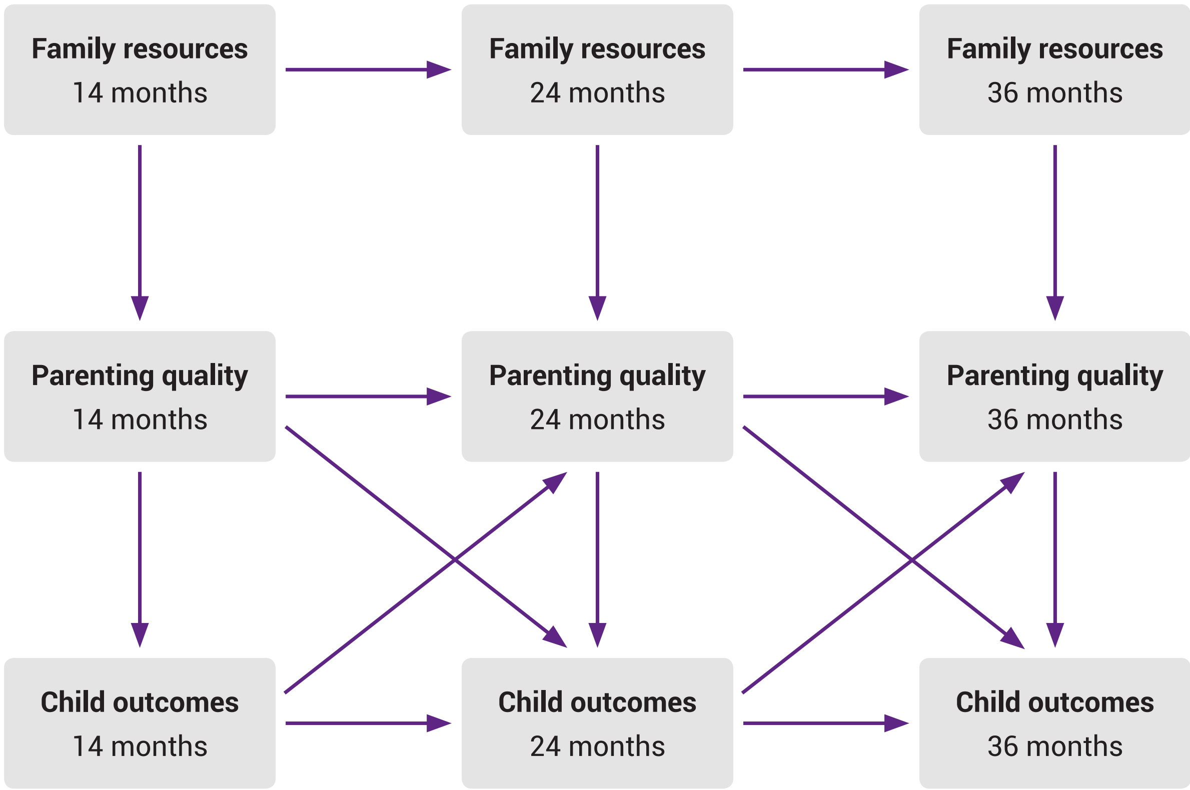
293 Melhuish, E. (2010) *Growing Up in Scotland: Impact of the home learning environment on child cognitive development* Edinburgh: Scottish Government

294 William, J., Murray, A., McCrory, C., & McNally, S. (2013). Growing Up in Ireland–Development from Birth to Three Years. Report No. 5 from the Infant Cohort. *Dublin: The Stationery Office*.

295 Lugo-Gil, J., & Tamis-LeMonda, C. S. (2008). Family resources and parenting quality: Links to children's cognitive development across the first 3 years. *Child Development*, *79*(4), 1065–1085.

FIGURE 3.3

Positive associations between parenting behaviours and child cognitive outcomes during the first three years



Source: Reproduced from Lugo-Gil, J., & Tamis-LeMonda, C. S. (2008). Family resources and parenting quality: Links to children's cognitive development across the first 3 years. *Child Development*, *79*(4), 1065–1085.
Note: All arrows suggest a significant, positive relationship which is independent of the others.

Nevertheless, these findings were replicated in a US twin study, which confirmed a reciprocal relationship between child behaviours and parental cognitive stimulation, which the authors speculate may be rooted in genetically-based differences.[296] Specifically, children's cognitive capabilities at age two predicted the quality of cognitive stimulation they received from their parents, which, in turn, predicted their pre-reading skills at age four. Statistical comparisons involving the identical and fraternal twins suggest that the impetus of this reciprocity may be based in heritable differences between the children at age two, which are then amplified by the parenting behaviours over time, which in turn contribute to the individual differences observed at age four.

Ages three to five

Studies considering individual differences in children's cognitive capabilities between the ages of three and five confirm many of the findings observed at previous points in their development.

- Early cognitive capabilities significantly predict later cognitive capabilities.
- Differences in the cognitive capabilities of high- and low-income children are clearly present at age three and continue to increase throughout preschool and later childhood.
- Income-related learning gaps are mediated by factors involving the parents' education, the quality of the home learning environment, and various other family characteristics.

[296] Tucker-Drob, E. M., & Harden, K. P. (2012). Early childhood cognitive development and parental cognitive stimulation: Evidence for reciprocal gene–environment transactions. *Developmental Science*, *15*(2), 250–259.

These trends are exemplified in an analysis involving the Growing Up in Scotland (GUS) cohort, which observed that factors related to family income differentially impacted children's understanding of objects in comparison to other cognitive skills.[297] Specifically, the analysis showed that different family processes contributed to preschool children's performance on the picture similarities subtest of the BAS3 in comparison to the naming vocabulary subtest. In addition, the study observed that income-related gaps involving both measures were already present by age three, and these gaps were perfectly predicted by parents' level of education. The gaps then continued to increase until the age of five, with children raised by degree-educated parents outperforming those whose parents had no qualifications by 13 months on the picture similarities subtest and by 18 months on the vocabulary subtest.

The study further showed that low-scoring three-year-olds were more likely to show improvement at age five if they were raised by degree-educated parents. By contrast, low-performing three-year-olds with parents lacking any qualifications were far less likely to improve and, in some cases, fell further behind.

Further analysis revealed that differences between the groups that were mediated by factors associated with the degree/non-degree-educated parents. Specifically, children with degree-educated parents were more likely to have been breastfed, have experienced a more enriching home learning environment (HLE) and have been raised in a household with more rules. In addition, degree-educated parents were more likely to:

- provide more enriching learning activities in their home that involve frequent book sharing and increased opportunities to engage in arts and crafts activities, educational games and early numeracy activities
- report either high or medium use of household rules and routines involving bedtimes, mealtimes, television viewing and chores
- report having a secure attachment with their child during infancy as assessed by a short-answer questionnaire.

Interestingly, the analysis observed a graded relationship between having one, two or three of the above factors present and children's vocabulary scores at age five.

Degree-educated parents were also more likely to report making greater use of community services. These services included antenatal courses before the baby was born, community centres, social support groups and formal childcare. Non-degree-educated parents, by contrast, were more likely to be younger, single, smoke and report having poor mental and/or physical health. Their children were also more likely to be premature or have a low birthweight. Further analyses observed that factors that would likely have the greatest impact on children raised in these homes included improved attachment security, and improved HLE and access to enriched preschool. The authors thus speculated that improved attachment security could potentially improve the vocabulary of children raised by non-degree parents, whereas increased home learning activities and enriching preschool would support their object reasoning capabilities.

These findings are broadly similar with those reported for the MCS cohort, which also observed a strong social gradient involving children's performance on the vocabulary and picture similarities subtests of the BAS3 at age five. Once again, parents' age, education and the child's birth weight were found to contribute to this relationship.[298] In addition, parenting behaviours (such as providing a more stimulating HLE) substantially reduced many of the income-related

[297] Bradshaw, P. (2011) Growing Up in Scotland: Changes in child cognitive ability in the pre-school years, Edinburgh: Scottish Government

[298] Hansen, K., & Jones, E. M. (2010). Age 5 cognitive development in England. *Child Indicators Research*, *3*(1), 105–126.

gaps in the children's cognitive abilities.[299] Family rules and routines also predicted children's later cognitive performance. Specifically, bedtime routines at age three were particularly indicative of children's cognitive performance and school achievement at age seven.[300,301]

The analyses further confirmed that a substantial proportion of the gap was attributable to factors other than parenting, such as maternal age, family size and parents' involvement in paid work.[302,303,304] Additionally, it was clear that children's skills at age three explained a proportion of the gaps at ages five and seven.[305] In other words, it is likely that differences in the HLE during the first three years of life contributed to differences in children's learning capabilities at age three, which in turn, predicted the income-related differences in their cognitive skills at ages five and seven.

In sum, there was broad consensus among the MCS analyses that improvements in the HLE of low-income children would go a long way in reducing income-related cognitive gaps at age five, *but* they would unlikely be sufficient for closing the gap. In this respect, the analyses highlighted the need for high-quality preschool education to further reduce income-related gaps in children's cognitive development, suggesting that it would likely have its greatest impact if provided before the age of three, when gaps are first apparent.

In support of these arguments, there is strong and consistent evidence that childcare and/or enriching early years programmes can reduce income-related gaps in children's early cognitive development.[306,307] For example, a recent UK study investigating the effects of early childcare on child cognitive outcomes verified positive associations between children's BSID scores at 18 months and their performance on the picture similarities subtest of the British Abilities Scale.[308] Taking these assiciations into account, as well as other family demographic factors, those who started group childcare earlier also had higher scores on both verbal and nonverbal ability based on the BAs, reflecting the additional boost that out-of home childcare experiences can have for children. Nonverbal skills were especially likely to be higher at 51 months if group childcare started before the age of two. This finding was of particular interest, given that the sample included both advantaged and disadvantaged families.

Additionally, there is strong and consistent evidence for providing two-generation programmes (that is, programmes targeting the HLE through support for parents and centre-based care for children) to low-income families where children are at particular risk.[309,310]

299 Kelly, Y., Sacker, A., Del Bono, E., Francesconi, M., & Marmot, M. (2011). What role for the home learning environment and parenting in reducing the socioeconomic gradient in child development? Findings from the Millennium Cohort Study. *Archives of Disease in Childhood*, archdischild195917.

300 Kelly, Y., Kelly, J., & Sacker, A. (2013). Time for bed: associations with cognitive performance in 7-year-old children: a longitudinal population-based study. *Journal of Epidemiology & Community Health*, jech-2012.

301 Bruckauf, Z., Chzhen, Y., & Unicef. (2016). *Poverty and Children's Cognitive Trajectories: Evidence from the United Kingdom Millennium Cohort Study*. UN.

302 Kiernan, K. E., & Mensah, F. K. (2011). Poverty, family resources and children's early educational attainment: the mediating role of parenting. *British Educational Research Journal*, *37*(2), 317–336.

303 Dearden, L., Sibieta, L., & Sylva, K. (2011). *The socio-economic gradient in early child outcomes: evidence from the Millennium Cohort Study* (No. 11, 03). IFS working papers.

304 Sullivan, A., Ketende, S., & Joshi, H. (2013). Social class and inequalities in early cognitive scores. *Sociology*, *47*(6), 1187–1206.

305 Hernández-Alava, M., & Popli, G. (2017). Children's Development and Parental Input: Evidence from the UK Millennium Cohort Study. *Demography*, *54*(2), 485–511.

306 George, A., Stokes, L., & Wilkinson, D. (2012). Does early education influence key stage 1 attainment? Evidence for England from the Millennium Cohort Study. *National institute economic review*, *222*(1), R67–R80.

307 Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (eds) (2010). *Early childhood matters: Evidence from the effective pre-school and primary education project*. Routledge.

308 Barnes, J., & Melhuish, E. C. (2017). Amount and timing of group-based childcare from birth and cognitive development at 51 months: A UK study. *International Journal of Behavioral Development*, *41*(3), 360–370.

309 Grindal, T., Bowne, J. B., Yoshikawa, H., Schindler, H. S., Duncan, G. J., Magnuson, K., & Shonkoff, J. P. (2016). The added impact of parenting education in early childhood education programs: A meta-analysis. *Children and Youth Services Review*, *70*, 238–249.

310 Geddes, R., Haw, S. and Frank, J. (2010) *Interventions for Promoting Early Child Development for Health: An environmental scan with special reference to Scotland*, Edinburgh: MRC Scottish Collaboration for Public Health Research and Policy.

This evidence not only shows that two-generation programmes can result in significant improvements in disadvantaged preschool performance, but also longer-term improvements in employment and mental wellbeing.[311,312] Such programmes are expensive, however, and many of their benefits on cognitive outcomes are relatively short-lived.[313] We will discuss the advantages and disadvantages of two-generation programmes in the concluding chapter of this report.

3.6 How is children's object knowledge assessed during the preschool years?

A wide variety of methods have been developed to assess children's understanding of objects during the early years. As mentioned previously, assessments used in infancy and toddlerhood are often based on Piaget's stages of sensorimotor development, assessing children's manipulation of objects and understanding of object permanence. In later preschool, children's object knowledge is assessed through measures that consider their conceptual understanding of object relationship and object categories.

In table 3.2, we provide information about some of the more commonly used assessment measures providing information about children's understanding of objects. These assessment tools include parent report measures, as well as standardised instruments that must be administered by a qualified and trained practitioner. Some of these measures are best used as screening instruments, meaning that they are useful for identifying whether an issue might be present, but are not sufficient for diagnosing a specific problem, or assessing improvement over time. Other measures listed here (such as IQ tests) have full diagnostic capabilities, although the extent to which these apply to specific subtests may not be fully understood. Regardless of their administration or diagnostic capabilities, findings from all measures require professional interpretation.

With the exception of the NBAS, all of the measures listed in table 3.2 have been age-validated, meaning that the child's performance relative to his or her age can be understood. While we provide some details to inform decisions about the feasibility of these tools in various settings, it is beyond the scope of this report to comment on the specificity and sensitivity of these tools within the UK. However, all of the assessment tools listed are available in the UK and further details about their evidence is available on their websites. Links to further details that summarised on the Educational Endowment Foundation website are also provided when available.

311 Englund, M., White, B., Reynolds, A. J., Schweinhart, L., & Campbell, F. A. (2014). Health outcomes of the Abecedarian, Child-Parent Center and High-Scope Perry Preschool Programs. In Reynolds, A. J., Rolnick, A. J., & J. A. Temple (eds), *Health and Education in Early Childhood: Predictors, Interventions and Policies* (pp. 257–285). New York: Cambridge University Press.

312 Campbell, F. A., Pungello, E. P., Burchinal, M., Kainz, K., Pan, Y., Wasik, B. H., Sparling, J., & Ramey, C. T. (2012). Adult outcomes as a function of an early childhood educational program: An Abecedarian Project follow-up. *Developmental Psychology, 48*, 1033–1043.

313 Gibbs, C., Ludwig, J., & Miller, D. L. (2011). *Does Head Start Do Any Lasting Good?* (No. w17452). National Bureau of Economic Research.

TABLE 3.2

Assessment tools which include items specific to the development of children's object knowledge

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Neonatal Behavioural Assessment Scale (NBAS)	The NBAS is a recognised neurobehavioural assessment tool. It can be used with full-term babies (from birth to two months old), but also with premature babies (from 35 weeks gestation) and with developmentally delayed babies. There is a total of 53 items including: behavioural items which assess the infant's behavioural response to positive and negative stimuli; reflex items, which assess the infant's neurological status and supplementary items to capture the range and quality of the behaviour of frail, high-risk infants.	Birth to two months	Practitioner	Screening	NBAS provides their own certification process	The Brazelton Centre
Mullen scales of early learning (MSEL)	The Mullen scales of early learning (MSEL) is a standardised assessment for measuring early motor and cognitive development from 0 to 68 months. Five scales assess children's gross motor, fine motor, visual reception, and expressive and receptive language capabilities. Administration takes 15 minutes for children age 1 and approximately 40 minutes for children who are age three or older.	0 to 68 months	Practitioner	Diagnostic	Certified professional with graduate qualification.	Pearson
Bayley Scales of infant and toddler development, Third edition (The Bayley-III; BSID)	The Bayley-III examines all the facets of a young child's development. Children are assessed in the five key developmental domains of cognition, language, social-emotional, motor and adaptive behaviour. It can be used for children between 1 month and 42 months. It takes from 30 minutes to 90 minutes to complete (depending upon the age of child).	1 to 42 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Ages & Stages Questionnaire (ASQ-3)	The Ages & Stages Questionnaires®, Third Edition (ASQ-3™) pinpoints developmental progress in children between the ages of one month to 5.5 years. It is a developmental screening tool designed for use by early educators and healthcare professionals. It relies on parents as experts. It takes 10–15 minutes for parents to complete and 2–3 minutes for professionals to score. It screens the following areas: communication, gross motor, fine motor, problem solving, and personal–social. Items from the problem-solving subtest are useful for understanding children's object knowledge up until 36 months. After 36 months, assessment is less useful.	1 month to five years	Practitioner or parent	Screening	No	Ages & Stages

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
The Denver Developmental Screening Test (Denver II)	The Denver II is used by healthcare providers to assess child development. It consists of 125 items (the DDST has 105) divided into four general areas of development: personal–social, fine motor-adaptive, language and gross motor. It screens for developmental delay. It is suitable for children aged 0 to 6 years. It takes from 20 to 60 minutes to complete depending on the stress tolerance of the child.	0 to 6 years	Practitioner	Screening	Yes	Hogrefe
Parental Evaluation of Development Status (PEDS)	PEDS screens development, behaviour, social-emotional/mental health and autism in children aged 0–8 years. It elicits and addresses parents' concerns about children's language, motor, self-help, early academic skills, behaviour and social-emotional/mental health. It consists of 6–18 questions. It takes about two minutes to administer and score if conducted as an interview. Less time is required if parents complete the brief questionnaire in waiting or exam rooms or at home prior to an encounter.	0 to 8 years	Practitioner or parent	Screening	No	PEDs
The Parent Report of Children's Abilities (PARCA-R)	The PARCA-R is designed to identify preterm children who are at risk for developmental delay. It is used as a neurodevelopmental outcome measure in observational studies and clinical trials and as a screening tool in child development clinics. It takes no more than 15 minutes to complete.	Pre-term children aged 2 years	Parent	Screening	No	EPICURE
British Ability Scales, Third Edition (BAS3)	BAS3 comprises a battery of individually administered tests designed for use by educational and clinical psychologists to assess children or adolescents who have been referred to them for a wide range of reasons, including learning and behavioural difficulties. It enables assessment of different aspects of a child's current intellectual functioning across the age range 3 years (3:00) to 17 years 11 months (17:11). It comprises 20 subtests, each measuring particular types of knowledge, thinking and/or skills. The Picture Similarities subtest can be considered a nonverbal measure of children's understanding of object relationships. It takes 30–45 minutes to administer, depending on the child. The Pictures Similarities subtest is particularly useful for understanding children's problem-solving skills pertaining to objects.	3 to 17 years	Practitioner	Diagnostic	Certified professional with graduate qualification	GL Assessment

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
The Bracken School Readiness Assessment (BSRA)	The Bracken School Readiness Assessment, Third Edition (BSRA-3) helps to determine if a child is ready for school. It includes five subtests to assess basic concepts related to school readiness: colours, letters, numbers/counting, size/comparison and shapes. It is for children aged 3 years to 6 years 11 months. It takes 10–15 minutes to complete. The comparisons subtest is useful for understanding children's problem-solving skills and object knowledge.	3 years to 6 years 11 months	Practitioner	Diagnostic	No	Pearson
Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK)	The WPPSI-IV UK measures cognitive development for children between 2 years 6 months to 7 years 7 months. The Primary Index scales include: verbal comprehension index, visual spatial index, working memory index, fluid reasoning index, processing speed index. The Ancillary Index scales include: vocabulary acquisition index, nonverbal index, general ability index and cognitive proficiency index. It takes 30–60 minutes to administer, depending on the age of the child.	2 years 6 months to 7 years 7 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Kaufman Assessment Battery for Children, Second Edition (KABC-II)	The Kaufman Assessment Battery for Children, Second Edition (KABC-II) measures cognitive ability and processing skills in children aged 3 years to 18 years. The following scales are included: sequential processing, simultaneous processing, learning ability, planning ability and knowledge. It takes 25 to 70 minutes to administer, depending on the model chosen.	3 years to 18 years	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Early Years Foundation Stage Profile (EYFSP)	The EYFS profile summarises and describes children's attainment at the end of the Early Years Foundation Stage. It assesses the child's attainment in relation to the 17 early learning goal descriptors and provides a short narrative describing the child's three characteristics of effective learning. The three prime areas of learning and development are: communication and language, physical development and personal, social and emotional development. The assessment takes place over time, primarily based on observation and interaction with the child in a range of contexts. The assessment should consider a range of perspectives, including those of the child, parents and other adults who have significant interactions with the child. The 'understanding the world' observations associated with Early Learning Goal (ELG) 14 are particularly useful for assessing children's object-related problem-solving skills. This knowledge includes: - an understanding of the key characteristics of places, objects, materials and living things and can explain how these things are are similar or different from one another - can explain hierarchical and causal relationships between familiar objects and animals - can describe the features of their own immediate environment and how environments might vary from one another.	Children who will be 5 on or before the last day of the academic year	Practitioner	Educational assessment	Practitioners at registered early years providers	Government website

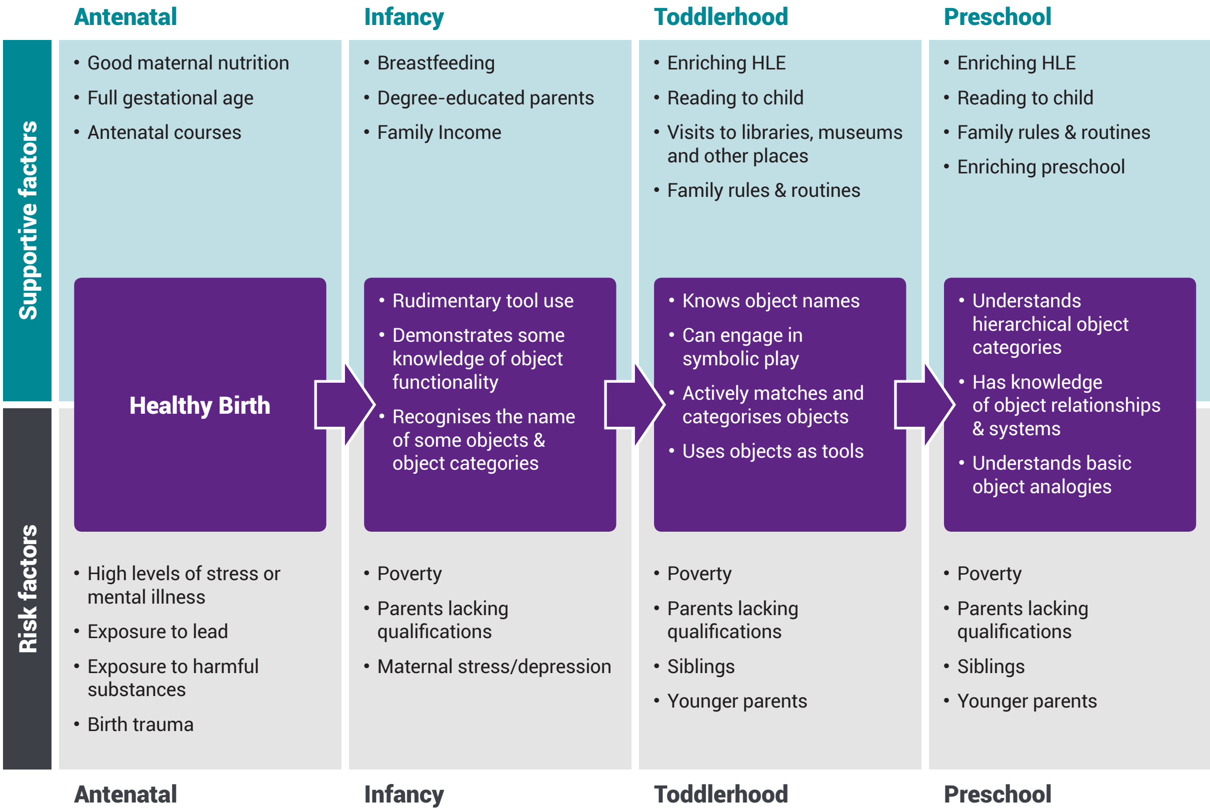
3.7 Implications for practice and commissioning

Summary of key messages

Figure 3.4 provides an overview of the key competencies involved in the development of children's theories of objects and the processes which support or interfere with this development. More details about this trajectory and age-appropriate methods for assessing progress are summarised further in table 3.3 at the end of this chapter.

FIGURE 3.4

Key milestones in children's understanding of objects and processes which support or interfere with typical development



Source: EIF

Key messages: the antenatal period

- A sufficiently nurturing antenatal environment supports children's brain development, so that they can perceive, track and understand the critical features of objects within their everyday environments within the first few weeks of life.
- Factors that support healthy antenatal brain development include a proper maternal diet and sufficiently low levels of stress. Factors that interfere with optimal brain development include exposure to harmful substances (such as tobacco, alcohol and other harmful drugs) and high levels of maternal stress and/or mental illness. A preterm birth is also detrimental to early brain development, especially if it takes place before 32 weeks gestation.
- Detectable signals of risk during the antenatal period include maternal mental health problems, tobacco, alcohol or other substance misuse and a preterm birth.
- Children are typically born with sufficient reflexive capabilities to understand the critical features of objects. This includes object permanence, consistency and cohesion. These

are considered biologically primary capabilities that are spontaneously mastered by most children.

- Other biologically primary competencies mastered during the child's first year include the ability to categorise objects by their critical features (such as texture, shape, colour), understand some basic functions and demonstrate some rudimentary tool use. With sufficient exposure to language, most children will understand the names of some objects by the time they are 12 months old.
- Infants learn about objects through observation, but also through sensorimotor manipulation. Sensorimotor development occurs through a predictable developmental sequence.
- Children differ in the rate at which they pass through the sensorimotor sequence and studies show that this can be associated with later cognitive competencies, including intelligence and school achievement.
- There is some evidence suggesting that individual differences in children's early object exploration may be heritable. The extent to which this is the case is currently unknown, however.
- Some studies show that the frequency and quality of parent–child interaction contributes to children's early sensorimotor development. The quality and frequency of this interaction appears to be linked to parents' level of education.
- Most children will know the names of a few objects by the end of the first year. The learning of object names is facilitated by joint attention activities taking place between the parent and child.
- Breastfeeding is associated with improved cognitive competencies at later points in children's development.
- Factors which potentially interfere with children's understanding of objects include high levels of parental stress, although this may be mediated by family income.
- Child-level signals of risks include delays in children's object exploration and motor development. The problem-solving and gross and fine motor skills subsections of the Ages and Stages Questionnaire (ASQ-3) can be used to initially screen for such problems. The Bayley Scales of Infant Development (BSID) is more appropriate for further diagnosis.
- Family-level signals of risk include high levels of parental stress and economic hardship.

Key messages: toddlerhood

- During the second year, most children rapidly master the words for many objects, as well as adjectives for describing objects' critical features.
- Most children also begin to engage in symbolic play during the second year, frequently substituting some objects for others during pretend play.
- Children demonstrate increasingly more sophisticated tool use between the ages of two and three.
- Children spontaneously engage in object categorisation activities during the second year. During the third year, children also start to grasp the basic principles of object relationships (part to whole, hierarchical categories) and can perform simple analogical reasoning tasks.
- Processes positively associated with children's object knowledge during the second and third year include family outings to libraries, parks and museums.
- Enriching home learning activities involving arts and crafts and educational games also provide toddlers with important opportunities to learn about objects.
- Reading to children and book sharing are also found to facilitate children's understanding of object words and object relationships.

- Parents' level of education is strongly associated with children's object reasoning capabilities by the end of the second year.
- Child-level signals of risk including language delays and difficulty understanding object relationships. The Bayley Scales of Infant Development (BSID) includes subscales for assessing children's object knowledge up until the age of three.
- Family-level signals of risk include low family income, low parental education, young parental age. Interventions can be targeted appropriately on the basis of these risks.

Key messages: ages three to five

- Between the ages of three and five, children gain an increasingly sophisticated understanding of object relationships, including hierarchical object categories and complex object systems.
- Children also gain a deeper understanding of the functionality and key features of objects, which allow them to make accurate predictions about object relationships.
- Children gain information about objects through trial and error testing of their own spontaneous theories. Children also gain knowledge of objects from information provided by parents and teachers.
- By the end of preschool, many children engage in analogical and inductive problem-solving involving object relationships. In other words, children can accurately predict the relationship between one set of objects on the basis of their knowledge of another.
- The child's parents' level of education is a strong predictor of their object knowledge upon entry to primary school.
- Access to enriching preschool has also been found to support children's object knowledge.
- Child-level signals of risk include difficulties reasoning about object relationships. The ASQ-3 no longer provides items which are sufficient for assessing these skills from age 3 onwards.
- Family-level signals of risk include low family income, low parental education, young parental age.

What are the implications for early intervention?

The findings summarised in this chapter have many implications for the content, targeting and dosage of programmes and practices delivered through early years services. We describe these implications here, with recommendations for how they might be implemented through health visiting, children centres, childcare and nurseries.

Content

The information described in this chapter highlights the need for specific content which has been found to facilitate children's object knowledge.

Support offered during infancy should promote the importance of object manipulation and exploration during the first six months of life. Parents should also be made aware of the value of joint attention activities, which help infants learn the names and functions of objects.

Some early intervention programmes already promote the importance of object play. However, the majority of interventions identified in the *Foundations for Life* review primarily emphasise the importance of language and book reading.[314] As we will see in chapter 6, these messages are important, as much of children's object knowledge is reliant on early language development. Nevertheless, **children's object knowledge is also reliant on opportunities to physically interact with objects, so the importance of object play should be emphasised to parents as well.**

The evidence reviewed here also suggests that **support offered during toddlerhood should promote the importance of learning experiences outside of the home.** This includes visits to parks and museums, although much also can be learned during routine visits to the grocers, supermarket and pharmacy.

Evidence also shows that **toddler's object knowledge is supported through an enriched home learning environment, which not only includes books and reading activities, but also educational toys, arts and crafts materials, and games.** These materials need not be elaborate or expensive, but they should be safe and developmentally appropriate.

The research described in this chapter highlights the benefits of these activities in the child's home, but it also stands to reason that these activities should be promoted within enriching and high-quality childcare and early years settings. As mentioned previously, it is important that infants and toddlers have opportunities to explore and manipulate activities on their own, so these activities need not be overly structured. However, it is also important that children have access to these enriching home learning experiences on a daily basis, so that children have sufficient opportunities to manipulate and interact with objects on their own.

Support offered to families with a child between the ages of three and five should continue to promote the importance of enriching learning experiences within and outside of the home. Once again, this means trips to parks, libraries and museums, as well as age-appropriate learning activities taking place within the home on a regular basis. Free play should also be encouraged, so that children have ample opportunities to formulate and test hypotheses about object relationships and systems.

The evidence reviewed in this chapter indicates that **household rules and routines support young children's cognitive development more generally.** In this respect, the evidence particularly supports the use of bedtime routines, which are associated with improved sleeping patterns during the preschool years and increased academic achievement once children enter primary school. It is also likely that family mealtimes provide children with opportunities to discuss and learn about objects and the physical world around them.[315]

314 Asmussen, K., Feinstein, L., Martin, J., & Chowdry, H. (2016) *Foundations for Life: What works to support parent-child interaction in the early years?* Early Intervention Foundation. https://www.eif.org.uk/report/foundations-for-life-what-works-to-support-parent-child-interaction-in-the-early-years

315 Zajicek-Farber, M. L., Mayer, L. M., Daughtery, L. G., & Rodkey, E. (2014). The buffering effect of childhood routines: Longitudinal connections between early parenting and prekindergarten learning readiness of children in low-income families. *Journal of Social Service Research*, *40*(5), 699–720.

We also reviewed evidence underscoring the value of enriching preschool, especially for narrowing the achievement gap between upper- and lower-income children upon entering primary school. While it is beyond the scope of this report to comment specifically on early years' curriculums, content which allows children to experiment with objects, categorise them and learn about object relationships and systems is likely to be beneficial. Preschool experiences often provide opportunities for manipulation or larger objects such as wooden blocks, that can complement the smaller-scale activities likely to be available in the home.

Targeting

The findings summarised in this chapter underscore the need for high quality, early interventions for low-income families. This is not a new message. However, this chapter provides more details about *when* in children's development these interventions are likely to be most effective.

Studies show that strong income-related gaps in children's object knowledge are already present at the age of three and that factors occurring during the antenatal period and infancy likely contribute to these differences. **The implication is that more high-quality, evidence-based support and interventions should be made available to low-income families during infancy and the antenatal period.** This support should then follow families until the child's entrance into primary school. Support could ideally be offered via health visiting during infancy, enriched childcare during toddlerhood and enriched preschool when children are between the ages of three and four.

The findings summarised in this chapter also underscore the importance of the antenatal period for supporting early brain development. Factors which threaten this process include high levels of maternal stress, tobacco, alcohol and substance misuse and a preterm birth. Children born under these circumstances are thus likely to be at greater risk and should therefore be monitored closely throughout their early development. This includes increased support during infancy, but also regular developmental screening throughout preschool. Midwives and health visitors do much of this work already, but this review underscores the importance of these activities. It has also identified a set of assessment tools which can be used to support ongoing assessment and monitoring.

Dosage

The evidence reviewed in this chapter has implications regarding the intensity of interventions to support children's understanding of objects. At the most general level, messages that promote the supportive factors identified in figure 3.3 would likely benefit everyone. These messages include the importance of breastfeeding during the first year of life and the need for enriching home learning experiences as children grow older. These experiences include book sharing and reading activities, but also educational games, toys, and arts and crafts activities.[316] The importance of family routines and visits outside of the family home is also worth promoting

However, there are many times when advice alone is *not* sufficient for improving parent and child outcomes, and this is particularly true when it comes to narrowing income-related learning gaps. In this respect, the evidence is clear that low-income families are likely to benefit from much more intensive support that provides them with many opportunities to learn and practice new skills.

During infancy, this support is likely best offered through frequent home visiting. For example, evidence from the UK and abroad shows that the intensive support provided through the Family Nurse Partnership (FNP) programme support children's early cognitive and language development. FNP is considered an intensive intervention involving bimonthly home visits

316 In a forthcoming resource, EIF will identify a list of appropriate toys, materials and activities grouped by children's age.

starting at pregnancy and continuing until the child's second birthday. During these visits, family nurses promote a range of activities that facilitate parent–child object play. It is likely that the frequency of these visits increases the number of opportunities parents have to practise new skills and receive tailored advice from a trusted professional that is based upon a validated curriculum.

By contrast, recent evaluations of less intensive interventions, such as the the PEEP and REAL programmes, observed no measurable benefits for parents or children after the intensity of their programme model had been reduced.[317] There is now also good evidence showing that light-touch book-gifting schemes in the absence of additional support are not sufficient for improving learning outcomes for low-income children.[318]

So how much is enough? The best evidence suggests the greater the intensity, the better, when it comes to reducing income-related learning gaps. In this respect, studies show that financially disadvantaged families benefit the most from 'two-generation' programmes providing childcare and/or nursery provision to children, and home visiting or group-based support for parents. We will provide further recommendations about how such interventions might be delivered in the final chapter of this report.

317 Barbour, L., Eisenstadt, N., Goodall, J. Jelley, F. & Sylva, K. (2018). *Parental Engagement Fund*. The Sutton Trust.

318 Goldfeld, S., Napiza, N., Quach, J., Reilly, S., Ukoumunne, O. C., & Wake, M. (2011). Outcomes of a universal shared reading intervention by 2 years of age: The Let's Read trial. *Pediatrics, 127*(3), 445–453.

TABLE 3.3

Developmental competencies – factors which make a difference and methods of assessing children's object knowledge

Age	Developmental competency	Manifestation/context	Factors known to impact developmental outcomes	Assessment
Antenatal	Sufficient cell formation, connectivity and myelination	Motor maturation (e.g. motor milestones); cognitive capabilities including language and problem-solving skills in later development	Maternal nutrition; high levels of maternal stress; maternal mental health problems; presence of toxins in the womb; a premature birth; genetic disorders; cerebral injury; exposure to lead.	Neonatal Behavioural Assessment Scale (at birth) BSID Mullen Scales
0–12 months	Child is actively exploring environment and reaching for objects; recognises the name of some objects and may be able to name several; searches for object when hidden (but does not necessarily persevere); is starting to use objects as tools	Object exploration Motor manipulation of objects Parent labelling activities during triadic play Parent–child interaction	Negative factors taking place during the antenatal period; motor-maturation; breastfeeding; exposure to environmental lead. Family income; parental education, high levels of parenting stress and mental illness.	BSID Fine Motor & Problem-Solving sections of the ASQ-3 Mullen Scales
12–24 months	Demonstrates object permanence by successfully finding deeply hidden objects; and will explore objects by taking them apart or building towers for example with toy bricks; demonstrates more advanced tool use; understands the function of many objects; knows the name of many objects; is engaging in symbolic play with double substitution	Object exploration Symbolic play Constructive play Parent–child interaction	Previous and current motor competencies; Parental responses during free-play; object labelling. Outings to parks, gardens, libraries and museums An enriching home-learning environment which includes books, but also toys, games and arts and craft materials. High-quality education and childcare.	BSID Fine Motor & Problem-Solving sections of the ASQ-3 Mullen Scales
24–36 months	Can match objects to pictures in a book; can engage in pretend-play, substituting one object for another; can categorise objects within groups and identify 'odd one out'	Play Parent–child interaction	Same as above Family rules and routines	BSID Fine Motor & Problem-Solving sections of the ASQ-3 Mullen Scales PEDS WIPPSI
36–60 months	Categorisation and tool use is more sophisticated; understands overlapping and hierarchical object categories; understands complex object systems; is capable of more complex analogical reasoning	Play Parent–child interaction Performance on school tasks	Same as above Access to enriching preschool education	British Ability Scales Naming Vocabulary Sub-test Analogies subtests

4. Children's theory of mind

4.1 What is it?

Understanding the desires, feelings and beliefs of others is a core skill for getting along and making friends. However, these thought processes cannot be seen, so children must either ask others what they are thinking or make do with educated guesses. These guesses – also referred to as children's 'theory of mind' (ToM) – are based on what people know about themselves and the behaviours of others.[319]

Fundamental to ToM is the awareness that all humans and animals have conscious thought processes and that these differ from person to person. Children's theory of mind is also informed by their understanding of how the desires, beliefs and actions of others are interrelated. As children develop, ToM capabilities allow children to anticipate what others are thinking and adopt differing points of view. By the end of the preschool years, most children are fully aware that their thoughts may be different from others. Children then learn how to exploit this information to comfort, share jokes and cooperate, as well as persuade, mislead or deceive.

Debates exist regarding the nature of ToM and the mental processes underpinning it. A very narrow definition restricts ToM skills to children's performance on false-belief tasks which require them to accurately predict what others are thinking in hypothetical situations. The 'Sally-Anne' task, as illustrated in figure 4.1, is perhaps the most famous example of an elicited false-belief task, where the child is asked to predict where Sally thinks the marble is based on what Sally – not the child – knows.

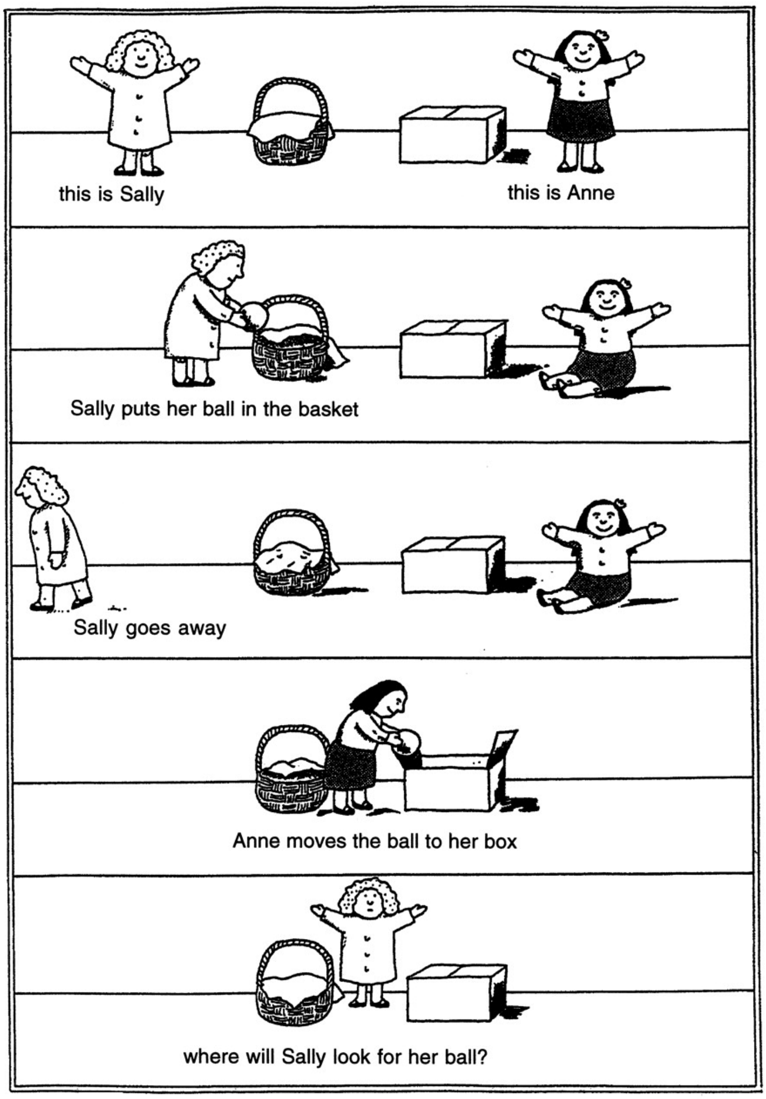
While the Sally-Anne task is seemingly simple, it involves a set of mental skills that are not readily evident in infants and toddlers. First, the child must understand what Sally believes. Second, the child must appreciate that the question is about what Sally believes and not what the child believes. Third, the child must be able to inhibit what he or she knows to be true, to correctly answer the question. Most children cannot do these three things with any consistency until around the age of four.

We view the skills used to solve the Sally-Anne task to be important but also believe that ToM encompasses a much broader set of capabilities. These capabilities include children's awareness of others as intentional beings and their cognitive understanding of thought processes as distinct mental activities occurring in human and animal brains. The remainder of this chapter will describe the development of these skills during the preschool years and the ways in which they are impacted by the child's environment and various inherited factors.

319 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

FIGURE 4.1

The Sally-Anne task



Source: Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a 'theory of mind'?. *Cognition*, *21*(1), 37–46.

4.2 What other competencies are associated with the development of children's theory of mind?

ToM is thought to have its roots in children's early social awareness, beginning with the infant's preference for human faces and speech. ToM additionally requires that children are sufficiently self-aware to understand that their thoughts are different to those of others. In this respect, ToM might be viewed as a social-emotional process.[320] However, ToM skills are also informed by children's causal understanding of the relationship between thoughts and actions, as well as their conceptual awareness of mental states more generally. Most researchers view these capabilities to be fundamentally cognitive, resulting in ToM's classification as a core cognitive function.[321]

320 Astington, J. W. and Hughes, C. (2013) Theory of Mind: Self-reflection and social understanding. In Phillip David Zalazo, *The Oxford handbook of Developmental Psychology Volume 2: self and Other*.

321 Gopnick, A. and Wellman, H. M. (1992) Why the Child's theory of mind really is a theory. *Mind and Language, 7*, 145–171.

Language

There is no question that the development of ToM is highly associated with the development of language.[322,323] A meta-analysis involving children under the age of seven observed that successful performance on ToM tasks was more closely associated with children's verbal ability than it was with age.[324] This is likely because language provides children with words that describe mental states (want, know, remember, guess, believe), perceptions (see, hear, touch) and emotions (happy, sad, angry).[325] Most children will have mastered the vocabulary for emotions and perceptions by the age of two and other mental states (such as 'concentrate', 'fantasise') by the age of five.[326] Studies additionally suggest that children's performance on false-belief tasks may be reliant on their understanding of grammar.[327] Researchers speculate that children's understanding of syntax supports the emergence of ToM during the preschool years, but then becomes redundant in ToM functioning once children are older.[328,329]

Causal inference

ToM skills are also reliant on children's ability to make causal inferences about other people's behaviours – that is, to predict *why* people do what they do. Clearly, older children gain insight into other people's motives when they are told why someone has done something. However, studies show that infants can make accurate assumptions about others' intentions long before they have acquired language, and it is thought that they do this on the basis of 'like-me' comparisons.[330,331]

'Like-me' comparisons are causal inferences informed by the infant's own first-hand experience. For example, violation of expectation experiments suggest that babies as young as three months of age can successfully infer that reaching for an object means that the object is desired, but only after he or she has had some previous experience of reaching for objects.[332] Researchers maintain that young children are constantly making and revising hypotheses informed by 'like me' comparisons and many times these hypotheses are correct.[333] However, the common failure of the Sally-Anne task before the age of four suggests that theories based on 'like-me' comparisons have their limitations. Children thus need to be able to understand when the thought processes of others are not 'like me', and this requires more sophisticated mental capabilities that are thought to involve the executive functions.[334,335]

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322 Strickland, B., Fisher, M., Keil, F., & Knobe, J. (2014). Syntax and intentionality: An automatic link between language and theory-of-mind. *Cognition, 133*(1), 249–261.

323 de Villiers, J. G., & de Villiers, P. A. (2014). The role of language in theory of mind development. *Topics in Language Disorders, 34*(4), 313–328.

324 Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: meta-analysis of the relation between language ability and false-belief understanding. *Child development, 78*(2), 622–646.

325 Astington, J. W., & Baird, J. A. (eds) (2005). *Why language matters for theory of mind*. Oxford: Oxford University Press.

326 Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child development*, *75*(2), 523–541.

327 Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development, 78*, 622–646.

328 Apperly, I. (2010). *Mindreaders: the cognitive basis of 'theory of mind'*. Hove, East Sussex: Psychology Press.

329 Apperly, I. A., Samson, D., & Humphreys, G. W. (2009). Studies of adults can inform accounts of theory of mind development. *Developmental psychology, 45*(1), 190.

330 Woodward, A. L., Sommerville, J. A., Gerson, S., Henderson, A. M., & Buresh, J. (2009). The emergence of intention attribution in infancy. *Psychology of learning and motivation*, *51*, 187–222.

331 Meltzoff, A. N. (2007). The 'like me' framework for recognizing and becoming an intentional agent. *Acta psychologica*, *124*(1), 26–43.

332 Gerson, S. A., and Woodward, A. L. (2014) Learning from their own actions: The unique effect of producing actions on infants' action understanding. *Child Development 85*(1): 264–277.

333 Gopnik, A., Meltzoff, A. N., & Kuhl, P. K. (1999). *The scientist in the crib: Minds, brains, and how children learn*. William Morrow & Company.

334 Apperly, I. A., Samson, D., & Humphreys, G. W. (2009). Studies of adults can inform accounts of theory of mind development. *Developmental psychology, 45*(1), 190.

335 Diamond, A. (2006). The early development of executive functions. *Lifespan cognition: Mechanisms of change*, *210*, 70–95.

Executive functions

As described in chapter 2 (and in more detail in chapter 5), the executive functions increase the efficiency of children's mental processing capabilities. These capabilities include information processing speed, the ability to think fluidly and flexibly, attention deployment skills (including inhibition) and working memory. It is thought that these skills allow children to mentally represent several points of view at the same time.[336,337] As a result, children will have difficulty understanding when others are not 'like me' until their executive functions allow them to deploy their attention towards the perspective of others and simultaneously represent both points of view through an improved working memory.[338,339]

4.3 How does the development of ToM impact children's development over time?

Understanding how one's thoughts and feelings are the same or different from someone else's is a core social skill. Indeed, a failure to understand the intentions of others, also referred to as *mindblindedness*, is a key characteristic of children diagnosed with autism spectrum conditions (ASCs). While children with ASCs often perform well on a variety of cognitive tasks, they frequently fail false-belief tasks and may have difficulty showing empathy.[340,341]

In non-clinical samples, studies show that ToM skills are consistently linked to prosocial behaviours. For example, several recent longitudinal studies have observed that children's preschool ToM capabilities predict more favourable peer and teacher ratings in primary school[342] and that this relationship is independent of children's verbal ability and previous prosocial behaviour.[343,344] Neverthelss, it is worth noting that the direction of causality between ToM skills and prosocial behaviour is often weak and the direction of causality unclear.[345,346,347] This is because mindreading skills are necessary for getting along with others, but are likely not sufficient for prosocial behaviours to be successful.[348] In this respect, researchers observe that prosocial behaviours also require an understanding of social conventions, as well as the child's willingness to cooperate.[349] It is also worth noting

336 Devine, R. T., & Hughes, C. (2014). Relations between false belief understanding and executive function in early childhood: A meta-analysis. *Child development*, *85*(5), 1777–1794.

337 Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: the truth about false belief. *Child development*, *72*(3), 655–684.

338 Devine, R. T., & Hughes, C. (2014). Relations between false belief understanding and executive function in early childhood: A meta-analysis. *Child development*, *85*(5), 1777–1794.

339 Wellman, H. M. (2014). *Making Minds*. Oxford: Oxford University Press.

340 Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive development*, *15*(4), 481–498.

341 Baron-Cohen, S. (2005). The empathising system: A revision of the 1994 model of the mindreading system. In B.J. Ellis & D.F. Bjorklund (eds), *Origins of the social mind: Evolutionary psychology and child development* (pp. 468–429). New York: Guilford.

342 Hughes, C., Ensor, R., & Marks, A. (2011). Individual differences in false belief understanding are stable from 3 to 6 years of age and predict children's mental-state talk with school friends. *Journal of Experimental Child Psychology*, *108*(1), 96–112.

343 Caputi, M., Lecce, S., Pagnin, A., & Banerjee, R. (2012). Longitudinal effects of theory of mind on later peer relations: the role of prosocial behavior. *Developmental psychology, 48*(1), 257.

344 Lockl, K., Ebert, S., & Weinert, S. (2017). Predicting school achievement from early theory of mind: Differential effects on achievement tests and teacher ratings. *Learning and Individual Differences*, *53*, 93–102.

345 Hughes, C., & Devine, R. T. (2015). A Social Perspective on Theory of Mind. *Handbook of Child Psychology and Developmental Science. 3*, *14*, 1–46.

346 Slaughter, V., Imuta, K., Peterson, C. C., & Henry, J. D. (2015). Meta-analysis of theory of mind and peer popularity in the preschool and early school years. *Child development*, *86*(4), 1159–1174.

347 Imuta, K., Henry, J. D., Slaughter, V., Selcuk, B., & Ruffman, T. (2016). Theory of mind and prosocial behavior in childhood: a meta-analytic review. *Developmental Psychology, 52*(8), 1192–1205.

348 Astington, J.W. & Jenkins, J.M. (1995). Theory of mind development and social understanding. *Cognition & Emotion*, *9*(2-3), 151–165.

349 Apperly, I. A. (2011). *Mindreaders: The cognitive basis of 'theory of mind'*. Hove, England: Psychology Press.

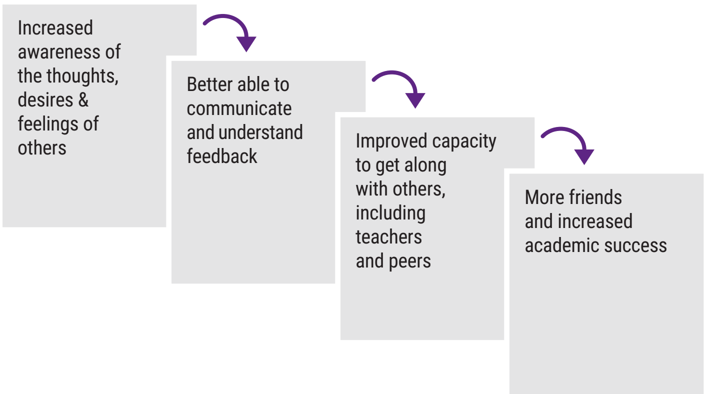
that ToM skills are linked to the development of a variety of anti-social behaviours, such as lying and mean-spirited teasing.[350]

Studies have also verified a longitudinal link between between preschoolers' performance on false-belief tasks and their later academic achievement, which appears to be mediated by an increased sensitivity towards teacher criticism.[351] Specifically, studies show that children who perform better on false-belief tasks have a heightened awareness of others' perspectives, including more critical points of view.[352] Researchers have thus speculated that this awareness of criticism is not necessarily demotivating, but rather increases children's ability to take feedback and perform better at school.[353,354]

In sum, the above findings suggest that the ability to anticipate the thoughts and feelings of others during preschool facilitates a cascade of developmental competencies which likely contribute to children's later social and academic success. As illustrated in figure 4.2, children's understanding of others' thought processes increases their ability to communicate and take feedback. In turn, these competencies improve children's capacity to get along with others, including teachers and other children, once they enter school. A greater sensitivity to teacher feedback and improved prosocial behaviour, in turn, is thought to predict children's later academic success.

FIGURE 4.2

Potential developmental cascades for children's theory of mind



Source: EIF

[350] Sodian, B., Taylor, C., Harris, P. L., & Perner, J. (1991). Early deception and the child's theory of mind: False trails and genuine markers. *Child development*, *62*(3), 468–483.

[351] Cutting, A. L., & Dunn, J. (2002). The cost of understanding other people: Social cognition predicts young children's sensitivity to criticism. *Journal of Child Psychology and Psychiatry, 43*, 849–860.

[352] Lecce, S., Caputi, M., & Hughes, C. (2011). Does sensitivity to criticism mediate the relationship between theory of mind and academic achievement? *Journal of Experimental Child Psychology, 110*(3), 313–331.

[353] Mizokawa, A. (2015). Theory of mind and sensitivity to teacher and peer criticism among Japanese children*. Infant and Child Development*, *24*(2), 189–205.

[354] Lecce, S., Caputi, M., & Pagnin, A. (2014). Long-term effect of theory of mind on school achievement: The role of sensitivity to criticism. *European Journal of Developmental Psychology, 11*(3), 305–318.

4.4 How does children's theory of mind develop during the first five years of life?

Theory of mind was first identified as a concept in the mid-1970s through a seminal study which considered whether chimpanzees could accurately infer the intentions of others.[355] Since that time, differing frameworks have emerged for describing the nature of theory of mind and its impact on children's development. Two frameworks, in particular, dominate the literature:

- **Nativist** perspectives maintain that ToM skills are necessary from an evolutionary standpoint and develop through innate processes which unfold on a maturational timetable.[356,357] Nativists also view ToM capabilities to be modular, involving domain-specific neurological processes that may become damaged, as is the case with ASD and other genetically-based disorders.[358]
- **Constructivist** accounts, by contrast, place a greater emphasis on children's own theories about others' mental states. Hence, the term 'theory theorist' is often used to describe the constructivist point of view. Although constructivists recognise that ToM skills are rooted in capabilities present at birth, they place a greater emphasis on the role experience and children's mental representations on the development of ToM skills.[359]

This chapter does not endorse one of these perspectives over the other, but instead uses both to provide a developmental account of children's ToM in terms of early ToM milestones.

Infancy (0–24 months)

Early ToM development has been conceptualised as taking place through two systems: a belief, or 'mindreading' system and an emotion reading or empathising system (see table 4.1).[360,361] The extent to which these systems reflect specific neurological functions is not yet fully understood, although they are useful for describing groups of early competencies that may contribute to children's later ToM understanding. Some of these capabilities may be present at birth, whereas others likely develop through experience.

The **Intentionality Detector** involves the infant's understanding that some objects have intentions and behave in goal-directed ways. Already within the first few hours of birth, infants demonstrate a preference for objects that move.[362] Some maintain that newborns can also distinguish movements that are human (unpredictable and non-continual) from movements that are mechanical (predictable and continual), although this view is not uniformly shared by all researchers.[363] There is, however, good evidence to suggest that by three months, infants can reliably detect differences between self- and mechanically-propelled objects.[364] By nine months, most infants will also perceive moving objects as intentional and goal-directed, although may still not reliably distinguish living and conscious

355 Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and brain sciences*, *1*(4), 515–526.

356 Scholl, B. J., & Leslie, A. M. (1999). Modularity, development and 'theory of mind'. *Mind & Language*, *14*(1), 131–153.

357 Scholl, B. J., & Leslie, A. M. (2001). Minds, modules, and meta-analysis. *Child development*, *72*(3), 696–701.

358 Baron-Cohen, S. (2005). The empathizing system. *Origins of the social mind: Evolutionary psychology and child development*, 468–492.

359 Gopnik, A., & Wellman, H. M. (2012). Reconstructing constructivism: Causal models, Bayesian learning mechanisms, and the theory theory. *Psychological bulletin*, *138*(6), 1085.

360 Sodian, B. (2011). Theory of mind in infancy. *Child Development Perspectives, 5*, 39–43.

361 Baron-Cohen, S. (2005). The empathizing system. *Origins of the social mind: Evolutionary psychology and child development*, 468–492.

362 Haith, M. M. (1966). The response of the human newborn to visual movement. *Journal of Experimental Child Psychology*, *3*(3), 235–243.

363 Mandler, J. M. (2003). Conceptual categorisation. In Rakison, D. H., & Oakes, L. M. (eds). Early category and concept development: Making sense of the blooming, buzzing confusion (pp. 103–132).

364 Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition*, *36*(1), 1–16.

beings from mechanical objects.[365,366] By two years, most children will understand the difference between objects that move and are conscious (humans, animals) and objects that move which are not conscious (vehicles, balls).[367]

TABLE 4.1

Systems contributing to the development of children's theory of mind

The Mindreading System	
Intentionality Detector (ID)	Involves the perceptual skills that allow the infant to understand moving objects as having intentions and volition. Is fully present by nine months.
Eye-Direction Detector (EDD)	Is made up of innate capabilities that allow the infant to detect eyes and determine where they are looking. Can follow gaze and infer that the eyes see something. Is typically fully present by nine months.
Shared-Attention Mechanism (SAM)	Involves the triadic three-way interaction between the infant, parent and object. Infants begin to engage in joint attention episodes at nine months and can fully share attention with others by 18 months.
Theory of Mind Module (ToMM)	Children acquire skills underpinning successful performance in false-belief tasks. Occurs between the ages of three and five.
The Empathising System	
The Emotion Detector (TED)	The ability to recognise shared emotional states between two people. Develops by nine months.
The Empathising System (TESS)	Allows the child to understand and react empathetically to the emotions of others. This may be accompanied by an associated drive to help others. Is present by 14 months.

Source: Baron-Cohen, S. (2005). The empathizing system. *Origins of the social mind: Evolutionary psychology and child developmen*t

The **Eye-Direction Detector (EDD):** This refers to behaviours which allow children to understand that others are looking at something. As mentioned in chapter 2, infants typically demonstrate a preference for face-like patterns and eyes.[368,369,370,371] By three months, most infants can also follow the gaze of others.[372,373] The extent to which very young infants mentally share others' gaze is debated, however, as some assume this capability may be reflexive.[374] Nevertheless, by nine months most infants understand that an individual's gaze means that he or she is looking at something. Most infants will therefore actively follow this gaze to gain information about what they are seeing.[375]

365 Baker, R. K., Pettigrew, T. L., & Poulin-Dubois, D. (2014). Infants' ability to associate motion paths with object kinds. *Infant Behavior and Development*, *37*(1), 119–129.

366 Scott, R. M., & Baillargeon, R. (2013). Do infants really expect agents to act efficiently? A critical test of the rationality principle. *Psychological science*, *24*(4), 466–474.

367 Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate–inanimate distinction. *Psychological bulletin*, *127*(2), 209.

368 Haith, M. M. (1966). The response of the human newborn to visual movement. *Journal of Experimental Child Psychology*, *3*(3), 235–243.

369 Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, *40*(1), 1–19.

370 Easterbrook, M. A., Kisilevsky, B. S., Hains, S. M. J., & Muir, D. W. (1999). Faceness or complexity: Evidence from newborn visual tracking of facelike stimuli. *Infant Behavior and Development*, *22*(1), 17–35.

371 DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science*, *208*(4448), 1174–1176.

372 Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental science*, *10*(1), 121–125.

373 Shepherd, S. V. (2010). Following gaze: gaze-following behavior as a window into social cognition. *Frontiers in integrative neuroscience*, *4*, 5.

374 Tomasello, M., Hare, B., Lehmann, H., & Call, J. (2007). Reliance on head versus eyes in the gaze following of great apes and human infants: the cooperative eye hypothesis. *Journal of human evolution*, *52*(3), 314–320.

375 Meltzoff, A. N., & Brooks, R. (2007). Eyes wide shut: The importance of eyes in infant gaze following and understanding other minds. In Flom, R., Lee. K., & Muir, D. (eds). *Gaze following: Its development and significance*. New York: Erlbaum.

The **Emotion Detector (TED):** The infant's own emotional states provide the starting point for learning about the emotional states of others. Caregivers help regulate these states through their use of infant-directed speech (IDS).[376] It is thought that the range of vocal tones and gentle affect-matching used in IDS helps the infant differentiate various emotions.[377,378] By three months, most infants can perceptually differentiate basic emotional states, such as happy, sad, angry and frightened.[379,380]

The **Empathising System (TES):** Evidence shows that infants may be capable of imitating simple facial expressions (tongue protrusions, opening the mouth and pursing lips) within 48 hours of birth.[381] Some researchers assume that this form of early imitation provides the basis for 'like-me' comparisons, whereby the infant consciously matches his or her facial movements to the movements of others.[382,383] While there is some neuroscientific evidence to support this view, others believe these behaviours initially occur reflexively, with true imitation (that is, the child consciously mimicking the behaviours of others) occurring in the latter half of the second year.[384,385]

The **Shared Attention Mechanism (SAM)** emerges at around nine months when most children start to engage in triadic interactions involving shared attention towards an object or event with their parents (see chapter 3). Many have argued that this is a pivotal point in the development of ToM, as the child demonstrates awareness that the parent has a mental state (that is, interest) towards an external object which is within sight.[386]

The protodeclarative point (involving the child's use of his or her index finger to point to an object), is a good example of the SAM in action.[387] This act specifically reflects the child's conscious awareness that he or she sees something and can share this understanding – this mental state – with others. Oftentimes, the child will make a sound to accompany the gesture to indicate that he or she knows that a sound is shared. As described in chapter 3, parents often reinforce the protodeclarative point by labelling the shared object. This is viewed as a watershed moment in the learning of language, as infants come to recognise that different sounds correspond to different objects, *and* that thoughts about these objects can be shared with others through a symbolic connection.[388]

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376 Fernald, A. (1995). Human maternal vocalizations to infants as biologically relevant signals: An Evolutionary Perspective. In J. H. Barkow L., Cosmides & J.Toby (eds). *The adapted mind: Evolutionary psychology and the generation of culture*, 391–428.

377 Trainor, L. J., Austin, C. M., & Desjardins, R. N. (2000). Is infant-directed speech prosody a result of the vocal expression of emotion?. *Psychological science*, *11*(3), 188–195.

378 Ma, W., Golinkoff, R. M., Houston, D., Hirsh-Pasek, A., (2011). Word Learning in Infant- and Adult-Directed Speech, *Language Learning and Development, 7*, 209–225.

379 Walker-Andrews, A. S. (1997). Infants' perception of expressive behaviors: differentiation of multimodal information. *Psychological bulletin*, *121*(3), 437.

380 Walker, A. S. (1982). Intermodal perception of expressive behaviors by human infants. *Journal of Experimental Child Psychology*, *33*(3), 514–535.

381 Meltzoff, A. N., & Moore, M. K. (1983). Newborn infants imitate adult facial gestures. *Child Development*, *54*, 702–709.

382 Meltzoff, A. N. (2002). Imitation as a mechanism of social cognition: Origins of empathy, theory of mind, and the representation of action. *Blackwell handbook of childhood cognitive development*, 6–25.

383 Meltzoff, A. N., & Moore, M. K. (1994). Imitation, memory, and the representation of persons. *Infant behavior and development*, *17*(1), 83–99.

384 Vincini, S., Jhang, Y., Buder, E. H., & Gallagher, S. (2017). Neonatal imitation: Theory, experimental design, and significance for the field of social cognition. *Frontiers in psychology*, *8*, 1323.

385 Jones, S. S. (2009). The development of imitation in infancy. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1528), 2325–2335.

386 Goldman, A. I. (2006). *Simulating minds: The philosophy, psychology, and neuroscience of mindreading*. Oxford University Press.

387 Baron-Cohen, S. (1989). Perceptual role taking and protodeclarative pointing in autism. *British Journal of Developmental Psychology*, *7*(2), 113–127.

388 Camaioni, L., Perucchini, P., Bellagamba, F., & Colonnesi, C. (2004). The role of declarative pointing in developing a theory of mind. *Infancy*, *5*(3), 291–308.

Toddlerhood (12–36 months)

Language and communication

Between 9 and 15 months, joint attention activities undergo a dramatic shift whereby the toddler is no longer passively sharing attention with the caregiver, but instead directing it. Toddlers do this through declarative gestures that include pointing, but also by showing or handing objects to others.[389] During the second year, most toddlers also start to engage in altruistic behaviours by comforting and helping others.[390,391] Many view these altruistic behaviours as evidence of toddlers' empathy and awareness of others' emotional and motivational states.[392,393]

Between 12 and 24 months, children's vocabulary also undergoes a rapid expansion. By the time of their second birthday, many children will have mastered the words associated with desires and wishes, such as 'want' and 'hope'.[394] It is assumed that this understanding is facilitated by conversations with parents and other adults who frequently ask toddlers whether they want something before they give it to them.[395] For example, the question 'do you want the juice' highlights both the juice and a mental state associated with it – that is, *want*.[396] Between 24 and 36 months, many children also understand the words associated with simple emotions (happy, sad, angry, frightened) and can talk about what other people 'know'.[397,398] By their third birthday, most children can also talk about the past and the future, using mental-state words such as 'remember' or 'guess'.[399]

False-belief understanding

What toddlers do and do not understand about others' false-beliefs is a current topic of controversy, fuelled by conflicting findings from various research labs across the globe. For example, several US labs have documented toddlers as young as 15 months expressing surprise during violation of expectation tasks involving actors who look for objects in new, correct places after the objects have been displaced when the actors were not looking. Researchers have interpreted the toddler's surprise to mean that the he or she expected that the actor would act on knowledge about the object *which is different*

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389 Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the society for research in child development*, i–174.

390 Eisenberg, N., & Fabes, R. A. (1998). Prosocial development. In Damon, W., & Eisenberg, N. (eds), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (5th edition, pp. 701–778). New York: Wiley.

391 Liszkowski, U., Carpenter, M., Striano, T., & Tomasello, M. (2006). 12- and 18-month-olds point to provide information for others. *Journal of Cognition and Development*, *7*(2), 173–187.

392 Baillargeon, R., Scott, R. M., & Bian, L. (2016). Psychological reasoning in infancy. *Annual Review of Psychology*, *67*, 159–186.

393 Meltzoff, A. N. (2011). Social cognition and the origins of imitation, empathy, and theory of mind. *The Wiley-Blackwell handbook of childhood cognitive development*, *2*, 49–75.

394 Astington, J. W., & Baird, J. A. (eds.) (2005). *Why language matters for theory of mind*. Oxford: Oxford University Press.

395 Ridgeway, D., Waters, E., & Kuczaj, S. A. (1985). Acquisition of emotion-descriptive language: Receptive and productive vocabulary norms for ages 18 months to 6 years. *Developmental Psychology*, *21*(5), 901.

396 Taumoepeau, M., & Ruffman, T. (2006). Mother and infant talk about mental states relates to desire language and emotion understanding. *Child development*, *77*(2), 465–481.

397 Bartsch, K., & Wellman, H. M. (1995). *Children talk about the mind*. Oxford University Press.

398 Taumoepeau, M., & Ruffman, T. (2008). Stepping stones to others' minds: Maternal talk relates to child mental-state language and emotion understanding at 15, 24, and 33 months. *Child development*, *79*(2), 284–302.

399 Atance, C. M., & Meltzoff, A. N. (2005). My future self: Young children's ability to anticipate and explain future states. *Cognitive Development*, *20*(3), 341–361.

to what the toddler knows.[400,401,402,403,404,405] Further confirmation of toddlers' awareness of others' false-beliefs comes from a series of German studies involving tasks where toddlers are asked to help actors locate objects which have been hidden and locked away in their absence.[406]

Research labs in France and Canada have not been able to replicate these findings, however, and this has led to some intense debates regarding what toddlers actually do and do not know in terms of others' false beliefs.[407,408] Some speculate that differences in the sample or the experimental situation have led to differences in the findings. Others argue that toddlers nevertheless have some awareness of what the actors might be thinking during experimental situations (perhaps through 'like me' comparisons), but do not yet fully comprehend the entire contents of the actor's false belief.[409]

Despite these conflicting findings, there is consistent evidence that toddlers become increasingly better at mastering simplifications of the Sally-Anne task between the ages of two and four. Thus, by 2.5 years, 80% of children are able to successfully *point to* where the actor will look, although many will continue to fail when they are asked to *say* where an actor will look.[410] This discrepancy has puzzled researchers, who offer differing interpretations as to why it exists.[411] Nativists assume that infants already have an implicit understanding of others' false beliefs, but fail on verbal false-belief tasks because they either do not have the inhibitory skills to suppress the knowledge of the correct location, and/or have not yet mastered the syntax to correctly understand the question.[412] Constructivists, by contrast, view this discrepancy as less trivial, arguing that while young children may have some success with educated guesses about the beliefs of others (through 'like me' comparisons), they cannot yet mentally represent what those beliefs might be, which leads to inconsistencies in their performance.[413,414]

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400 Garnham, W. A., & Ruffman, T. (2001). Doesn't see, doesn't know: is anticipatory looking really related to understanding or belief? *Developmental Science, 4*(1), 94–100.

401 He, Z., Bolz, M., & Baillargeon, R. (2012). 2.5-year-olds succeed at a verbal anticipatory-looking false-belief task. British *Journal of Developmental Psychology, 30*(1), 14–29.

402 Senju, A., Southgate, V., Snape, C., Leonard, M., & Csibra, G. (2011). Do 18-month-olds really attribute mental states to others? A critical test. *Psychological science, 22*(7), 878–880.

403 Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false belief by 2-year-olds. *Psychological Science, 18*(7), 587–592.

404 Thoermer, C., Sodian, B., Vuori, M., Perst, H., & Kristen, S. (2012). Continuity from an implicit to an explicit understanding of false belief from infancy to preschool age. *British Journal of Developmental Psychology, 30*(1), 172–187.

405 Wang, L., & Leslie, A. M. (2016). Is Implicit Theory of Mind the 'Real Deal'? The Own-Belief/True-Belief Default in Adults and Young Preschoolers. *Mind & Language, 31*(2), 147–176.

406 Buttelmann, D., Carpenter, M., & Tomasello, M. (2009). Eighteen-month-old infants show false belief understanding in an active helping paradigm. *Cognition, 112*(2), 337–342.

407 Poulin-Dubois, D., & Yott, J. (2018). Probing the depth of infants' theory of mind: Disunity in performance across paradigms. *Developmental Science*, *21*(4), e12600..

408 Dörrenberg, S., Rakoczy, H., & Liszkowski, U. (2018). How (not) to measure infant theory of mind: testing the replicability and validity of four non-verbal measures. *Cognitive Development*..

409 Powell, L. J., Hobbs, K., Bardis, A., Carey, S., & Saxe, R. (2018). Replications of implicit theory of mind tasks with varying representational demands. *Cognitive Development*, *46*, 40–50.

410 Setoh, P., Scott, R.M. and Baillargeon, R. (2016). Two-an-a-half-year-olds succeed at a traditional false-belief task with reduced processing demands. *PNAS, 113*, 13360–13365.

411 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

412 Scholl, B. J., & Leslie, A. M. (2001). Minds, modules, and meta-analysis. *Child development*, *72*(3), 696–701.

413 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

414 Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological review*, *116*(4), 953.

Preschool (three to five years)

False-belief understanding

It is not until the end of the fourth year that children reliably predict the false beliefs of others during Sally-Anne or related tasks. Up until this time, children will, in fact, choose the wrong answer at rates which are much greater than chance. For example, children aged four and younger will reliably say that Sally will look for her marbles in the place the child knows them to be instead of where Sally last left them. Three-year-olds will similarly fail false-belief tasks involving surprising contents. In these experiments, children are asked to predict what is in a box designed to hold one thing (such as crayons) and are shown that it actually holds another (such as birthday candles).[415,416] Children are then asked to predict what someone else will think is in the box. Before the age of four and a half, children will typically claim that others will believe candles to be in the box, after just previously confirming that the box contained crayons.

However, between the ages of three and four, children become increasingly able to appreciate the ways in which others' thoughts can be different to their own. Studies observe that this understanding unfolds a progression which is virtually the same for all children living in western countries (as set out in table 4.2).

TABLE 4.2

Developmental sequence of false-belief understanding

Task	Description	Average age of capability
Diverse Desires (DD)	The child understands that two people (the child vs someone else) can have different desires about the same object. Experiments which tap this knowledge ask children to indicate which of two snacks they prefer – broccoli or biscuits. The child is then asked to predict the choice of an actor who has the opposite preference.	3.5 years
Diverse Beliefs (DB)	The child understands that two people (the child vs someone else) can have different beliefs about the same object, when the child does not know which belief is true or false.	3.8 years
Knowledge Access (KA)	The child has knowledge of an item hidden in a box, but understands that others may be ignorant of it	4.5 years
Explicit False Belief (FB)	The child can predict how someone will search, given knowledge of their false belief, as in traditional Sally-Anne tasks.	4.8 years
Hidden Emotion (HE)	The child understands that a person can feel one thing but display a different emotion.	5.2 years

Source: Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child development, 75*(2)

This progression begins with the awareness that people can differ in terms of their desires, which occurs on average at around 3.5 years. By the end of the fourth year, most children can accurately predict where an actor will look on the basis of the actor's belief about an item's location, when the child is ignorant of whether the actor's belief is true or false. It is not until the middle of the fifth year, however, that children reliably predict the behaviour of someone holding a false belief, with knowledge that the belief is false – as in traditional Sally-Anne tasks. Most children do not, however, understand that others can mask or feign their emotions until sometime during the sixth year.

415 Flavell, J. H., Flavell, E. R., & Green, F. L. (1983). Development of the appearance-reality distinction. *Cognitive psychology, 15*(1), 95–120.

416 Flavell, J. H., Green, F. L., Flavell, E. R., Watson, M. W., & Campione, J. C. (1986). Development of knowledge about the appearance-reality distinction. *Monographs of the society for research in child development*, *51*, i–87.

Telling lies, keeping secrets and the art of persuasion

Interestingly, improvements in children's false-belief understanding parallel improvements in their ability to lie. As one researcher put it: 'lying, in essence, is ToM in action … because to do so successfully, [children] must represent and differentiate the mental states of themselves and the listener and make appropriate statements to conceal the truth while instilling false beliefs into the mind of the listener (the intentionality component).'[417]

Studies observe that lying typically occurs during the child's fifth year. While most parents report their child lying already at the age of two, studies find that the lies told by two-year-olds are not particularly sophisticated.[418] While two-year-olds might lie to evade punishment or boast, they are terrible at telling a convincing lie or remembering how to stick to it.[419,420] More fundamentally, two-year-olds do not lie in a way that *intentionally* creates a false belief in others.[421]

Children become increasingly better at lying between the ages of four and five, with studies showing that this 'skill' develops in parallel with their performance on false-belief tasks.[422] Up until the age of four, children tell *primary* lies that are deliberate false statements to cover up transgressions. For example, two-year-olds may deny they broke something when they actually did. However, most two-year-olds do not go out of their way to provide an alternative explanation about what could have happened. Four-year-olds, by contrast, are more capable of *secondary* lies which represent deliberate attempts to create false beliefs in others.

This developmental shift is exemplified in experimental tasks where children are tempted to lie about peeking at a toy when they have been explicitly told not to. Before the age of three, children are less likely to lie, and when they do – are more likely to immediately confess when they are caught out. However, once children are capable of successfully predicting the false beliefs of others, they realise that they can manipulate others' perceptions. Thus, from the age of four onwards, children are increasingly better able to lie and stick to their story in a way that is convincing to others.[423] By the time children are seven or eight, most children are capable of telling a good lie and sticking to it in a way that others will likely believe.[424]

Similar parallels have been observed between children's false-belief understanding and their ability to hide, keep a secret or develop a persuasive argument.[425,426] For example, it is not uncommon for a game of hide-and-seek involving a two- or three-year-old to end with the child blurting out 'I'm under the bed' or 'here I am' before the seeker has had a chance to find him or her. Similarly, two- and three-year-olds are terrible at concealing information about birthday surprises. In these instances, children not only have difficulty inhibiting what they know, but also appear not to understand that the primary point of the secret or game is to manipulate the beliefs of others. However, once children understand the point is to manipulate others' thoughts, they often become master players, inventing increasingly more sophisticated ways of tricking or surprising others as they develop.

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417 Lee, K. (2013). Little liars: Development of verbal deception in children. *Child Development Perspectives*, *7*(2), 91–96.

418 Newton, P., Reddy, V., & Bull, R. (2000). Children's everyday deception and performance on false-belief tasks. *British Journal of Developmental Psychology*, *18*(2), 297–317.

419 Talwar, V., & Lee, K. (2002). Development of lying to conceal a transgression: Children's control of expressive behaviour during verbal deception. *International Journal of Behavioral Development*, *26*(5), 436–444.

420 Evans, A. D., & Lee, K. (2013). Emergence of lying in very young children. *Developmental Psychology*, *49*(10), 1958.

421 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

422 Talwar, V., & Lee, K. (2008). Social and cognitive correlates of children's lying behavior. *Child development*, *79*(4), 866–881.

423 Evans, A. D., Xu, F., & Lee, K. (2011). When all signs point to you: Lies told in the face of evidence. *Developmental Psychology*, *47*(1), 39.

424 Polak, A., & Harris, P. L. (1999). Deception by young children following noncompliance. *Developmental psychology*, *35*(2), 561–568.

425 Peskin, J., & Ardino, V. (2003). Representing the Mental World in Children's Social Behavior: Playing Hide-and-Seek and Keeping a Secret. *Social Development*, *12*(4), 496–512.

426 Slaughter, V., Peterson, C. C., & Moore, C. (2013). I can talk you into it: Theory of mind and persuasion behavior in young children. *Developmental Psychology*, *49*(2), 227.

What factors might contribute to these shifts in children's understanding? As mentioned previously, children's ability to anticipate others' false beliefs is influenced by their knowledge of language and the maturation of the executive functions. The executive functions likely support children's performance on ToM tasks by (1) improving their ability to inhibit responses involving the item's true location, and (2) allowing them to mentally represent multiple points of view, including those that are false.[427] Indeed, studies observe that the ability to lie is predicted both by the children's performance on false-belief tasks, as well as their inhibitory control.

Theory of mind and symbolic play

It has traditionally been assumed that the symbolic play described in chapter 3 facilitates children's false-belief understanding.[428] As described previously, symbolic play requires children to entertain different representations of objects through symbolic substitutions.[429,430,431] Between the ages of three and five, children's symbolic play becomes increasingly more advanced, involving the use of props, costumes and other materials to create make-believe worlds. Within these worlds, children 'try on' the mental states of others, including adult professionals (such as firemen), super heroes and fairytale princesses. The extent to which this kind of symbolic play (also known as sociodramatic play) specifically facilitates the development of ToM skills remains unclear, however.[432] While studies consistently observe an association between sociodramatic play and children's ToM development, it may be that ToM skills facilitate sociodramatic play rather than the other way around.[433,434,435]

4.5 What factors influence the development of children's theory of mind during the first five years of life?

ToM development is frequently understood through children's progression through the false-belief milestones summarised in table 4.2. The previous section provided an overview of how children typically progress through this sequence. This section summarises what is known about the ways in which child- and family-level factors predict individual differences in the rate at which false-belief milestones are achieved.

427 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

428 Leslie, A. M. (1987). Pretense and representation: The origins of 'theory of mind'. *Psychological review*, *94*(4), 412.

429 Lillard, A. S. (1993). Pretend play skills and the child's theory of mind. *Child development*, *64*(2), 348–371.

430 Bosco, F. M., Friedman, O., & Leslie, A. M. (2006). Recognition of pretend and real actions in play by 1- and 2-year-olds: Early success and why they fail. *Cognitive Development, 21*, 3–10.

431 Onishi, K. H., Baillargeon, R., & Leslie, A. M. (2007). 15-Month-old infants detect violations in pretend sequences. *Acta Psychologica, 124,* 106–128.

432 Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2013). The impact of pretend play on children's development: A review of the evidence. *Psychological bulletin*, *139*(1), 1.

433 Youngblade, L. M., & Dunn, J. (1995). Individual differences in young children's pretend play with mother and sibling: Links to relationships and understanding of other people's feelings and beliefs. *Child Development*, *66*(5), 1472–1492.

434 Jenkins, J. M., & Astington, J. W. (2000). Theory of mind and social behavior: Causal models tested in a longitudinal study. *Merrill-Palmer Quarterly (1982-)*, 203–220.

435 Dore, R. A., Smith, E. D., & Lillard, A. S. (2015). How is theory of mind useful? Perhaps to enable social pretend play. *Frontiers in psychology, 6*.

Genetic factors

Heritability

Twin studies involving typically developing populations observe conflicting findings regarding the heritability of ToM capabilities. For example, an early study involving a relatively small sample of three-year-old twins observed a heritability estimate of .67, suggesting ToM capabilities to be highly heritable.[436] However, a subsequent study, involving a larger and more varied sample of five-year-old twins, observed environmental factors accounting for over 93% of the ToM variance. Environmental factors implicated in this second study included family income, parenting behaviours and parent–child conversations. The authors concluded that the discrepancy between the two twin studies may have been due to differences in the subject's age, with five-year-olds receiving greater exposure to environmental influences in comparison to the three-year-olds.[437]

Subsequent twin studies have further confirmed an association between parenting behaviours, children's verbal ability (see following sections) and the development of children's ToM in non-clinical samples.[438,439] Researchers nevertheless continue to look for genes which may be responsible for ToM delays, with several confirming links between heritable factors associated with the development of inhibition, early language capabilities and children's early understanding of ToM.[440,441,442]

Autism spectrum conditions

Impairments in children's ToM are accepted as a hallmark characteristic of autism spectrum conditions (ASCs).[443,444,445] ASCs occur in approximately 1% of the total population and are thought to have a strong heritable component, with heritability estimates ranging from .70 to .90.[446,447] However, the extent to which they are associated with rare genetic mutations, or interactions involving multiple, more common genes, remains a topic of debate, although studies show that siblings are 25 times more likely to share autistic traits, suggesting that a family history of ASC is a significant risk.[448]

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436 Hughes, C., & Cutting, A. L. (1999). Nature, nurture, and individual differences in early understanding of mind. *Psychological Science, 10*(5), 429–432.

437 Hughes, C., Jaffee, S. R., Happé, F., Taylor, A., Caspi, A., & Moffitt, T. E. (2005). Origins of individual differences in theory of mind: from nature to nurture? *Child Development, 76*(2), 35–370.

438 Ronald, A., Happe, F., Hughes, C., & Plomin, R. (2005). Nice and nasty theory of mind in preschool children: Nature and nurture. *Social Development*, *14*(4), 664–684.

439 Ronald, A., Viding, E., Happé, F., & Plomin, R. (2006). Individual differences in theory of mind ability in middle childhood and links with verbal ability and autistic traits: A twin study. *Social Neuroscience*, *1*(3-4), 412–425.

440 Xia, H., Wu, N., & Su, Y. (2012). Investigating the genetic basis of theory of mind (ToM): the role of catechol-O-methyltransferase (COMT) gene polymorphisms. *PloS One, 7*(11), e49768.

441 Wu, N., & Su, Y. (2015). Oxytocin receptor gene relates to theory of mind and prosocial behavior in children. *Journal of Cognition and Development, 16*(2), 302–313.

442 Lackner, C., Sabbagh, M. A., Hallinan, E., Liu, X., & Holden, J. J. (2012). Dopamine receptor D4 gene variation predicts preschoolers' developing theory of mind. *Developmental science, 15*(2), 272–280.

443 Baron-Cohen, S., Bowen, D. C., Holt, R. J., Allison, C., Auyeung, B., Lombardo, M. V., ... & Lai, M. C. (2015). The 'reading the mind in the eyes' test: complete absence of typical sex difference in ~400 men and women with autism. *PLoS One, 10*(8), e0136521.

444 Back, E., Ropar, D., & Mitchell, P. (2007). Do the eyes have it? Inferring mental states from animated faces in autism. *Child Development, 78*(2), 397–411.

445 Iao, L. S., & Leekam, S. R. (2014). Nonspecificity and theory of mind: new evidence from a nonverbal false-sign task and children with autism spectrum disorders. *Journal of Experimental Child Psychology, 122*, 1–20.

446 Brugha T. S, McManus S., Bankart J, et al. (2011). Epidemiology of autism spectrum disorders in adults in the community in England. *Archives of General Psychiatry, 68*, 459–465.

447 Geschwind, D. H. (2009). Advances in autism. *Annual review of medicine*, *60*, 367–380.

448 Abrahams, B. S., Geschwind, D. H. (2008). Advances in autism genetics: on the threshold of a new neurobiology. *National Review of Genetics, 9*, 341–55.

An early indicator of ASC in late infancy is a failure to use and understand protodeclarative pointing.[449] Other indicators of ASC include:

- deficits and delays in the emergence of joint attention, pretend play and perspective taking
- deficits in reciprocal affective behaviour
- decreased response to own name
- decreased imitation
- delayed verbal and nonverbal communication
- motor delay
- unusually repetitive behaviours
- atypical visuomotor exploration
- inflexibility in disengaging visual attention
- extreme variation in temperament.[450,451]

These indicators are now used in a variety of screening and diagnostic measures developed for infants and toddlers, as described in section 4.6.[452,453]

Attention deficit hyperactivity disorder

Attention deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder in children and adolescents, affecting approximately 7% of children worldwide.[454] It is thought to have a strong heritable component (sharing the same genetic risks as ASCs) and is characterised by developmentally inappropriate impulsivity and attention difficulties. Studies consistently show that attention difficulties are reliably identifiable by the age of three and often persist throughout childhood and into adulthood.[455] A number of studies now confirm deficits in ADHD children's perceptions of emotion in facial expressions, although these impairments appear to be very subtle in adults with ADHD.[456,457] It is possible that complications involving the executive functions contribute to symptoms associated with ADHD and children's ToM development.[458]

Specific language impairments

Specific language impairments (SLIs) are diagnosed when children are assessed as having marked language delays on standardised language tests, despite being assessed as having

449 Baron-Cohen, S. (1989). Perceptual role taking and protodeclarative pointing in autism. *British Journal of Developmental Psychology*, *7*(2), 113–127.

450 Mundy, P., Kim, K., McIntyre, N., Lerro, L., & Jarrold, W. (2016). Brief report: Joint attention and information processing in children with higher functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders, 46*(7), 2555–2560.

451 Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: an investigation of empathy, pretend play, joint attention, and imitation. *Developmental Psychology, 33*(5), 781.

452 Elsabbagh M, Johnson MH. (2010). Getting answers from babies about autism. *Trends in Cognitive Science, 14,* 81–87.

453 Zwaigenbaum, L., Bryson, S., Lord, C., Rogers, S., Carter, A., Carver, L., ... & Fein, D. (2009). Clinical assessment and management of toddlers with suspected autism spectrum disorder: Insights from studies of high-risk infants. *Pediatrics, 123*(5), 1383–1391.

454 Thomas, R., Sanders, S., Doust, J., Beller, E., & Glasziou, P. (2015). Prevalence of attention-deficit/hyperactivity disorder: a systematic review and meta-analysis. *Pediatrics, 135*(4), e994–e1001.

455 Kessler, R. C., Adler, L. A., Barkley, R., Biederman, J., Conners, C. K., Faraone, S. V., ... & Üstün, T. B. (2005). Patterns and predictors of attention-deficit/hyperactivity disorder persistence into adulthood: results from the national comorbidity survey replication. *Biological psychiatry, 57*(11), 1442–1451.

456 Uekermann, J., Kraemer, M., Abdel-Hamid, M., Schimmelmann, B. G., Hebebrand, J., Daum, I., ... & Kis, B. (2010). Social cognition in attention-deficit hyperactivity disorder (ADHD). *Neuroscience & Biobehavioral Reviews, 34*(5), 734–743.

457 Bora, E., & Pantelis, C. (2016). Meta-analysis of social cognition in attention-deficit/hyperactivity disorder (ADHD): comparison with healthy controls and autistic spectrum disorder. *Psychological Medicine, 46*(4), 699–716.

458 Mary, A., Slama, H., Mousty, P., Massat, I., Capiau, T., Drabs, V., & Peigneux, P. (2016). Executive and attentional contributions to Theory of Mind deficit in attention deficit/hyperactivity disorder (ADHD). *Child Neuropsychology, 22*(3), 345–365.

normal intelligence on other measures (see chapter 6).[459] Prevalence studies currently estimate that SLIs are present in approximately 8% of all preschoolers.[460] While specific causes of SLIs are unknown, it is assumed they are related to heritable factors.[461] ToM difficulties are frequently present in children diagnosed with an SLI.[462]

The mechanism by which SLIs may contribute to ToM impairments is difficult to determine, as few longitudinal studies have considered the relationship between SLIs and ToM directly.[463] Several processes have been proposed, however, including difficulties in children's understanding of grammar.[464] It is also thought that impairments in the executive functions (working memory and attention, in particular) simultaneously impact children's language development and ToM capabilities.[465] ToM difficulties associated with speech impairments are usually evident from the age of three onwards.

Congenital deafness

It is believed that congenital deafness indirectly influences the development of ToM skills by limiting children's access to conversations with others.[466] Specifically, deaf children born to hearing parents often do not master sign language until they attend school.[467] This limits deaf children's access to conversations about mental states which, in turn, may delay children's understanding of false beliefs by up to five years.[468,469] By contrast, deaf children born to deaf parents achieve false-belief milestones within the same developmental period (late preschool) as hearing children do. This is likely because deaf children born to deaf parents learn about mental states during the first two years of life at the same time they are acquiring sign language.

Congenital blindness

Congenital blindness is associated with developmental delays in children's false-belief understanding, although this has not been investigated as extensively as it has been in deaf children.[470] Some suspect that delays in blind children's false-belief reasoning may be due to their inability to follow the gaze or share joint attention prior to acquiring language.[471]

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459 Leonard, L. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

460 Norbury, C. F., Gooch, D., Wray, C., Baird, G., Charman, T., Simonoff, E., Vamvakas, G., & Pickles, A. (2016). The impact of nonverbal ability on prevalence and clinical presentation of language disorder: evidence from a population study. *Journal of Child Psychology and Psychiatry*, doi:10.1111/jcpp.12573

461 Bishop, D. V. (2006). What causes specific language impairment in children? *Current directions in psychological science*, *15*(5), 217–221.

462 Nilsson, K. K., & López, K. J. (2016). Theory of Mind in children with Specific Language Impairment: A systematic review and meta-analysis. *Child Development*, *87*(1), 143–153.

463 ibid.

464 Bishop, D. V. M. (2014). Problems with tense marking in children with specific language impairment: Not how but when. Philosophical Transactions of the Royal Society, *Biological Science, 369*, 1–8.

465 Henry, L. A., Messer, D. J., & Nash, G. (2012). Executive functioning in children with specific language impairment. *Journal of Child Psychology and Psychiatry, 53*, 37–45.

466 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

467 Schick B., de Villiers P., de Villiers J., & Hoffmeister, R. (2007) Language and theory of mind: a study of deaf children. *Child Development, 78*, 376–396.

468 Peterson, C. C., & Wellman, H. M. (2009). From fancy to reason: Scaling deaf and hearing children's understanding of theory of mind and pretence. *British Journal of Developmental Psychology*, *27*(2), 297–310.

469 Peterson, C. C., Wellman, H. M., & Liu, D. (2005). Steps in Theory-of-Mind development for children with deafness or autism. *Child development*, *76*(2), 502–517.

470 Minter, M., Hobson, R. P., & Bishop, M. (1998). Congenital visual impairment and 'theory of mind'. *British Journal of Developmental Psychology*, *16*(2), 183–196.

471 Hobson, P. R., & Bishop, M. (2003). The pathogenesis of autism: Insights from congenital blindness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1430), 335–344.

Infancy 0–12 months

Relatively few studies have considered the longitudinal relationship between environmental processes occurring during infancy and children's later ToM development. Those that have, suggest that caregiver sensitivity towards the infant's mental states supports the infant's understanding of him or herself as an intentional being, as well as an awareness of the mental states of others.[472] This sensitivity – also referred to as 'mind-mindedness' – is often expressed through the caregiver's mentally-attuned statements about the infant's feelings or thoughts. For example, the statement '*oh, what a sleepyhead*' said to an infant who is clearly very tired draws attention to the sleepy child's mental state and communicates a sense of empathy.

Studies show that mind-minded caregiving behaviours at six months predict children's ToM capabilities at four years.[473,474] Other caregiving behaviours occurring during infancy found to be associated with later ToM development include:

- **Mindful facilitation:** the ability to engage and maintain the infant's attention in activities that he or she finds interesting.
- **Joint attention commenting:** showing sensitivity to the child's internal states; asking questions about what the child sees, thinks or feels.
- **Pacing:** maintaining the pace of interaction so that the infant is not over- or understimulated.
- **Affect catching:** demonstrating sensitivity to the infant's emotional states by sharing positive or negative affect.[475]

It is worth noting that infants differ in their ability to elicit mental-state behaviours from their caregivers. For example, caregivers frequently reinforce infant gesturing in the form of reaching and pointing, with mental-state comments such as 'do you want that?'[476,477] In this respect, studies find that a precocious awareness of gesturing in infancy predicts the accelerated use of mental-state language at age two[478,479] The extent to which such infant behaviour continues to predict later ToM behaviour after other parenting factors have been controlled for has not yet been specifically investigated, however.[480]

Other factors associated with maternal mind-minded behaviours include parenting stress, the extent to which the pregnancy was planned and the extent to which obstetric complications occurred.[481,482,483] Studies consistently confirm an association between these maternal

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472 Meins, E., Fernyhough, C., Wainwright, R., Clark-Carter, D., Das Gupta, M., Fradley, E., & Tuckey, M. (2003). Pathways to understanding mind: Construct validity and predictive validity of maternal mind-mindedness. *Child Development*, *74*(4), 1194–1211.

473 ibid.

474 Meins, E., Fernyhough, C., Wainwright, R., Das Gupta, M., Fradley, E., & Tuckey, M. (2002). Maternal mind–mindedness and attachment security as predictors of theory of mind understanding. *Child Development*, *73*(6), 1715–1726.

475 Ereky-Stevens, K. (2008). Associations between mothers' sensitivity to their infants' internal states and children's later understanding of mind and emotion. *Infant and Child Development*, *17*(5), 527–543.

476 Slaughter, V., Peterson, C. C., & Carpenter, M. (2008). Maternal talk about mental states and the emergence of joint visual attention. *Infancy*, *13*(6), 640–659.

477 Olson, J., & Masur, E. F. (2011). Infants' gestures influence mothers' provision of object action and internal state labels. *Journal of Child Language, 38*, 1028–1054.

478 Kristen, S., Sodian, B., Thoermer, C., & Perst, H. (2011). Infants' joint attention skills predict toddlers' emerging mental-state language. *Developmental psychology*, *47*(5), 1207.

479 Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive development*, *15*(4), 481–498.

480 Devine, R. T., & Hughes, C. (2016). Family Correlates of False Belief Understanding in Early Childhood: A Meta-Analysis. *Child Development*.

481 Meins, E., Fernyhough, C., Arnott, B., Turner, M., & Leekam, S. R. (2011). Mother-versus infant-centered correlates of maternal mind-mindedness in the first year of life. *Infancy*, *16*(2), 137–165.

482 Arnott, B., & Meins, E. (2007). Links among antenatal attachment representations, postnatal mind–mindedness, and infant attachment security: A preliminary study of mothers and fathers. *Bulletin of the Menninger Clinic*, *71*(2), 132–149.

483 McMahon, C. A., & Meins, E. (2012). Mind-mindedness, parenting stress, and emotional availability in mothers of preschoolers. *Early Childhood Research Quarterly*, *27*(2), 245–252.

characteristics, children's attachment security and later child behavioural outcomes, although an explicit link between these parenting characteristic and specific child ToM skills has yet to be established.[484] It is additionally worth noting that mind-minded behaviours have not been found to be associated with family income or a previous history of having children.[485]

Toddlerhood (12–36 months)

12–24 months

Mind-minded caregiving behaviours occurring during the second year continue to predict children's ToM capabilities in later preschool.[486] As toddlers acquire language, caregivers are increasingly able to engage them in mental-state conversations and (as mentioned in section 4.4) the topics of these conversations follow a predictable trajectory.[487] Between 12 and 18 months, mental-state conversations primarily involve people's desires. By 24 months, toddlers and caregivers also typically begin to talk about their emotions and things that they have remembered.[488,489]

Studies observe that conversations about emotional states are particularly likely to facilitate the development of prosocial behaviour in toddlers.[490,491] For example, a recent study involving a book-sharing task aimed at eliciting mental-state talk (the book only included illustrations of happy and sad events, no words) found that the frequency with which parents referred to the emotional states of story protagonists predicted their children's altruistic behaviour during a subsequent helping task. More generally, studies find that emotion and mental-state talk occurs *less* frequently when parents read to their children in comparison to other parent–child activities.[492] For example, studies consistently show that mental-state talk occurs more frequently during parent and child object play.[493,494]

24–36 months

Children's exposure to mental-state talk during the third year consistently predicts the rate at which they acquire false-belief understanding at later points in their development.[495] A recent longitudinal study observed that maternal mental-state references at age two significantly predicted children's false-belief understanding at age 10, even after children's verbal abilities were statistically taken into account. This study further found that conversations about cognitive states – that is, what others think and know – are better predictors of later ToM capabilities than are conversations about desires and emotions.

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484 Walker, T. M., Wheatcroft, R., & Camic, P. M. (2012). Mind-mindedness in parents of pre-schoolers: A comparison between clinical and community samples. *Clinical Child Psychology and Psychiatry*, *17*(3), 318–335.

485 Meins, E., Fernyhough, C., Wainwright, R., Das Gupta, M., Fradley, E., & Tuckey, M. (2002). Maternal mind–mindedness and attachment security as predictors of theory of mind understanding. *Child Development*, *73*(6), 1715–1726.

486 Meins, E., & Fernyhough, C. (1999). Linguistic acquisitional style and mentalising development: The role of maternal mind-mindedness. *Cognitive Development*, *14*(3), 363–380.

487 Bretherton, I., & Beeghly, M. (1982). Talking about internal states: The acquisition of an explicit theory of mind. *Developmental psychology*, *18*(6), 906.

488 Bartsch, K., & Wellman, H. M. (1995). *Children talk about the mind*. Oxford University Press.

489 Taumoepeau, M., & Ruffman, T. (2008). Stepping stones to others' minds: Maternal talk relates to child mental-state language and emotion understanding at 15, 24, and 33 months. *Child Development*, *79*(2), 284–302.

490 Brownell, C. A., Svetlova, M., Anderson, R., Nichols, S. R., & Drummond, J. (2013). Socialization of early prosocial behavior: Parents' talk about emotions is associated with sharing and helping in toddlers. *Infancy*, *18*(1), 91–119.

491 Newton, E. K., Thompson, R. A., & Goodman, M. (2016). Individual differences in toddlers' prosociality: Experiences in early relationships explain variability in prosocial behavior. *Child development*, *87*(6), 1715–1726.

492 Tompkins, V., Benigno, J. P., Kiger Lee, B., & Wright, B. M. (2018). The relation between parents' mental state talk and children's social understanding: A meta-analysis. *Social Development*, *27*(2), 223–246.

493 Hoff-Ginsberg, E. (1991). Mother-child conversation in different social classes and communicative settings. *Child Development*, *62*(4), 782–796.

494 Howe, N., Rinaldi, C., & Recchia, H. (2010). Patterns in mother–child internal state discourse across four contexts. *Merrill-Palmer Quarterly, 56*, 1–20.

495 Pavarini, G., de Hollanda Souza, D., & Hawk, C. K. (2013). Parental practices and theory of mind development. *Journal of Child and Family Studies*, *22*(6), 844–853.

These findings are consistent with other studies which have verified a relationship between parents' early use of mental-state terms (and cognitive references in particular) and children's later ToM understanding.[496,497,498] In this respect, findings suggest that the third year may be a particularly optimal time for mental-state conversations to take place, when children are first mastering their mental-state words.[499,500] Indeed, caregivers' use of cognitive verbs, such as *think* and *know* at age three is specifically associated with their children's performance on false-belief tasks at age six.[501]

Studies also find that the connectedness of caregiver's mental-state talk likely facilitates children's awareness of their own and others' thought processes. Connected mental-state talk involves conversations where someone's mental-state is provided as a reason for why someone did what they did.[502,503] Similarly, studies have found that collaborative caregiver-child interactions, such as turn taking and co-constructed play, also predict children's later false-belief understanding.[504]

Ages three to five

The vast majority of ToM research involves children between the ages of three and five, when false-belief understanding is first fully evident. While mind-minded caregiver behaviours and mental-state talk continue to predict children's ToM capabilities, studies find that other environmental factors also become influential during this time. These factors include the child's culture, the presence of siblings and the family's socioeconomic status (SES; as measured by family income, parental education and family affluence).[505,506]

Culture

Global studies observe that while children's performance on false-belief tasks improves dramatically between the ages of three and five, there are also notable cultural differences in the rate at which false-belief milestones are achieved.[507,508] Specifically, Australian children consistently reach their false-belief milestones first, followed by children living in Canada, mainland China, the US and then the UK. By comparison, children living in Japan and Hong Kong consistently lag behind other cultures by as much as two years. Studies additionally confirm differences in the sequence in which false-belief milestones are reached, with

496 Tompkins, V., Benigno, J. P., Kiger Lee, B., & Wright, B. M. (2018). The relation between parents' mental state talk and children's social understanding: A meta-analysis. *Social Development*, *27*(2), 223–246.

497 Pavarini, G., de Hollanda Souza, D., & Hawk, C. K. (2013). Parental practices and theory of mind development. *Journal of Child and Family Studies*, *22*(6), 844–853.

498 Hughes, C., & Devine, R. T. (2015). A Social Perspective on Theory of Mind. *Handbook of Child Psychology and Developmental Science. 3*(14), 1–46.

499 Jenkins, J. M., Turrell, S. L., Kogushi, Y., Lollis, S., & Ross, H. S. (2003). A longitudinal investigation of the dynamics of mental-state talk in families. *Child Development*, *74*(3), 905–920.

500 Shatz, M., Wellman, H. M., & Silber, S. (1983). The acquisition of mental verbs: A systematic investigation of the first reference to mental-state. *Cognition*, *14*(3), 301–321.

501 Adrián, J. E., Clemente, R. A., & Villanueva, L. (2007). Mothers' use of cognitive state verbs in picture-book reading and the development of children's understanding of mind: a longitudinal study. *Child development*, *78*(4), 1052–1067.

502 Slaughter, V., & Peterson, C. C. (2012). How conversational input shapes theory of mind development in infancy and early childhood. *Access to Language and Cognitive Development*, 3–22.

503 Ensor, R., & Hughes, C. (2008). Content or connectedness? Mother–child talk and early social understanding. *Child Development*, *79*(1), 201–216.

504 Sung, J., & Hsu, H. C. (2014). Collaborative mother–toddler communication and theory of mind development at age 4. *Journal of Applied Developmental Psychology*, *35*(5), 381–391.

505 Ruffman, T., Slade, L., Devitt, K., & Crowe, E. (2006). What mothers say and what they do: The relation between parenting, theory of mind, language and conflict/cooperation. *British Journal of Developmental Psychology*, *24*(1), 105–124.

506 Ruffman, T., Slade, L., & Crowe, E. (2002). The relation between children's and mothers' mental-state language and theory-of-mind understanding. *Child Development*, *73*(3), 734–751.

507 Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford University Press.

508 Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: the truth about false belief. *Child development*, *72*(3), 655–684.

children in mainland China and Iran consistently acquiring knowledge access (KA) before understanding diverse beliefs (DB).[509,510]

Why do these cultural differences exist? First, it is thought that cultural differences highlight the role language and social values play in the development of children's ToM.[511] In support of this argument, researchers observe that Mandarin parents living in mainland China place a high value on *knowing* over thinking, believing or having an opinion. Thus, young children are expected to know the correct way to tie their shoes, make their bed or recite well-known Chinese poems, and beliefs about these activities are de-emphasised. Similar practices have been observed in Iran, where children's knowledge of specific tasks is highly valued, but individual opinions and independent thought are actively discouraged. Researchers speculate that a cultural emphasis on knowledge accelerates children's awareness of what others know at the expense of appreciating differences in what others believe.

When it comes to Japanese children's seemingly delayed performance, researchers speculate that the Japanese culture's strong emphasis on social conventions may decrease children's awareness of differences in the thoughts and beliefs of others until later points of their development.[512] Nevertheless, the majority of Japanese children catch up to their western and mainland Chinese peers by the time they are seven or eight years old, suggesting that these differences are only temporary.

In sum, it is likely that culture contributes to the rate at which children acquire false-belief understanding during the preschool years. However, the implications for children's later understanding has yet to be fully understood, as typically developing children across the globe eventually acquire the same level of understanding. As we have observed previously, individual differences within cultures may nevertheless have meaningful developmental implications. Thus, understanding the nature of individual differences occurring within cultures remains important for knowing if and when early intervention might be necessary.

Siblings

Studies observe that within western societies, having a sibling may accelerate the rate at which preschoolers achieve ToM milestones by as much as six months.[513,514] It is assumed that siblings support ToM development by increasing opportunities for social interaction and sociodramatic play, although not all siblings are equal in this respect.[515,516] Specifically, studies find that more siblings are better than fewer siblings, and that effects are stronger when siblings are child age – that is, younger than 12 years, but greater than 12 months.[517,518]

509 Liu, D., Wellman, H. M., Tardif, T., & Sabbagh, M. A. (2008). Theory of mind development in Chinese children: a meta-analysis of false-belief understanding across cultures and languages. *Developmental Psychology*, *44*(2), 523–531.

510 Shahaeian, A., Peterson, C. C., Slaughter, V., & Wellman, H. M. (2011). Culture and the sequence of steps in theory of mind development. *Developmental Psychology*, *47*(5), 1239–1247.

511 Hughes, C., & Devine, R. T. (2015). A Social Perspective on Theory of Mind. *Handbook of Child Psychology and Developmental Science. 3*, *14*, 1–46.

512 Naito, M., & Koyama, K. (2006). The development of false-belief understanding in Japanese children: Delay and difference? *International Journal of Behavioral Development*, *30*(4), 290–304.

513 Dunn, J., Brown, J., & Beardsall, L. (1991). Family talk about feeling states and children's later understanding of others' emotions. *Developmental Psychology*, *27*(3), 448.

514 Perner, J., Ruffman, T., & Leekam, S. R. (1994). Theory of mind is contagious: You catch it from your sibs. *Child Development*, *65*(4), 1228–1238.

515 Lewis, C., Freeman, N. H., Kyriakidou, C., Maridaki-Kassotaki, K., & Berridge, D. M. (1996). Social influences on false belief access: specific sibling influences or general apprenticeship? *Child Development*, *67*(6), 2930–2947.

516 Peterson, C. C. (2000). Kindred spirits: Influences of siblings' perspectives on theory of mind. *Cognitive Development, 15,* 435–455.

517 McAlister, A., & Peterson, C. (2007). A longitudinal study of child siblings and theory of mind development. *Cognitive Development*, *22*(2), 258–270.

518 McAlister, A. R., & Peterson, C. C. (2013). Siblings, theory of mind, and executive functioning in children aged 3–6 years: New longitudinal evidence. *Child development*, *84*(4), 1442–1458.

Studies also find that having older siblings is better than having younger siblings.[519] Thus, having a twin sibling does not appear to accelerate false-belief understanding in the same way that having a sibling one or two years older does.[520]

Another interesting feature of the 'sibling effect' is that its benefits do not appear to be evident until children are at least three years old.[521] This may have to do with children's maturational readiness, including their verbal ability, as well as a potential need for a minimal amount of time for sibling benefits to become evident.[522] Regardless, it is likely that siblings support children's ToM development in ways that parents do not – not only through increased opportunities for pretend play, but also through teasing and blaming behaviours – which also draw attention towards others' mental states.[523,524,525]

Socioeconomic status

Much of the ToM research conducted to date has involved small samples of middle-class preschool children. However, a growing number of studies have verified a social gradient, with higher-income preschoolers consistently reaching false-belief milestones before lower-income peers.[526] A recent meta-analysis involving children between the ages of three and seven observed this association to be modest, but nevertheless significant after controlling for a variety of other child and parent influences, including children's verbal ability, family size, parental mind-mindedness and parental mental-state talk.[527] In addition, the influence of SES appeared to be stronger for older, rather than younger children.

Relatively few studies have directly considered the influences which might underpin the relationship between family income and false-belief understanding, although a number of processes have been proposed.[528] These processes include child language, which is highly associated with family income (see chapter 6), and parents' use of discipline, which is also consistently linked to family income and parenting stress.[529] A recent study comparing the relative value of both of these factors in predicting low-income children's ToM observed that child language was positively associated with ToM skills, while harsh discipline was negatively associated. However, when comparing the relative value of both influences, child language remained the only significant predictor.[530]

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519 Ruffman, T., Perner, J., Naito, M., Parkin, L., & Clements, W. A. (1998). Older (but not younger) siblings facilitate false belief understanding. *Developmental psychology*, *34*(1), 161.

520 Cassidy, K. W., Fineberg, D. S., Brown, K., & Perkins, A. (2005). Theory of mind may be contagious, but you don't catch it from your twin. *Child Development*, *76*(1), 97–106.

521 Ruffman, T., Perner, J., Naito, M., Parkin, L., & Clements, W. A. (1998). Older (but not younger) siblings facilitate false belief understanding. *Developmental psychology*, *34*(1), 161.

522 Jenkins, J. M., & Astington, J. W. (1996). Cognitive factors and family structure associated with theory of mind development in young children. *Developmental Psychology, 32*, 70–78.

523 Hughes, C., & Devine, R. T. (2015). A Social Perspective on Theory of Mind. *Handbook of Child Psychology and Developmental Science. 3*, *14*, 1–46.

524 Ruffman, T., Perner, J., & Parkin, L. (1999). How parenting style affects false belief understanding. *Social Development, 8,* 395–441.

525 Farrant, B. M., Devine, T. A. J., Maybery, M. T., & Fletcher, J. (2011). Empathy, perspective taking and prosocial behaviour: The importance of parenting practices. *Infant and Child Development, 21*, 175–188.

526 Cutting, A. L., & Dunn, J. (1999). Theory of mind, emotion understanding, language, and family background: Individual differences and interrelations. *Child development*, *70*(4), 853–865.

527 Devine, R. T., & Hughes, C. (2018). Family correlates of false belief understanding in early childhood: A meta-analysis. *Child development*, *89*(3), 971–987.

528 Pears, K. C., & Moses, L. J. (2003). Demographics, parenting, and theory of mind in preschool children. *Social Development*, *12*(1), 1–20.

529 Hughes, C., Deater-Deckard, K., & Cutting, A. L. (1999). 'Speak roughly to your little boy'? Sex Differences in the Relations Between Parenting and Preschoolers' Understanding of Mind. *Social Development*, *8*(2), 143–160.

530 Tompkins, V., Logan, J. A., Blosser, D. F., & Duffy, K. (2017). Child language and parent discipline mediate the relation between family income and false belief understanding. *Journal of Experimental Child Psychology*, *158*, 1–18.

4.6 How is children's theory of mind measured during the first five years?

As described in the beginning of this chapter, researchers traditionally assess children's ToM understanding through observational paradigms such as the Sally-Anne task and other activities outlined in table 4.3. These tasks are good for conducting research with children but are impractical for conducting individual assessments. This section provides a list of some of the more commonly used ToM measures, including those which are appropriate for assessing the risks associated with ASCs, ADHD and other related disorders.

TABLE 4.3
Commonly used measures of ToM for typically and atypically developing children

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Ages & Stages Questionnaire (ASQ-3)	The Ages & Stages Questionnaires®, Third Edition (ASQ-3™) assess children's developmental progress between the ages of one month to 5.5 years. It is a developmental screening tool designed for use by early educators and healthcare professionals. It relies on parents as experts. It takes 10–15 minutes for parents to complete and 2–3 minutes for professionals to score. It screens the following areas'communication, gross motor, fine motor, problem solving, and personal–social. Items from the communication domain have been assessed as appropriate for initial screening for autism.[1]	1 month to five years	Practitioner or parent	Screening	No	Ages & Stages
Ages & Stages Questionnaire – Social Emotional (ASQ-SE-2)	The ASQ-SE-2 was developed specifically to assess children's social and emotional problems, but there is preliminary evidence that it can effectively screen for symptoms of autism. Items consider a range of skills pertaining to children's self-regulation, compliance, social-communication, adaptive functioning, autonomy, affect, and interaction with people. It takes 15 minutes for the parent to complete and approximately three minutes to score.	1–72 months	Practitioner or parent	Screening	No	ASQ-SE-1
Bayley Scales of infant and toddler development, Third edition (The Bayley-III)	The Bayley-III examines all the facets of a young child's development. Children are assessed in the five key developmental domains of cognition, language, social-emotional, motor and adaptive behaviour. It can be used for children between 1 month and 42 months. It takes from 30 minutes to 90 minutes to complete (depending upon the age of child). Lower on the cognitive and language sections before 3.5 years have been found to be predictive of a diagnosis of an ASD at age four.[2]	1 to 42 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
The Denver Developmental Screening Test (Denver II)	The Denver II is used by healthcare providers to assess child development. It consists of 125 items (the DDST has 105) divided into four general areas of development: personal–social, fine motor-adaptive, language and gross motor. It screens for developmental delay. It is suitable for children aged 0 to 6 years. It takes from 20 to 60 minutes to complete depending on the stress tolerance of the child.	0 to 6 years	Practitioner	Screening	No	Hogrefe

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Checklist for Autism in Toddlers (CHAT)	The CHAT stands for The CHecklist for Autism in Toddlers and was developed to identify children who are at risk of developing social-communication disorders by assessing their pointing behaviours and ability to engage in pretend play.	18-month check	GP or health visitor	Diagnostic	No	Public Autism Awareness
The Parent Report of Children's Abilities (PARCA-R)	The PARCA-R is designed to identify preterm children who are at risk for developmental delay. It is used as a neurodevelopmental outcome measure in observational studies and clinical trials and as a screening tool in child development clinics. It takes no more than 15 minutes to complete.	Pre-term children aged 2 years	Parent	Screening	No	EPICURE
The Theory of Mind Inventory-2	The Theory of Mind Inventory-2 is a standardised assessment of children's theory of mind based upon parent-report and designed for use with children aged 2 years and above. The inventory consists of subscales which assess age-appropriate theory of mind abilities including gaze monitoring, joint attention, and social referencing (Early Subscale), metarepresentation, theory of mind-based action, seeing-leads-to-knowing, and false-belief understanding (Basic Subscale) and second-order false belief, sarcasm, and complex social judgment (Advanced Subscale). There is also an Emotion Recognition subscale designed to assess recognition of basic and complex emotions and ability to discriminate emotions; a Mental-state Term Comprehension subscale, which assesses understanding of terms such as 'want' and 'think' and 'know' and speech acts like 'promise', and a Pragmatics subscale, which assesses comprehension of idiomatic language, play on words, and audience adaptation.	Ages 2 or older	Parent	Diagnostic	Yes	Theory of Mind Inventory
Theory of Mind Story Books[3]	Theory of mind story books involves the use of an interactional story book, where children must complete 34 tasks involving children's understanding of a protagonist's emotional beliefs, desires and mental–physical distinctions. A trained practitioner facilitates the child's completion of the tasks for a period of 40 minutes to one hour.	3–6 years (normed to age 12)	Practitioner	Diagnostic	Yes	Publication explaining validity and use
Kaufman Assessment Battery for Children, Second Edition (KABC-II)	The Kaufman Assessment Battery for Children, Second Edition (KABC-II) measures cognitive ability and processing skills in children aged 3 years to 18 years. The following scales are included: sequential processing, simultaneous processing, learning ability, planning ability and knowledge. It takes 25 to 70 minutes to administer, depending on the model chosen.	3 years to 18 years	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
The Early Years Foundation Stage Profile (EYFSP)	The EYFS profile summarises and describes children's attainment at the end of the Early Years Foundation Stage. It assesses the child's attainment in relation to the 17 early learning goal descriptors and provides a short narrative describing the child's three characteristics of effective learning. The three prime areas of learning and development are: communication and language, physical development and personal, social and emotional development. The assessment takes place over time, primarily based on observation and interaction with the child in a range of contexts. The assessment should consider a range of perspectives, including those of the child, parents and other adults who have significant interactions with the child. The 'people and communities' section (ELG 13) and 'making relationships' (ELG 08) are particularly useful for understanding children's ToM capabilities. ToM related knowledge includes: - the child understands that other children do not always enjoy the same things and are sensistive to this (ELO 08) - the child can take account of other people's ideas and uses this knowledge to organise their activity (ELO 08).					

Notes:

1. Hardy, S., Haisley, L., Manning, C., & Fein, D. (2015). Can screening with the Ages and Stages Questionnaire detect autism?. *Journal of developmental and behavioral pediatrics: JDBP, 36*(7), 536.
2. Torras-Mañá, M., Gómez-Morales, A., González-Gimeno, I., Fornieles-Deu, A., & Brun-Gasca, C. (2016). Assessment of cognition and language in the early diagnosis of autism spectrum disorder: usefulness of the Bayley Scales of infant and toddler development. *Journal of Intellectual Disability Research, 60*(5), 502-511.
3. Bulgarelli, D., Testa, S., & Molina, P. (2015). Factorial structure of the 'ToM Storybooks': a test evaluating multiple components of theory of mind. *British Journal of Developmental Psychology, 33*(2), 187–202.

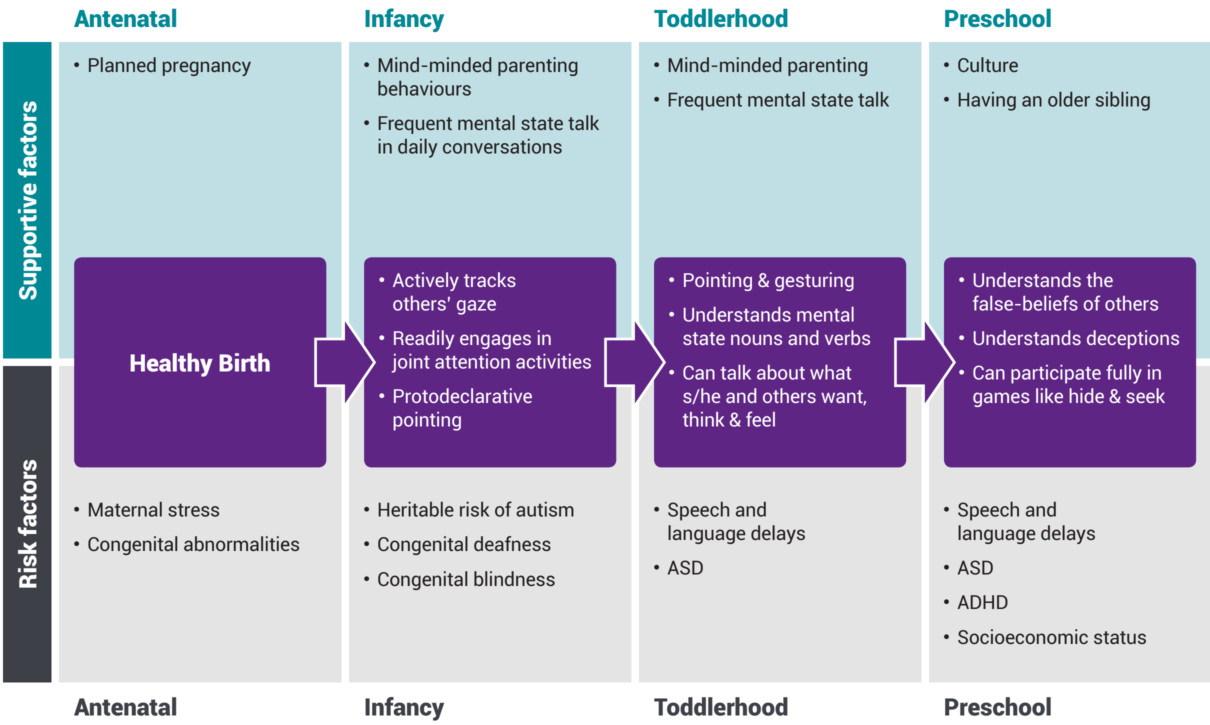
4.7 Implications for practice and commissioning

Summary of key messages

Figure 4.3 provides an overview of the developmental milestones in children's ToM understanding, as well as associated risk and supportive factors. More details regarding key ToM milestones and age-appropriate methods for assessing them are provided in table 4.4 at the end of this chapter.

FIGURE 4.3

Key competencies in children's ToM understanding and processes which support or interfere with typical ToM development



Source: EIF

Key messages: the antenatal period

- Twin studies offer conflicting messages about the heritability of ToM competencies, although the most recent evidence indicates that the child's environment likely plays a strong role in the development of ToM understanding.
- ToM impairments associated with autism and ADHD are nevertheless likely due to heritable processes which influence the development of the executive functions and children's language development.
- Heritable and antenatal factors associated with congenital deafness and congenital blindness may negatively impact children's ToM development, depending on how and when children with these impairments reach their other language and communication milestones.
- A planned pregnancy and positive obstetric history may be associated with children's ToM development, through its impact on parental mind-minded behaviours. In this respect, studies show that maternal mind-minded behaviours occurring during infancy and toddlerhood predict improved ToM capabilities when children are in preschool and early primary school.

- ToM risks associated with the antenatal period include complications during pregnancy, (as described in chapter 3), as well as family history of ASC and whether or not the pregnancy was planned.

Key messages: infancy

- The majority of infants are born with competencies sufficient for them to develop an understanding of the intentions and feelings of others. These competencies include a preference for human faces, higher-pitched vocal tones and the ability to track moving objects.
- By three months, most infants can follow the gaze of others and differentiate basic emotional states, such as happy and sad.
- By nine months, most infants can share attention with their caregivers or others towards an object or event.
- At nine months, most infants are aware that they can communicate and share emotions with others.
- The protodeclarative point is believed to be indicative of the infant's awareness that he or she can share intentions and emotions with others, as well as gain knowledge from them. Children typically begin to point at objects some time around nine months.
- The extent to which individual differences in protodeclarative pointing and other ToM-related behaviours during infancy predict ToM competencies in later development has yet to be fully investigated. However, delays in these capabilities are frequently indicative of autism and other related disorders, so require further assessment.
- Factors occurring in infancy known to predict later ToM competencies include the extent to which the child's caregivers engage in 'mind-minded' behaviours. Mind-minded behaviours include empathic verbal construals of the infant's feelings or thoughts.

Key messages: toddlerhood

- Behaviours thought to be associated with the development of ToM during the child's second year include the mastery of mental-state words and engaging in conversations about the feelings, desires and wishes of others.
- Spontaneous acts of altruism are also indicative of toddlers' awareness of the feelings of others.
- Sometime during the third year, many toddlers are able to accurately anticipate what others might be thinking and the ways in which thoughts and behaviours are associated.
- Factors thought to influence toddlers' ToM understanding include mind-minded parenting behaviours and the frequency in which parents engage in mental-state conversations with their toddlers.
- Mental-state conversations occur less frequently during parent–child book reading activities and more frequently during parent–child object play.
- Child-level signals of risk include language delays, as well as difficulties showing empathy and engaging in shared attention activities.

Key messages: ages three to five

- Between the ages of three and five, children become increasingly able to predict the false beliefs of others. This capability develops in a predictable sequence.
- Most four-year-olds are also able to talk about complex mental processes, such as concentrating, planning, understanding and having an idea.

- By the age of four, children are increasingly more able to deliberately lie and may actively try to manipulate others' thoughts.
- Sociodramatic play is thought to be indicative of children's awareness of differences in the mental states of others.
- Culture predicts the rate at which children progress through false-belief milestones between the ages of three and five, although it is likely that culture is influential before this time.
- High levels of mental-state talk within the child's home continues to predict children's ToM understanding between the ages of three and five. Sources of mental-state talk include parents and siblings.
- Family SES is associated with the rate at which preschool children pass through ToM milestones.
- Child-level signals of risk include delays in children's false-belief understanding, symptoms associated with ADHD and language difficulties.
- Family-level signals of risk include low SES.

What are the implications for early intervention?

Research involving the development of children's ToM is relatively new in comparison to the other competencies described in this review. This means that many of the factors that support early ToM development have yet to be fully understood. Nevertheless, the findings described in this chapter have implications for early interventions that can be offered at the universal, targeted-selective and targeted-indicated level which we describe here.

Universal

Individual differences in children's ToM understanding begin to emerge between the ages of three and five and these are predictive of children's later academic success. This makes children's ToM a valuable target for early intervention. One clear message arising from the research literature is the important role caregiver mental-state talk plays in facilitating young children's understanding of others' thoughts, intentions and beliefs. As a result, **activities which encourage parents and other caregivers to use more mental-state talk with children will likely support the development of children's theory of mind.** Moreover, mental-state talk occurring from the second year onwards – coincident with children's initial language acquisition – is likely to be particularly beneficial. In this respect, studies show that mental-state talk is more likely to occur spontaneously during caregiver–child object play than it does during book sharing and other parent–child activities. **Parents and other caregivers should therefore be made aware of the value of object play for facilitating children's ToM understanding.**

Targeted-selective

The findings summarised in this chapter indicate **that children between the ages of three and five may benefit from school curriculums with content emphasising others' mental states.** While all children might benefit from this training, preliminary evidence shows that it may specifically reduce SES-related gaps if offered to low-income families at the targeted-selective level.[531] Examples of potentially effective interventions for low-income families include teacher-led book reading activities that emphasise the protagonist's feelings and false beliefs.[532] The majority of these interventions are intended to be delivered in preschool settings, with studies showing they are most effective when delivered to children individually

531 Tompkins, V. (2015). Improving low-income preschoolers' theory of mind: A training study. *Cognitive development*, *36*, 1–19.

532 Guajardo, N. R., & Watson, A. C. (2002). Narrative discourse and theory of mind development. *The Journal of Genetic Psychology*, *163*(3), 305–325.

during short, one-to-one sessions occurring over a period of five weeks.[533] Other examples of preschool-based training activities include activities involving false-belief tasks where children receive corrective feedback, videos with themes which promote children's false-belief understanding and sociodramatic play coached by teachers to encourage mental-state awareness.[534,535,536]

The extent to which many ToM activities could be described as 'evidence-based' remains unclear, however. Although a recent systematic review observed that various interventions appeared to accelerate children's false-belief understanding, the strength of the evidence underpinning these models was not directly considered. In many cases, it is clear that the evidence is still quite preliminary, as studies frequently involve extremely small samples or make use of biased evaluation designs. Thus, further evaluation is necessary before many ToM interventions could be considered 'evidence-based'.

It is worth noting, however, that several classroom-based interventions on the EIF guidebook contain content relevant for children's ToM understanding. These interventions include the Incredible Years Child Training (Dinosaur School),[537] which includes content aimed at increasing preschool children's awareness of the feelings and desires of others, as well as the PATHS Preschool/Kindergarten programme, which similarly aims to increase children's understanding of others' emotional states.[538] While neither of these programmes has specific evidence of accelerating children's false-belief understanding (as measured via the milestones summarised in figure 4.2), they do have good evidence (EIF level 3+) of improving children's understanding of emotions and prosocial behaviour.

Targeted-indicated

The findings reviewed in this chapter have implications for identifying children where there are concerns about ASC. Difficulties following the gaze of others or failing to engage in joint attention activities may suggest the presence of an ASC already in the child's first year, and these can be effectively screened for with the communications section of the ASQ-3 already during the child's first year.[539] The recently developed Ages and Stages Social Emotional scales (ASQ-SE-2) also has preliminary evidence of being effective for screening for autism. Other tools useful for screening for ASC include the Checklist for Autism in Toddlers (CHAT) and the Bayley Scales of Infant and Toddler Development.[540,541] Further details about early ASC treatment and referral can be found in the NICE clinical guidance 128.[542]

The EIF Guidebook also provides the details of various forms of the Triple P Stepping Stones Programme, which targets families with learning disabilities, including those with ASC.[543] The Stepping Stones model has good evidence of improving the behavior of children with serious learning disabilities. However, the majority of this evidence involves children aged

533 Tompkins, V. (2015). Improving low-income preschoolers' theory of mind: A training study. *Cognitive development*, *36*, 1–19.

534 Kloo, D., & Perner, J. (2003). Training transfer between card sorting and false belief understanding: Helping children apply conflicting descriptions. *Child Development*, *74*(6), 1823–1839.

535 Qu, L., Shen, P., Chee, Y. Y., & Chen, L. (2015). Teachers' Theory-of-mind Coaching and Children's Executive Function Predict the Training Effect of Sociodramatic Play on Children's Theory of Mind. *Social Development*, *24*(4), 716–733.

536 Gola, A. (2012). Mental verb input for promoting children's theory of mind: A training study. *Cognitive Development*, *27*, 64–76.

537 See: **https://guidebook.eif.org.uk/programme/incredible-years-child-training-dinosaur-school**

538 See: **https://guidebook.eif.org.uk/programme/paths-preschool-kindergarten-curriculum**

539 Hardy, S., Haisley, L., Manning, C., & Fein, D. (2015). Can screening with the Ages and Stages Questionnaire detect autism? *Journal of developmental and behavioral pediatrics: JDBP*, *36*(7), 536.

540 Baron-Cohen, S., Wheelwright, S., Cox, A., Baird, G., Charman, T., Swettenham, J., ... & Doehring, P. (2000). Early identification of autism by the Checklist for Autism in Toddlers (CHAT). *Journal of the royal society of medicine*, *93*(10), 521–525.

541 Torras-Mañá, M., Gómez-Morales, A., González-Gimeno, I., Fornieles-Deu, A., & Brun-Gasca, C. (2016). Assessment of cognition and language in the early diagnosis of autism spectrum disorder: usefulness of the Bayley Scales of infant and toddler development. *Journal of Intellectual Disability Research*, *60*(5), 502–511.

542 See: **https://www.nice.org.uk/guidance/cg128**

543 See: **https://guidebook.eif.org.uk/programme/selected-seminars-stepping-stones-triple-p**

five or older, and the extent to which children with ASC specifically benefit has not been explicitly reported.

Further recommendations about how this information might be used to inform commissioning decisions and improve the quality of childcare and nursery are provided at the end of this report.

TABLE 4.4

Developmental competencies – associated risks and methods of assessing children's theory of mind

Age	Developmental competency	Manifestation/context	Factors which make a difference	Assessment
0–12 months	A preference for faces and female voices Can actively track moving objects By three months, infants can track others' gaze At nine months, infants begin to participate in joint attention activities; start to use protodeclarative pointing	Parent–child interaction Triadic play activities Joint attention activities	Inherited factors associated with ASD Parental mind-mindedness Congenital deafness Congenital blindness	ASQ-3 ASQ-SE-2 BSID
12–24 months	Altruisitic behaviours Pointing and gesturing Understands the nouns and verbs associated with desires, emotion and perception	Parent–child interaction Pretend play Joint attention activities Conversations about desires, emotions and past events Story book reading	Parental mind-mindedness Mental-state talk involving feelings, desires and emotions Speech and language delay	ASQ-3 ASQ-SE-2 BSID CHAT
24–36 months	Engages in conversations about mental states, including what other people think and know	Play Parent–child interaction Play with siblings Story book reading	Parental mind-mindedness Mental-state talk involving cognitive states Speech and language delay	ASQ-3 ASQ-SE-2 The Theory of Mind Inventory
36–60 months	Understanding of false belief in terms of differences in desires, beliefs and emotions Sociodramatic play	Play Social awareness at school and with peers	Culture Mental-state talk involving cognitive states SES ADHD Older, child-age siblings Diagnosis of ADHD	ASQ-3 ASQ-SE-2 The Theory of Mind Inventory Theory of Mind Story Books The Kaufman ABC

5. Children's theory of numbers

5.1 What is it?

Understanding numbers and number relationships is a central component of everyday functioning. It would indeed be difficult to follow a recipe, keep an appointment or read a bank statement without some basic understanding of numbers and number relationships. These skills also underpin advances in science and technology and are therefore highly valued within societies and the workforce. For example, the entry level salary for those graduating with a maths-related degree (such as engineering or computer sciences) is typically 40% higher than salaries offered to those graduating with degrees in the humanities, education or the fine arts.[544]

Children's numerical development is currently conceptualised by many researchers as the deepening awareness of magnitude – in other words, the ability to understand concepts of more and less with increasing precision.[545] At birth, infants can discriminate imprecise differences in magnitude through their perceptual capabilities. By contrast, adults make highly precise discriminations of magnitude through their knowledge of numbers and sophisticated mathematical calculations. This gradual shift in numerical understanding is supported by four numerical processes which develop in succession throughout childhood:

1. **Non-symbolic mental representations of magnitude.** This process is supported by two nonverbal systems:[546]
   - The approximate number system (ANS), which allows humans to discriminate differences in size and amount.[547] At six months, infants can discriminate ratios of one to two. By six years, this precision has increased to ratios of 5 to 6 (see figure 5.1).[548]
   - The precise number system (PNS; also referred to as the object tracking system (OTS) or object file system (OFS)) which allows humans the ability to rapidly and precisely recognise quantities of small numbers without counting (also referred to as subitising).[549] Infants as young as five months can accurately detect differences in quantity involving three items or less; adults can recognise up to five.
2. **The ability to link nonsymbolic representations of magnitude to symbols and words.** This capability allows children to link mental representations of magnitude to symbolic number words. Most children learn the words and symbols associated with numbers during their second and third years. However, children typically do not associate numerical symbols with specific amounts (also referred to as numerosities, see box 5.1) until the fourth or fifth year.[550]

544 de Vries, R. (2014). Earning by Degrees: Differences in the career outcomes of UK graduates. The Sutton Trust. Available: https://www.suttontrust.com/wp-content/uploads/2014/12/Earnings-by-Degrees-REPORT.pdf

545 Siegler, R. S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental science*, *19*(3), 341–361.

546 Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in cognitive sciences*, *8*(7), 307–314.

547 Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants' choice of more: Object files versus analog magnitudes. *Psychological Science*, *13*(2), 150–156.

548 Siegler, R. S., & Lortie-Forgues, H. (2014). An integrative theory of numerical development. *Child Development Perspectives*, *8*(3), 144–150.

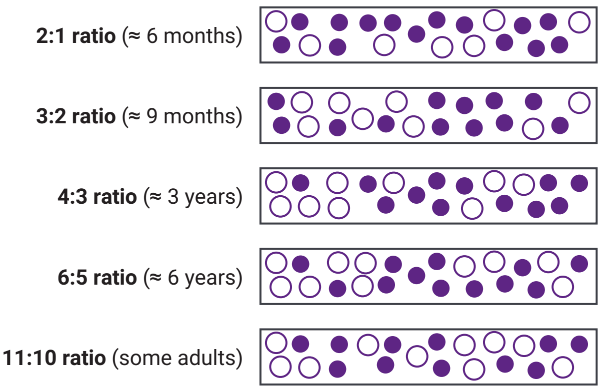
549 Van Loosbroek, E., & Smitsman, A. W. (1990). Visual perception of numerosity in infancy. *Developmental Psychology*, *26*(6), 916.

550 Van Loosbroek, E., & Smitsman, A. W. (1990). Visual perception of numerosity in infancy. *Developmental Psychology*, *26*(6), 916.

3. **Extending the range of whole numbers that can be accurately represented.** Throughout primary school, children become increasingly better at discriminating differences in numerosity involving whole numbers of 100 or more.[551] At age five, most children can accurately position numbers on a number line bounded by the values 1 and 10. By age 12, most children can accurately position numbers on a number line with values ranging from 0 to 1,000.
4. **Representing numbers other than whole numbers, including fractions, decimals and negative numbers.** Most children begin to understand fractions, decimals and negative values by the time they enter secondary school. For many, this knowledge does not come easy, requiring hours of practice and explicit instruction. Studies show that the mental demands required to understand fractions are much higher than those required for understanding relative values involving whole numbers.[552]

FIGURE 5.1

Development of the nonsymbolic magnitude discrimination precision throughout childhood



Source: Reproduced from Siegler, R. S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental science*, *19*(3), 341–361.

Each one of these processes underpins a wide range of cognitive skills associated with children's understanding of numbers and mathematics. These skills include the ability to count, perform arithmetic, measure size and volume and understand geometric relationships. This chapter considers the ways in which these skills develop during the first five years.

Box 5.1: Numeracy or numerosity?

The term numeracy is commonly used to describe one's ability to understand and work with numbers. Numerosity, by comparison, is a term used by developmental psychologists to refer an amount that exists as a conceptual property independent of a specific group of objects. While it is possible to see five objects, hear five sounds, or have five appointments in your diary, numerosity pertains to the abstract representation of the concept of five which exists independently of any of these number sets.[553]

[551] Friso-van den Bos, I., Kroesbergen, E. H., Van Luit, J. E., Xenidou-Dervou, I., Jonkman, L. M., Van der Schoot, M., & Van Lieshout, E. C. (2015). Longitudinal development of number line estimation and mathematics performance in primary school children. *Journal of Experimental Child Psychology*, *134*, 12–29.

[552] DeWolf, M., Grounds, M. A., Bassok, M., & Holyoak, K. J. (2014). Magnitude comparison with different types of rational numbers. *Journal of Experimental Psychology: Human Perception and Performance*, *40*(1), 71.

[553] Butterworth, B. (2005). The development of arithmetic abilities. *Journal of Child Psychology and Psychiatry, 46*(1), 3–18.

5.2 What other competencies are associated with the development of children's understanding of number and mathematics?

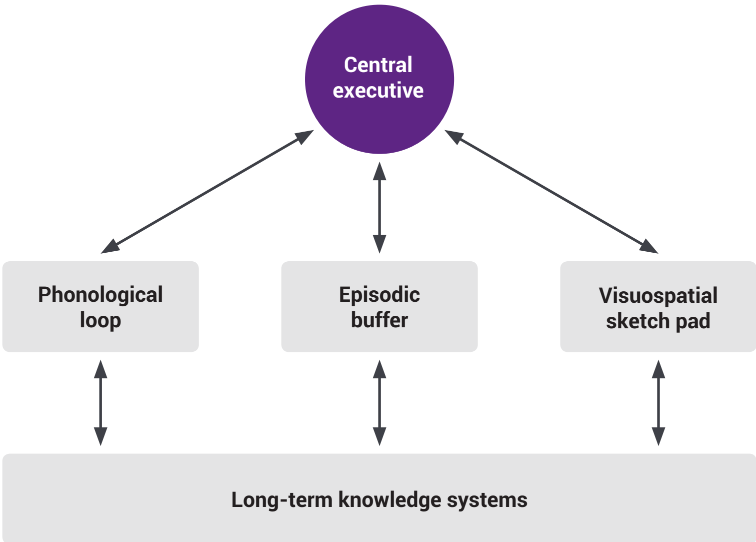
A wide variety of competencies are associated with children's numerical understanding. These competencies include the executive functions, children's verbal ability, their fine motor skills and feelings towards maths (for example, maths anxiety).[554,555] While the relative contribution of these competencies for predicting children's understanding of number is not yet fully understood, three competencies are particularly influential during the early years: the executive functions, verbal ability and early fine motor development.[556]

Working memory

The executive functions (see box 2.3), and working memory in particular, are believed to underpin all aspects of children's numerical understanding.[557,558,559,560] Working memory involves the retrieval of information from the long-term memory so that it can be combined with perceptual information and information retained in the short-term memory. Working memory is therefore in constant use but is especially relevant for problem-solving and decision-making. Working memory is commonly understood to operate through four separate subsystems, as illustrated in figure 5.2.[561]

FIGURE 5.2

Baddeley-Hitch model of working memory



Source: Reproduced from Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417–422.

[554] Goswami, U. (2008). *Cognitive Development: The Learning Brain*. Hove, East Sussex: Psychology Press.

[555] Moore, A. M., Rudig, N. O., & Ashcraft, M. H. (2014). Affect, motivation, working memory, and mathematics. In Kadosh, R. C., & Dowker, A. (eds), *The Oxford handbook of numerical cognition*. Oxford: Oxford University Press.

[556] Cirino, P. T. (2011). The interrelationships of mathematical precursors in kindergarten. *Journal of Experimental Child Psychology*, *108*(4), 713–733.

[557] Purpura, D. J., Schmitt, S. A., & Ganley, C. M. (2017). Foundations of mathematics and literacy: The role of executive functioning components. *Journal of Experimental Child Psychology*, *153*, 15–34.

[558] Friso-van den Bos, I., van der Ven, S. H., Kroesbergen, E. H., & van Luit, J. E. (2013). Working memory and mathematics in primary school children: A meta-analysis. *Educational research review*, *10*, 29–44.

[559] Peng, P., Namkung, J., Barnes, M., & Sun, C. (2016). A meta-analysis of mathematics and working memory: Moderating effects of working memory domain, type of mathematics skill, and sample characteristics. *Journal of Educational Psychology*, *108*(4), 455.

[560] Chu, F. W., vanMarle, K., & Geary, D. C. (2016). Predicting children's reading and mathematics achievement from early quantitative knowledge and domain-general cognitive abilities. *Frontiers in Psychology*, *7*, 775.

[561] Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*, 417–422.

The first of these is the **central executive**, which identifies and makes salient information which is most relevant, while at the same time suppressing information which is irrelevant. For example, driving and having a conversation at the same time is relatively straightforward when one knows how to drive and is familiar with the route. However, having a conversation becomes more difficult when the route is unfamiliar or hazardous factors become apparent. In these instances, an efficient central executive will automatically increase the salience of the hazardous or unknown factors and decrease the salience of the conversation.

Researchers speculate that the central executive is instrumental in helping children identify relevant information during numerical problem-solving tasks.[562] It is also assumed that the central executive is also responsible for supervising and coordinating information managed by three specialist, or 'slave', subsystems which process information on an active, short-term basis:

- The **phonological loop** stores and processes verbal representations associated with language. Verbal representations decay rapidly, however, so the phonological loop is constantly updating itself through the form of an inner speech which literally rehearses verbal information as it is being processed. The phonological loop is believed to support children's counting capabilities and number vocabulary.[563]
- The **visuospatial sketch pad** processes and stores visual and spatial information used in navigation and object recognition. The visuospatial sketch pad is used in visual assessments of magnitude, subitising and recognition of number symbols.[564,565,566]
- The **episodic buffer** receives perceptual information and integrates it with information from the visuospatial sketch pad and the phonological loop. The episodic buffer also serves as the go-between for the central executive and long-term memory. Information processed through the working memory is then combined into episodic chunks which may or may not be stored in the long-term memory.

Studies confirm that these working memory subsystems are functional by the time children are four years old.[567,568] While it is likely that the central executive plays a critical role in all tasks, the relative contribution of the audio and visual subsystems likely shift, depending on the child's age and the demands of the task.[569,570,571,572] For example, word problems are commonly used to assess children's numerical understanding in grades 2 through 4, thereby placing greater demands on the phonological loop. In later grades, numerical capabilities are

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562 Geary, D., Hoard, M,, Byrd-Craven, J., & DeSoto, M. (2004). Strategy choices in simple and complex addition: Contributions of working memory and counting knowledge for children with mathematical disability. *Journal of Experimental Child Psychology, 88,* 121–151

563 Furst, A., & Hitch, G. J. (2000). Separate roles for executive and phonological components in mental arithmetic. *Memory and Cognition, 28*, 774–782.

564 Kyttälä, M., Aunio, P., Lehto, J. E., Van Luit, J., & Hautamäki, J. (2003). Visuospatial working memory and early numeracy. *Educational and Child Psychology*, *20*(3), 65–76.

565 Reuhkala, M. (2001). Mathematical skills in ninth-graders: Relationship with visuo-spatial abilities and working memory. *Educational Psychology, 21*(4), 387–399.

566 Dehaene, S., Spelke, E., Pinel, P., Stanescu, R., & Tsivkin S. (1999). Sources of mathematical thinking: Behavioral and brain imaging evidence. *Science, 284,* 970–974.

567 Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177.

568 Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? *Child Development*, *77*(6), 1698–1716.

569 Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Hamlett, C. L., Seethaler, P. M., ... & Schatschneider, C. (2010). Do different types of school mathematics development depend on different constellations of numerical versus general cognitive abilities? *Developmental Psychology*, *46*(6), 1731.

570 Fuchs, L. S., Geary, D. C., Compton, D. L., Fuchs, D., Hamlett, C. L., & Bryant, J. D. (2010). The contributions of numerosity and domain-general abilities to school readiness. *Child Development*, *81*(5), 1520–1533.

571 Simmons, F. R., Willis, C., & Adams, A. M. (2012). Different components of working memory have different relationships with different mathematical skills. *Journal of Experimental Child Psychology*, *111*(2), 139–155.

572 Alloway, T. P., & Passolunghi, M. C. (2011). The relationship between working memory, IQ, and mathematical skills in children. *Learning and Individual Differences*, *21*(1), 133–137.

more frequently assessed through pen and paper exercises involving fractions, which creates greater visuospatial demands.[573,574] Studies also suggest that the visuospatial sketchpad may be particularly relevant during preschool.[575,576] For example, visual memory at age two has been found to predict children's magnitude discrimination capabilities at age six.[577]

Language

In chapter 6, we describe in detail the transformative role language plays in supporting children's cognitive understanding during early development.[578] As mentioned at the beginning of this chapter, learning the verbal and visual symbols associated with numbers is an important milestone in children's numerical understanding and is strongly predictive of their mathematical achievement at school.[579,580]

The acquisition of language is thought to facilitate children's numerical understanding in several important ways. First, the learning of plural words places an emphasis on values greater than one and the difference between numerosities. The learning of number words also highlights the conceptual features of value that exist independently of any specific array of objects – two dogs, two chairs, two cars, and so on.[581] Children's knowledge about number, in turn, is influenced by children's exposure to number words and their ability to process language. For example, a study involving profoundly deaf Nicaraguan adults lacking number vocabulary observed that they were unable to count past four or replicate a given number of objects using a set of tokens beyond three objects.[582] So, having a verbal 'count list' or sequence of numbers appears to be crucial for counting and understanding the cardinal principles associated with number names (see following sections).

It is also likely that verbal ability influences the efficiency of the working memory. A key function of the working memory is to retrieve and process information stored in the long-term memory. Some therefore argue that the efficiency of the working memory is, in part, contingent on the quality of the information available to it.[583,584] Few studies have directly compared the relative contribution of language and working memory on children's early numerical understanding, however. The findings from those that have done so indicate that language and working memory likely interact with children's numerical understanding in unique and specific

573 Martin, R. B., Cirino, P. T., Sharp, C., & Barnes, M. (2014). Number and counting skills in kindergarten as predictors of grade 1 mathematical skills. *Learning and individual differences*, *34*, 12–23.

574 Li, Y., & Geary, D. C. (2013). Developmental gains in visuospatial memory predict gains in mathematics achievement. *PloS One*, *8*(7), e70160.

575 Meyer, M. L., Salimpoor, V. N., Wu, S. S., Geary, D. C., & Menon, V. (2010). Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. *Learning and Individual Differences*, *20*(2), 101–109.

576 De Smedt, B., Janssen, R., Bouwens, K., Verschaffel, L., Boets, B., & Ghesquière, P. (2009). Working memory and individual differences in mathematics achievement: A longitudinal study from first grade to second grade. *Journal of Experimental Child Psychology*, *103*(2), 186–201.

577 Mulder, H., Verhagen, J., Van der Ven, S. H., Slot, P. L., & Leseman, P. P. (2017). Early Executive Function at Age Two Predicts Emergent Mathematics and Literacy at Age Five. *Frontiers in Psychology*, *8*, 1706.

578 Spelke, E. S. (2017). Core knowledge, language, and number. *Language Learning and Development*, *13*(2), 147–170.

579 Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental psychology*, *45*(3), 850.

580 Jordan, N. C. (2010). Early predictors of mathematics achievement and mathematics learning difficulties. http://www.child-encyclopedia.com/sites/default/files/dossiers-complets/en/numeracy.pdf#page=11

581 Xu, F. (2007). Sortal concepts, object individuation, and language. *Trends in Cognitive Sciences*, *11*(9), 400–406.

582 Spaepen, E., Coppola, M., Spelke, E. S., Carey, S. E., and Goldin-Meadow, S. (2011). Number without a language model. *Proceedings of the National Academy of Sciences, 22* (108).

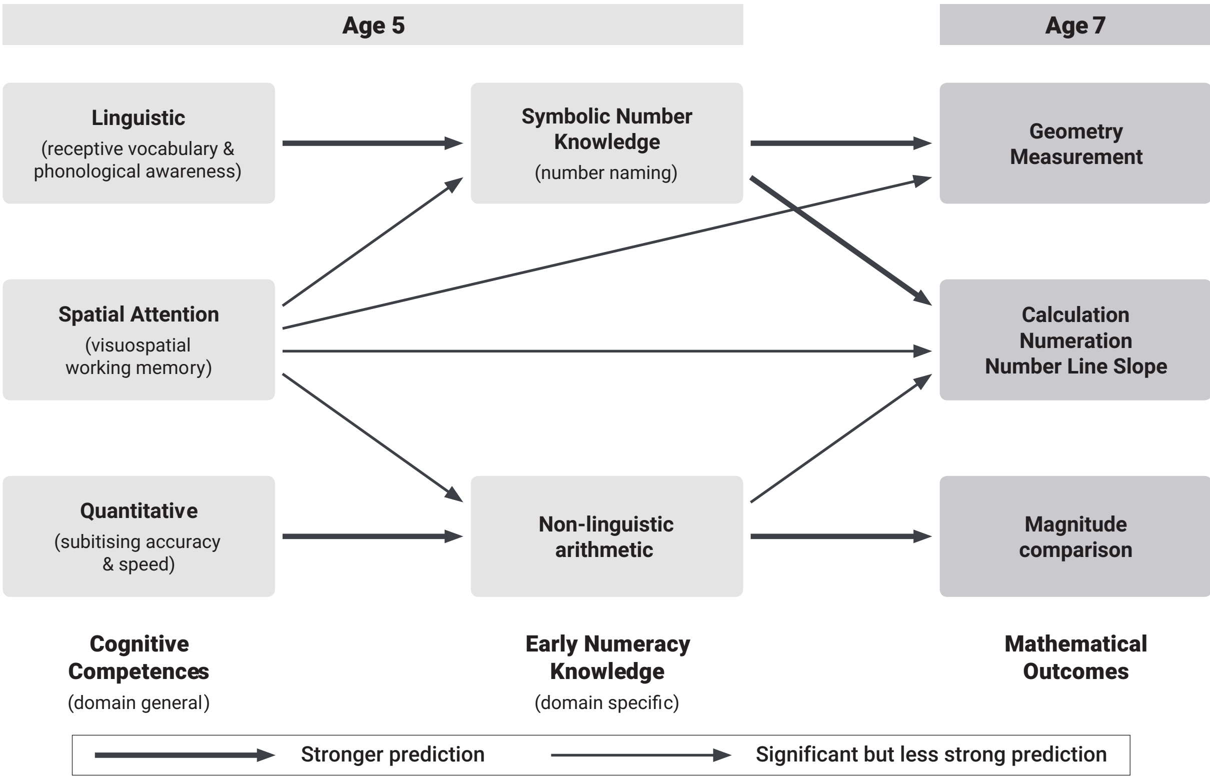
583 Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition*, *162*, 12–26.

584 Geary, D. C., Nicholas, A., Li, Y., & Sun, J. (2017). Developmental change in the influence of domain-general abilities and domain-specific knowledge on mathematics achievement: An eight-year longitudinal study. *Journal of Educational Psychology, 109*(5), 680–693.

ways.[585,586,587,588,589] The model in figure 5.3 summarises findings from a 2010 Canadian study observing multiple pathways involving the language, spatial and numerical capabilities of five-year-olds in predicting their performance on mathematical tests two years later.

FIGURE 5.3

Potential pathways in children's early numerical development



Source: Reproduced from LeFevre, J. A., Fast, L., Skwarchuk, S. L., Smith-Chant, B. L., Bisanz, J., Kamawar, D., & Penner-Wilger, M. (2010). Pathways to mathematics: Longitudinal predictors of performance. *Child Development*, *81*(6), 1753–1767.

In particular, the study observed:

- Verbal ability was concurrently associated with preschool children's symbolic number knowledge (understanding of the Arabic numerals and number names). Symbolic number knowledge, in turn, predicted children's mathematical performance on all tasks at age seven, but most strongly predicted their understanding of numeration.
- Preschool visuospatial working memory concurrently predicted children's understanding of non-linguistic arithmetic and symbolic number knowledge at age five. Visuospatial working memory at age five also predicted children's performance on all mathematical tasks at age seven, with the exception of magnitude comparison tasks.

585 Merkley, R., & Ansari, D. (2016). Why numerical symbols count in the development of mathematical skills: Evidence from brain and behavior. *Current Opinion in Behavioral Sciences*, *10*, 14–20.

586 Purpura, D. J., & Logan, J. A. (2015). The nonlinear relations of the approximate number system and mathematical language to early mathematics development. *Developmental Psychology*, *51*(12), 1717.

587 Hornung, C., Schiltz, C., Brunner, M., & Martin, R. (2014). Predicting first-grade mathematics achievement: the contributions of domain-general cognitive abilities, nonverbal number sense, and early number competence. *Frontiers in Psychology*, *5*, 272.

588 Rousselle, L., & Noël, M. P. (2008). The development of automatic numerosity processing in preschoolers: evidence for numerosity-perceptual interference. *Developmental Psychology*, *44*(2), 544.

589 Soto-Calvo, E., Simmons, F. R., Willis, C., & Adams, A. M. (2015). Identifying the cognitive predictors of early counting and calculation skills: Evidence from a longitudinal study. *Journal of Experimental Child Psychology*, *140*, 16–37.

- Preschool quantitative understanding at age five, as measured by their subitising accuracy and speed, was concurrently associated with their nonlinguistic knowledge of arithmetic during preschool. Nonlinguistic understanding of arithmetic, in turn, predicted children's performance on a variety of mathematical tasks at age seven. Specifically, nonlinguistic understanding strongly predicted children's performance on magnitude comparison tasks, but weakly predicted performance on calculation, numeration and number line tasks. The importance of these relationships for children's early numerical learning will be discussed at later points in this chapter.

Motor skills

Studies consistently observe an association between children's early fine motor skills and preschool numerical capabilities, especially when it comes to their ability to count.[590] Researchers speculate that this association may be explained by the fact that children often represent numerosities with their fingers. Fine motor skills also facilitate the procedural counting of objects which, in turn, is believed to support children's conceptual knowledge of the counting principles.[591] Fine motor activities such as writing and sorting additionally provide children with opportunities to practise and consolidate their visual recognition of Arabic symbols and their spatial awareness of magnitude.[592,593] Some also assume that the link between fine motor skills and numerical understanding is underpinned by the executive functions, although recent investigations suggest that fine motor skills predict children's early achievement independently of executive function capabilities.[594,595]

5.3 How does children's early understanding of number impact their development over time?

Studies consistently show that children's early numerical understanding is strongly associated with their later mathematical achievement. Mathematical achievement, in turn, is one of the strongest predictors of children's overall academic success throughout primary and secondary school. For example, a 2007 cross-national study combining data sets from six large-scale cohort studies found that children's numerical knowledge upon entry to primary school was the strongest predictor of academic achievement in comparison to a variety of other important capabilities, including their literacy skills and behavioural self-regulation.[596] These findings have since been replicated in a number of large-scale studies, with research additionally confirming a link between early numerical understanding and adult income.[597,598] For example, a recent analysis of the US National Child Development Study observed that mathematics and reading achievement at age seven were the strongest

590 Suggate, S., Stoeger, H., & Fischer, U. (2017). Finger-Based Numerical Skills Link Fine Motor Skills to Numerical Development in Preschoolers. *Perceptual and motor skills*, *124*(6), 1085–1106.

591 Fischer, U., Suggate, S. P., Schmirl, J., & Stoeger, H. (2018). Counting on fine motor skills: links between preschool finger dexterity and numerical skills. *Developmental science*, *21*(4), e12623..

592 Becker, D. R., Miao, A., Duncan, R., & McClelland, M. M. (2014). Behavioral self-regulation and executive function both predict visuomotor skills and early academic achievement. *Early Childhood Research Quarterly*, *29*(4), 411–424.

593 Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, *83*, 1229–1244.

594 Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child development*, *83*(4), 1229–1244.

595 Schmidt, M., Egger, F., Benzing, V., Jäger, K., Conzelmann, A., Roebers, C. M., & Pesce, C. (2017). Disentangling the relationship between children's motor ability, ecxecutive function and academic achievement. *PloS one*, *12*(8), e0182845.

596 Duncan, Greg J., Chantelle J. Dowsett, Amy Claessens, Katherine Magnuson, Aletha C. Huston, Pamela Klebanov, Linda S. Pagani et al. (2007). School readiness and later achievement. *Developmental psychology, 43*(6), 1428.

597 Romano, E., Babchishin, L., Pagani, L. S., & Kohen, D. (2010). School readiness and later achievement: replication and extension using a nationwide Canadian survey. *Developmental Psychology*, *46*(5), 995.

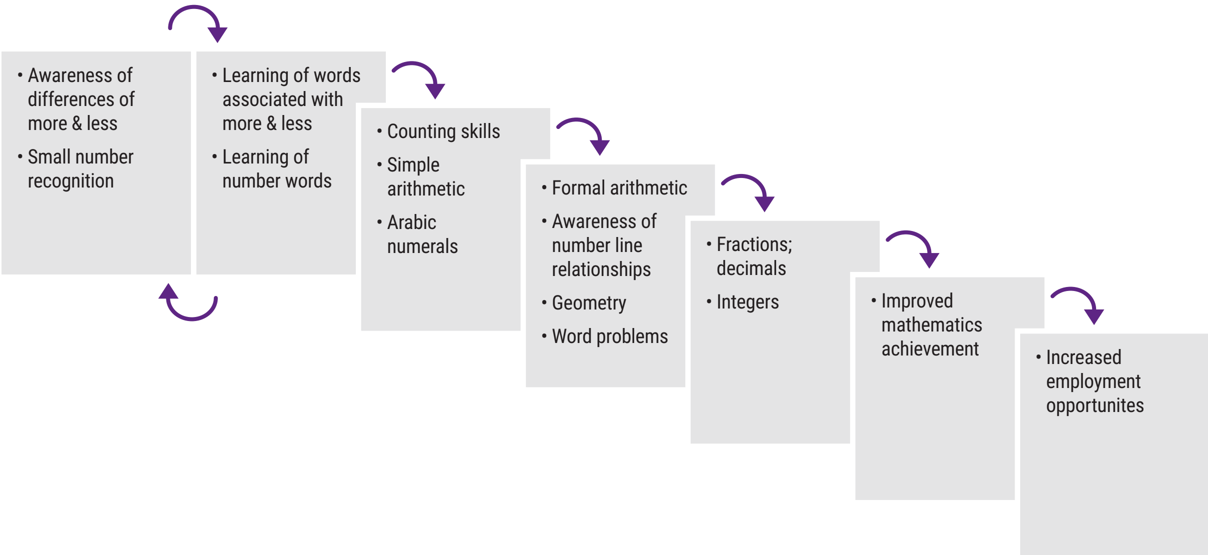
598 Murnane, R. J., Willett, J. B., & Levy, F. (1995). *The growing importance of cognitive skills in wage determination* (No. w5076). National Bureau of Economic Research.

predictors of socioeconomic status (SES) at age 42, after statistically controlling for a wide range of other factors, including SES at birth and intelligence during secondary school.[599]

These longitudinal relationships, combined with some of the developmental trends discussed in earlier sections, suggest a trajectory of developmental competencies which contribute to children's numerical understanding over time.[600] As illustrated in figure 5.4, children's numerical understanding begins with the ability to discriminate differences between more and less. This understanding is then reinforced as children begin to learn their number words, usually in the second year of life. Awareness of the number words, in parallel with improved working memory capabilities, in turn predict children's counting capabilities and understanding of Arabic symbols at ages four and five.

FIGURE 5.4

Developmental cascades in the development of children's numerical understanding



Source: EIF

Studies further show that counting and Arabic symbol recognition are highly predictive of children's mathematical achievement once children enter primary school. Primary school mathematical achievement (alongside working memory), in turn, predicts children's understanding of fractions and integers in early secondary school. Mastery of these abstract mathematical concepts thus ultimately determines children's mathematical achievement in secondary school, as well as their numerical capabilities in higher education and the workforce.

It is therefore clear that children's early numerical understanding is associated with positive life outcomes. However, questions remain about the nature of these associations. For example, are these relationships primarily driven by a core set of numerical competencies? Or do other important capabilities, not measured in the above studies (such as working memory), also significantly contribute? Additionally, when are individual differences in children's early numerical capabilities first evident and to what extent are they influenced by environmental factors, such as the home learning environment and enriching preschool education?

599 Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science*, *24*(7), 1301–1308

600 Purpura, D. J., Baroody, A. J., & Lonigan, C. J. (2013). The transition from informal to formal mathematical knowledge: Mediation by numeral knowledge. *Journal of Educational Psychology*, *105*(2), 453.

A primary aim of the remainder of this chapter is to shed light on these issues as they pertain to the early years. However, several developmental trends are worth highlighting at this point:

1. There is good evidence showing that general capabilities, including working memory and other related competencies, support children's understanding of numerical concepts and performance on mathematical tests at all points of their development.[601,602,603] General capabilities appear to be particularly predictive of children's numerical understanding during the early years, but remain important throughout primary and secondary school.[604,605]
2. Individual differences in a specific set of quantitative capabilities (such as magnitude discrimination, precise number recognition) are present during the preschool years and are predictive of children's numerical understanding throughout primary and secondary school.[606,607,608,609] Studies indicate that these differences are independent of differences in children's working memory, and increase in magnitude throughout primary and secondary school, thereby reflecting the cumulative effects of previous numerical competencies.[610,611]
3. Third, a number of environmental factors are consistently associated with individual differences in children's early numerical understanding.[612,613,614] These environmental factors include the quality of the home learning environment, but also enriching mathematic curriculums provided during preschool and early primary school.

We now describe in more detail the ways in which children's numerical competencies develop during the first five years of life and the factors which support them or place them at developmental risk.

601 Gilligan, K. A., Flouri, E., & Farran, E. K. (2017). The contribution of spatial ability to mathematics achievement in middle childhood. *Journal of experimental child psychology*, *163*, 107–125.

602 Martin, R. B., Cirino, P. T., Sharp, C., & Barnes, M. (2014). Number and counting skills in kindergarten as predictors of grade 1 mathematical skills. *Learning and individual differences*, *34*, 12–23.

603 Gilmore, C. K., Keeble, S., Richardson, S., & Cragg, L. (2017). The interaction of procedural skill, conceptual understanding and working memory in early mathematics achievement. *Journal of Numerical Cognition, 3*(2), 400–416.

604 Östergren, R., & Träff, U. (2013). Early number knowledge and cognitive ability affect early arithmetic ability. *Journal of Experimental Child Psychology*, *115*(3), 405–421.

605 Geary, D. C., Nicholas, A., Li, Y., & Sun, J. (2017). Developmental change in the influence of domain-general abilities and domain-specific knowledge on mathematics achievement: An eight-year longitudinal study. *Journal of Educational Psychology, 109*(5), 680–693.

606 Chu, F. W., & Geary, D. C. (2015). Early numerical foundations of young children's mathematical development. *Journal of Experimental Child Psychology*, *132*, 205–212.

607 Nguyen, T., Watts, T. W., Duncan, G. J., Clements, D. H., Sarama, J. S., Wolfe, C., & Spitler, M. E. (2016). Which preschool mathematics competencies are most predictive of fifth grade achievement? *Early Childhood Research Quarterly*, *36*, 550–560.

608 Nanu, C. E., McMullen, J., Munck, P., Hannula-Sormunen, M. M., & Pipari Study Group. (2018). Spontaneous focusing on numerosity in preschool as a predictor of mathematical skills and knowledge in the fifth grade. *Journal of experimental child psychology*, *169*, 42–58.

609 Halberda, J., Mazzocco, M. M., & Feigenson, L. (2008). Individual differences in non-verbal number acuity correlate with maths achievement. *Nature*, *455*(7213), 665.

610 Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher*, *43*(7), 352–360.

611 Geary, D. C., Nicholas, A., Li, Y., & Sun, J. (2017). Developmental change in the influence of domain-general abilities and domain-specific knowledge on mathematics achievement: An eight-year longitudinal study. *Journal of Educational Psychology, 109*(5), 680–693.

612 Rittle-Johnson, B., Fyfe, E. R., Hofer, K. G., & Farran, D. C. (2017). Early Math Trajectories: Low-Income Children's Mathematics Knowledge From Ages 4 to 11. *Child Development*, *88*(5), 1727–1742.

613 Siegler, R. S. (2016). Continuity and change in the field of cognitive development and in the perspectives of one cognitive developmentalist. *Child Development Perspectives*, *10*(2), 128–133.

614 Jordan, N. C., Kaplan, D., Nabors Oláh, L., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development*, *77*(1), 153–175.

5.4 How does children's understanding of number develop during the first five years of life?

Preschool children's understanding of number involves the following capabilities:

- the ability to distinguish differences in magnitude
- the ability to subitise – that is, to precisely discriminate differences within small numbers sets with values less than five
- knowing the verbal and visual symbols for whole number values
- the ability to count accurately
- a conceptual understanding of cardinal and ordinal relationships
- the ability to understand arithmetic principles and perform basic calculations.

The first two competencies are thought to be already present at birth, and mature with relatively little instruction.[615] However, the learning of numerical symbols requires social guidance and increasingly more instruction as children grow older.[616] This section describes how these processes develop during the child's first five years.

Infancy (0–12 months)

It is widely assumed that humans and many animals are born with an innate sense of number.[617] Support for this assumption comes from studies observing that species as varied as fish, chickens and primates all discriminate differences of more and less during the very early stages of life.[618,619] For example, guppies have been trained to discriminate groups of dots in ratios of two to one to obtain a food reward already within a few hours of birth.[620]

As described in section 5.1, there is broad consensus that animals and preverbal infants use two perceptual systems to make judgements about magnitude and numerosity.

- An approximate number system (ANS) that allows humans and animals to detect differences in magnitude. The ANS operates under Weber's law, meaning that the ability to detect changes in magnitude is reliant on the ratio of change. Differences are therefore easier detect at higher ratios with lower numbers, than lower ratios with higher numbers. For example, a change from 5 to 10 is easier to perceive than a change from 45 to 50.
- A precise number system (PNS) that allows humans to immediately recognise if there are one, two, three or four items within small sets.[621,622] This is also referred to as perceptual subitising and permits a rapid and precise understanding of number, but has a hard capacity limit of three items in young children and five in adults. Amounts greater than five are difficult for humans to distinguish without either counting them or breaking them into separate groups. For example, humans identify six dots on a die as '6', by subconsciously breaking them down into two groups of three. This is known as conceptual subitising and is thought to underpin the learning of counting and arithmetic.

615 Siegler, R. S., & Braithwaite, D. W. (2017). Numerical development. *Annual Review of Psychology*, *68*, 187–213.

616 Siegler, R. S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental Science*, *19*(3), 341–361.

617 Brannon, E. M. (2006). The representation of numerical magnitude. *Current opinion in neurobiology*, *16*(2), 222–229.

618 Dehaene, S. (2011). *The number sense: How the mind creates mathematics*. OUP USA.

619 Rugani, R., Vallortigara, G., Priftis, K., & Regolin, L. (2015). Number-space mapping in the newborn chick resembles humans' mental number line. *Science*, *347*(6221), 534–536.

620 Piffer, L., Petrazzini, M. E. M., & Agrillo, C. (2013). Large number discrimination in newborn fish. *PLoS One*, *8*(4), e62466.

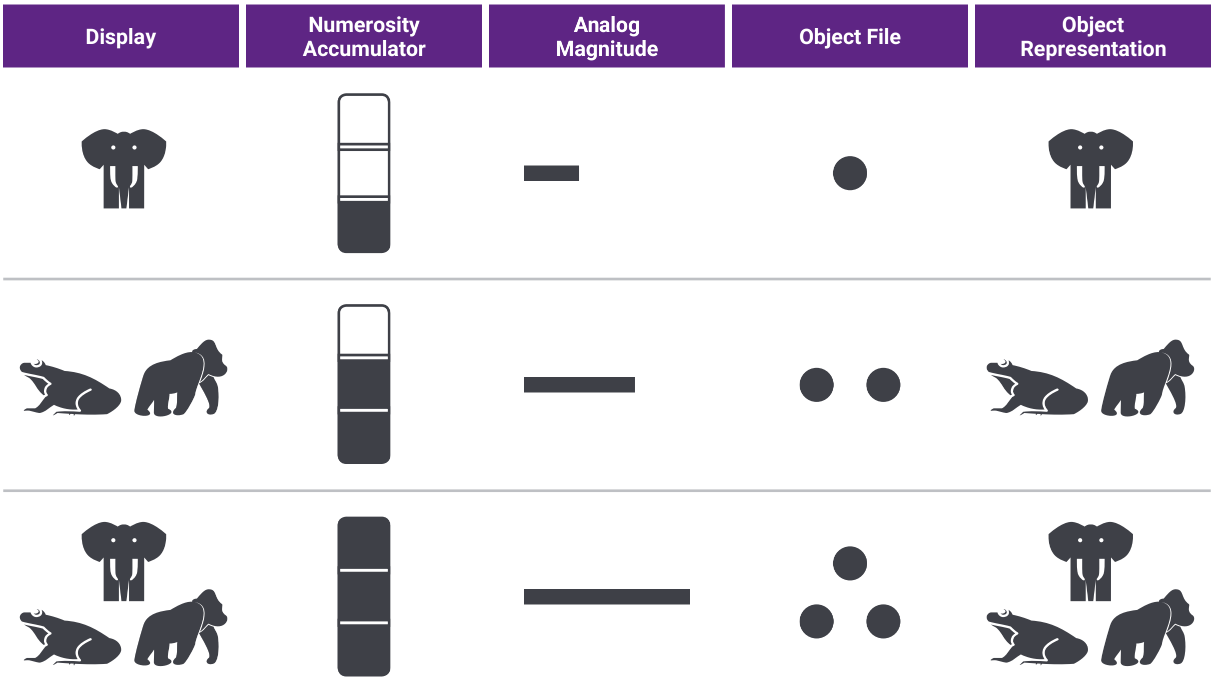
621 Feigenson, L. & Carey, S. (2003). Tracking individuals via object files: evidence from infants' manual search. *Developmental Science, 6*(5):568–584.

622 Ross-Sheehy S., Oakes L., Luck S. J. (2003). The development of visual short-term memory capacity in infants. *Child Development, 74*, 1807–1822.

Researchers speculate that the ANS and PNS operate through processes that count or 'accumulate' perceptual units of stimulation (objects, sounds, episodes) and represent them mentally as an end size which is then compared to stored representations of magnitude.[623,624] Analogies for how ANS and PNS 'accumulators' might work are provided in figure 5.5.[625]

FIGURE 5.5

'Accumulator' mechanisms underlying infants' and young children's understanding of number



Source: Reproduced from Geary, D. C. (2006). Development of mathematical understanding. In *Handbook of child psychology. Vol. 4 Conceptual Understanding and Achievements*

It is assumed that the ANS accumulator operates similarly to a mental measuring cup or analogue number line which can accurately represent magnitude in small amounts but lose precision with higher amounts. The PNS mechanism, by contrast, contains mental representations of one to four whole objects but does not provide any mechanism for comparison to higher amounts. This information initially exists in the form of specific representations of the objects but becomes increasingly more abstract as children develop.

Both the ANS and PNS permit a precise understanding of number in numerosities involving amounts of four or less. At higher values, however, the PNS is no longer functional and the ANS increasingly loses its precision.[626,627] Habituation studies (see box 3.1 in chapter 3) suggest that already within days of birth, infants can make ANS magnitude discriminations at very low ratios of one to three.[628,629] However, the degree to which infants are reliably

623 ibid.

624 Meck, W. H., & Church, R. M. (1983). A mode control model of counting and timing processes. *Journal of Experimental Psychology: Animal Behavior Processes*, *9*(3), 320–334.

625 Geary, D. C. (2006). Development of mathematical understanding. In *Handbook of child psychology*. *Vol. 4 Conceptual Understanding and Achievements.*

626 Dahaene, S. (2001) Precis of the number sense. *Mind and language, 16*, 16–36.

627 Whalen, J., Gallistel, C. R., & Gelman, R. (1999). Nonverbal counting in humans: The psychophysics of number representation. *Psychological Science*, *10*(2), 130–137.

628 Izard, V., Sann, C., Spelke, E. S., & Streri, A. (2009). Newborn infants perceive abstract numbers. *Proceedings of the National Academy of Sciences*, *106*(25), 10382–10385.

629 Coubart, A., Izard, V., Spelke, E. S., Marie, J., & Streri, A. (2014). Dissociation between small and large numerosities in newborn infants. *Developmental Science*, *17*(1), 11–22.

detecting differences in *numerical* magnitude (differences in the number of dots) versus differences in *continuous* magnitude (that is, changes in the surface area covered), remains unclear.[630]

By six months, infants reliably discriminate magnitude differences in ratios of 1:2 and at nine months in ratios of 2:3.[631,632,633,634] Children's magnitude discrimination then continues to increase in precision until adulthood, when ratios as small as 10:11 can be detected.[635] Although much of this research is conducted with visual stimuli, studies show that infants distinguish differences in magnitude across a variety of stimuli, including auditory tones and episodic sequences, such as a puppet jumping.[636,637]

Infants are also capable of making PNS discriminations between sets of one, two and three items, although the extent to which the PNS exists as a system separate from the ANS at the time of birth remains debated.[638] Studies have found that newborns can discriminate differences in small number sets when the smallest number is 2, but not 1, therefore suggesting that the PNS has not yet fully developed.[639,640] Infants can, however, make these discriminations by the time they are five months.[641]

Infants also appear to be capable of addition and subtraction within small sets by the time they are four to six months old. Specifically, infants express surprise during violation of expectation (VOE) tasks (see chapter 3) when dolls progressively hidden behind a screen differ from what is ultimately revealed.[642] Some researchers interpret this to mean that infants understand the rudimentary principles of addition and subtraction, whereas others argue that the infants are simply noticing differences in the amount of 'stuff' that is visible.[643]

Initially, PNS representations are restricted to mental images of the actual items – that is, two dolls are mentally represented as two dolls. By the end of the first year, however, infant representations of number appear to become increasingly abstracted from the physical dimensions of objects. For example, studies observe that six-month-old infants habituate to numerical similarities between diverse forms of sensory input – three tones are perceived to correspond with three objects or three episodes.[644] Researchers interpret these findings to mean that infants have a representation of the numerosity of 'three' which exists across the different modalities. Studies similarly show that 10-month-old infants match similarities

630 Leibovich, T., Katzin, N., Harel, M., & Henik, A. (2017). From 'sense of number' to 'sense of magnitude': The role of continuous magnitudes in numerical cognition. *Behavioral and Brain Sciences*, *40*.

631 Lipton, J. S., & Spelke, E. S. (2004). Discrimination of large and small numerosities by human infants. *Infancy*, *5*(3), 271–290.

632 Xu, F. (2003). Numerosity discrimination in infants: Evidence for two systems of representations. *Cognition*, *89*(1), B15–B25.

633 Brannon, E. M., Abbott, S., & Lutz, D. J. (2004). Number bias for the discrimination of large visual sets in infancy. *Cognition*, *93*(2), B59–B68.

634 Lipton, J. S., & Spelke, E. S. (2003). Origins of number sense: Large-number discrimination in human infants. *Psychological science*, *14*(5), 396–401.

635 Halberda, J., & Feigenson, L. (2008). Developmental change in the acuity of the 'Number Sense': The Approximate Number System in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental psychology*, *44*(5), 1457.

636 Wood, J. N., & Spelke, E. S. (2005). Infants' enumeration of actions: Numerical discrimination and its signature limits. *Developmental science*, *8*(2), 173–181.

637 Lipton, J. S., & Spelke, E. S. (2003). Origins of number sense: Large-number discrimination in human infants. *Psychological science*, *14*(5), 396–401.

638 Posid, T., & Cordes, S. (2015). The small–large divide: a case of incompatible numerical representations in infancy. In *Mathematical Cognition and Learning* (Vol. 1, pp. 253–276). Elsevier.

639 Coubart, A., Izard, V., Spelke, E. S., Marie, J., & Streri, A. (2014). Dissociation between small and large numerosities in newborn infants. *Developmental Science*, *17*(1), 11–22.

640 Antell, S. E., & Keating, D. P. (1983). Perception of numerical invariance in neonates. *Child Development, 54,* 695–701.

641 Van Loosbroek, E., & Smitsman, A. W. (1990). Visual perception of numerosity in infancy. *Developmental Psychology*, *26*(6), 916.

642 Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, *358*(6389), 749–750.

643 Mix, K. S., Huttenlocher, J., & Levine, S. C. (2002). Multiple cues for quantification in infancy: Is number one of them? *Psychological Bulletin*, *128*(2), 278.

644 Starkey, P., Spelke, E. S., & Gelman, R. (1990). Numerical abstraction by human infants. *Cognition*, *36*(2), 97–127.

in magnitude across space, number and time.[645] It is believed that this level of abstraction is necessary for children to learn the linguistic symbols associated with numbers, which begins in their second year.

Children's representations of magnitude are also thought to be informed by their understanding of ordinal relationships – that is, the extent to which values can be ordered by size. Studies show that by seven months, infants can identify when ordered sequences of visual arrays reverse from small to large, or large to small, independently of changes in magnitude.[646,647] By this time, most infants also demonstrate a clear preference for left-to-right magnitude ordering, which is believed to be a precursor of the left-to-right canonical organisation of number lines thought to inform adult representations of magnitude.[648]

Toddlerhood (12–36 months)

Children's symbolic understanding of numbers begins with the acquisition of language. As described in chapter 6, children rapidly learn the names of many words during their second year. At 20 or so months, most children understand the phrase 'all gone' and can also correctly apply the word 'one' in a variety of settings (such as pick out one sock from a pile, give everyone in the room one cookie, etc.).[649] Some studies also report children as young as 18 months being able to recognise some Arabic numerals.[650]

By 22 months, most children understand that plural words refer to more than one item and that determiners, such as 'a', 'this', 'that' and 'some' refer to item amounts.[651,652] Interestingly, studies show that children exposed to languages with plural markers (such as English and Russian) learn the word 'two' more quickly than children exposed to languages lacking plural markers (such as Chinese and Japanese).[653,654] At 30 months, many children also implicitly recognise when sets of small objects are 'more than', 'less than' or 'the same' as each other, although it is unlikely that they understand the meaning of the phrase 'more than'.[655] Children may also understand that the words two, three, four or higher involve distinct number values greater than one, although it is not likely that they will be able to apply them accurately when attempting to count.[656,657] Many children also learn the sequence of number names during the third year and will learn to accurately recite this sequence to 10 or higher.[658]

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645 Lourenco, S. F., & Longo, M. R. (2010). General magnitude representation in human infants. *Psychological Science*, *21*(6), 873–881.

646 Brannon, E. M. (2002). The development of ordinal numerical knowledge in infancy. *Cognition*, *83*(3), 223–240.

647 Picozzi, M., de Hevia, M. D., Girelli, L., & Cassia, V. M. (2010). Seven-month-olds detect ordinal numerical relationships within temporal sequences. *Journal of Experimental Child Psychology*, *107*(3), 359–367.

648 de Hevia, M. D., Girelli, L., Addabbo, M., & Cassia, V. M. (2014). Human infants' preference for left-to-right oriented increasing numerical sequences. *PloS one*, *9*(5), e96412.

649 Potter, M. C., & Levy, E. I. (1968). Spatial enumeration without counting. *Child Development*, *39*, 265–272.

650 Mix, K. S. (2009). How Spencer made number: First uses of the number words. *Journal of Experimental Child Psychology*, *102*(4), 427–444.

651 Barner, D., Thalwitz, D., Wood, J., Yang, S. J., & Carey, S. (2007). On the relation between the acquisition of singular–plural morpho-syntax and the conceptual distinction between one and more than one. *Developmental Science*, *10*(3), 365–373.

652 Soja, N. N., Carey, S., & Spelke, E. S. (1991). Ontological categories guide young children's inductions of word meaning: Object terms and substance terms. *Cognition*, *38*(2), 179–211.

653 Sarnecka, B. W., Kamenskaya, V. G., Yamana, Y., Ogura, T., & Yudovina, J. B. (2007). From grammatical number to exact numbers: early meanings of one, 'two,' and three in English, Russian, and Japanese. *Cognitive Psychology, 55*, 136–168.

654 Li, X., Sun, Y., Baroody, A. J., & Purpura, D. J. (2013). The effect of language on Chinese and American 2- and 3-year olds' small number identification. *European Journal of Psychology of Education, 28*, 1525–1542.

655 Bullock, M., & Gelman, R. (1977). Numerical reasoning in young children: The ordering principle. *Child Development, 48,* 427–434.

656 Slusser, E., Ditta, A., & Sarnecka, B. (2013). Connecting numbers to discrete quantification: A step in the child's construction of integer concepts. *Cognition*, *129*(1), 31–41.

657 Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive psychology*, *24*(2), 220–251.

658 Fuson, K. C. (1991). Children's early counting: Saying the number-word sequence, counting objects, and understanding cardinality. *Language in mathematical education: Research and practice*, 27–39.

Despite these capabilities, the two-year-old's understanding of counting is relatively superficial in comparison to older children. For example, studies suggest that young children often believe the sequence 'onetwothreefourfive' is just one big word.[659] Two-year-olds also frequently misapply the number sequence when attempting to count objects – either skipping numbers or double counting them. Although two-year-olds often understand that the words two, three and four refer to numerosities, they have yet to understand the specific numerosities the numbers correspond to (see box 5.2).[660] This is because many two-year-olds do not yet understand that number words refer to cardinal values – in other words, that the word 'three' refers to a set of three things. Hence, the two-year-old's understanding of number words is still separate from his or her ability to perceptually discriminate differences in magnitude and numerosity.[661,662]

Box 5.2: The Give-N Task

Children between the ages of two and three often know the names of numbers and can recite them in order, but this does not mean that they can accurately count out small sets of numbers. However, over time, children come to know the relationship between number words and numerosity values.

The task most commonly used to assess children's 'knower level' is the give-N task. The give-N task typically begins with children receiving a pile of items. A researcher or puppet then asks the child if he or she can give them a certain number of items (for example, can you please give Cookie Monster two cookies?).

Children as young as age two are often capable of giving one item when asked to provide only one. However, those who are not yet two 'knowers' will frequently just grab a pile of toys, thus showing they understand the numerosity requested is more than one, but do not know the specific value it corresponds with. Hence, two-year-olds are typically 'grabbers,' usually not progressing through the knower levels until they are at least three if not older.

Sometime late in the third year, the child begins to understand that number words correspond with specific values of four or less.[663] It is likely that this mapping occurs as a function of the PNS, as the child learns to match values to small sets of numbers retained in his or her short-term memory. This is a relatively slow process in comparison to the mastery of other words, taking place one number at a time over a period lasting between five months and a year.[664] At first, children are 'one-knowers' who can correctly apply the word one to single entities. Children then become 'two-knowers' who understand that the word two refers to two entities. Eventually, children become 'three knowers,' followed by 'four knowers.' However, children then do not go onto become exclusive 'five knowers'. At this point, most children will *conceptually* understand that the cardinal principle applies to numerosities of five or higher

659 Fuson, K.C. (1992). Relationships between counting and cardinality from age 2 to 8. In J. Bideaud, C. Meljac, & J.P. Fisher (Eds.), *Pathways to number, children's developing numerical abilities.* Hillsdale, NJ: LEA.

660 Wynn, K. (1990). Children's understanding of counting.*Cognition, 36,* 155–193.

661 Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24*(2), 220–251.

662 Wynn, K. (1995). Origins of numerical knowledge*. Mathematical Cognition, 1*, 35–60.

663 Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24*(2), 220–251.

664 Sarnecka, B. W., & Lee, M. D. (2009). Levels of number knowledge during early childhood. *Journal of Experimental Child Psychology*, *103*(3), 325–337.

and correctly apply the number words when counting all numerosities.[665] Children typically do not have this conceptual understanding, however, until the middle of their fifth year when they have fully mastered the counting principles, as described in the next section.

Ages three to five

Learning to count

During their third year, most children come to understand that number words refer to quantities and that counting is an activity that occurs in a sequence. However, to fully understand the value of counting, children must also recognise that number words are associated with specific numerosities. This conceptual understanding of cardinality is the first of five counting principles that children implicitly master between the ages of three to five:[666]

1. **The one-to-one principle** refers to children's understanding that one, and only one, distinct counting word can be assigned to each item to be counted. The child must thus recognise two categories of objects: those that have been tagged with a number name and those that have not. If an item is not tagged with a number name or is tagged with more than one number name, the resulting count will be incorrect. Most two-year-olds implicitly understand that one and only one number name can apply to a single item. However, two-year-olds often skip items or double count because of pointing inaccuracies.
2. **The stable order principle** refers to the child's understanding of the conventional number sequence. In order to master this, the child must (1) know the number vocabulary (that is, a child will not be able to count to seven unless he or she knows the number seven); (2) know the order of this vocabulary; and (3) understand that this sequence applies to the activity of counting. As described in the previous section, children frequently learn to do this by rote and many can 'count' up to 10 or higher by accurately reciting the numbers in the correct sequence. Children can also recognise mistakes in this sequence when others do not adhere to it.
3. **The cardinal principle** refers to the child's understanding that the final number name allocated to the last counted object refers to a numerical total if the one-to-one and stable-order principles have been followed. In other words, the child understands that the final number not only signals the end of the count but reveals how many objects have been counted – that is, the numerosity of the object set.
4. **The abstraction principle** refers to the understanding that the 'how-to-count' principles can be applied to non-tangible things, including ideas, events and sounds (*I've already told you five times!*).
5. **The order-irrelevance principle** refers to children's recognition that items can be counted in any order to arrive at the same numerosity. It therefore does not matter if counting begins from left to right, in the middle, of from the top, just as long as every item in the set is counted once and only once.

Table 5.1 summarises approximate age-related changes in children's mastery of the counting principles. Principles 1–3 are described as 'how-to-count' principles as they apply to the activity of counting. The remaining two are 'what-to-count' principles, as they pertain to what can be counted.

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665 Le Corre, M., & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. *Cognition*, *105*(2), 395–438.

666 Gelman, R., & Gallistel, C. R. (1978). *The child's understanding of number.* Cambridge, MA: Harvard University Press.

TABLE 5.1

Age-related capabilities in preschool children's mastery of the counting principles (ages are approximate)

Task	Age 2	Age 3	Age 4
How-to-count principles			
One-to-one principle	Will likely understand that one number applies to one item, although will inadvertently skip items or double count.	Accuracy in counting improves, although is not always 100%.	Is fully mastered in sets of five or less.
Stable order principle	Children know that number words are used for counting and apply to numerosities. Counting is sequential, but numbers maybe skipped (1, 2, 5, 7, 11).[1]	Children are typically able to accurately and consistently apply the stable order when counting within set sizes of five or less.	Children are progressively able to accurately count sets of numbers of five or more at increasingly higher numbers.
The cardinal principle	Children do not appear to understand that specific numbers over one apply to specific amounts, although gradually understand the numerosities associated with numbers one through four.	Children can accurately apply the principle within sets of five or less, depending on their 'knower' level.	Children can apply the cardinal principle when counting out sets greater than four.
What-to-count principles			
The abstraction principle	Children understand that objects, sounds and episodes can be counted, although are often not able to count them correctly.[2]	Children understand that collections of diverse objects can nevertheless be equivalent in number. For example, a set of four apples and a set of four oranges are similar in that both sets have four.	Children are able to apply sets within groups of objects and count them accurately. For example, they can count only apples in a collection of fruit, dinosaurs in a collection of toy animals, and so on. They are also able to perform addition and subtraction within small sets.
The order irrelevance principle		Children can understand that order is irrelevant but is more likely to make counting errors when reordering items.	Children can accurately count a large number of items, but always need to start at the beginning and in the same order.

Notes
1. Gelman, R., & Gallistel, C. R. (1978). *The child's understanding of number.* Cambridge, MA: Harvard University Press.
2. Wynn, K. (1990). Children's understanding of counting. *Cognition, 36,* 155–193.

Studies find that most children will have mastered the counting principles by their fifth birthday. This means that they will know the number names, their specific sequence and understand that the last number counted refers to the numerosity of a given set. However, most preschoolers can only apply this knowledge successfully in a narrow range of circumstances: (1) when numerosities are four or less, and thus recognisable through the PNS; (2) when numerosities are 10 or less and can be counted on both sets of fingers; and (3) when objects can be physically counted by touching or pointing.[667] In these

[667] Siegler, R. S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental Science*, *19*(3), 341–361.

circumstances, children can count accurately above 10, but will often make mistakes by inadvertently skipping or double-counting objects.

Preschoolers also appear limited in their ability to link their understanding of the one-to-one principle and cardinality to visual judgements of more and less. As Piaget illustrated with his conservation task, preschool children's judgements of more or less remain governed by their senses instead of their conceptual understanding.[668] During this task, children are asked to count equivalent rows of objects and verify that they have the same number. After carefully counting all of the objects, children will typically say that both rows are the same. The researcher will then separate the objects in one row to make the row appear longer and then ask again which row has more. In this instance, the majority of children will reply that the stretched-out row has more objects, and will insist this is the case, even after recounting them and verifying they have the same number.

Piaget maintained that children's failure to conserve number value was evidence that they had not yet fully mastered the abstract concept of cardinality, as well as the ordinal (e.g. +1) relationship between sequential number values.[669,670] Further evidence of preschool children's fragile understanding of ordinal relationship can be seen in their performance on number line tasks.[671] While their ability to discriminate changes in magnitude continues to increase (children discriminate ratio differences of 3:4 and 5:6 at ages 3 and 6 respectively), their ability to accurately position numbers on a symbolic number line is limited to the ranges they can count.[672,673] In this respect, three- and four-year-olds will accurately position numbers 1 through 3, but fail with higher values.[674] By the age of six, however, most children will have made the connection between number symbols and differences in magnitude, as governed by the ANS.[675,676]

Early arithmetic

Studies show that accurate number line estimations are informed both by children's ability to count, as well as their understanding of addition and subtraction principles. For example, successful number location on bounded number lines requires children to implicitly add or subtract values from the bounded end.[677] On a number line from 1 to 10, the accurate positioning of the number three requires an understanding of three in relation to the start and finish of the line. Studies observe that most preschoolers cannot yet apply addition and subtraction principles to number line estimation activities, although many will do so by the age of six or seven.[678,679]

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668 Ginsburg, H. P., & Opper, S. (1988). *Piaget's theory of intellectual development*. Prentice-Hall, Inc.

669 Bryant, P., & Nunes, T. (2014). Childrens understanding of mathematics. In Goswami, U. (ed.) *The Wiley-Blackwell Handbook of Childhood Cognitive Development* (pp. 549–573). Chichester, West Sussex: Blackwell Publishing.

670 Butterworth, B. (2005). The development of arithmetical abilities. *Journal of Child Psychology and Psychiatry*, *46*(1), 3–18.

671 Siegler, R. S., & Braithwaite, D. W. (2017). Numerical development. *Annual review of psychology*, *68*, 187–213.

672 Halberda, J., & Feigenson, L. (2008). Developmental change in the acuity of the 'Number Sense': The Approximate Number System in 3-, 4-, 5-, and 6-year-olds and adults. *Developmental Psychology*, *44*(5), 1457.

673 Sella, F., Berteletti, I., Lucangeli, D., & Zorzi, M. (2017). Preschool children use space, rather than counting, to infer the numerical magnitude of digits: Evidence for a spatial mapping principle. *Cognition*, *158*, 56–67.

674 Berteletti, I., Lucangeli, D., Piazza, M., Dehaene, S., & Zorzi, M. (2010). Numerical estimation in preschoolers. *Developmental Psychology*, *46*(2), 545.

675 Le Corre, M., & Carey, S. (2007). One, two, three, four, nothing more: An investigation of the conceptual sources of the verbal counting principles. *Cognition*, *105*(2), 395–438.

676 Siegler, R. S. (2016). Magnitude knowledge: The common core of numerical development. *Developmental science*, *19*(3), 341–361.

677 Cohen, D. J., & Sarnecka, B. W. (2014). Children's number-line estimation shows development of measurement skills (not number representations). *Developmental Psychology*, *50*(6), 1640.

678 Ebersbach, M., Luwel, K., & Verschaffel, L. (2015). The relationship between children's familiarity with numbers and their performance in bounded and unbounded number line estimations. *Mathematical Thinking and Learning*, *17*(2-3), 136–154.

679 Friso-van den Bos, I., Kroesbergen, E. H., Van Luit, J. E., Xenidou-Dervou, I., Jonkman, L. M., Van der Schoot, M., & Van Lieshout, E. C. (2015). Longitudinal development of number line estimation and mathematics performance in primary school children. *Journal of Experimental Child Psychology*, *134*, 12–29.

Preschool children nevertheless appear to have an implicit understanding of addition and subtraction principles. Recall from previous sections that children as young as six months old express surprise when objects disappear and reappear in violation of these principles.[680] While researchers disagree on the significance of this behaviour, there is good evidence to suggest that children's ability to add and subtract steadily improves throughout infancy and toddlerhood. For example, 14-month-old toddlers will successively search for missing objects placed out of view within sets of three.[681] Two-year-olds are also able to add and subtract 1–4 objects in simple calculation activities one item at a time.[682] Many have therefore argued that even very young children understand some of the basic principles of addition and subtraction, but have difficulty applying them to numerosities greater than four.[683,684]

The addition and subtraction of larger number sets becomes easier once children have mastered the principle of cardinality.[685] While preschoolers will often not know the meaning of the words 'plus', 'minus' and 'equal', they can usually answer questions involving 'how many' and 'all together' with accuracy. For example, some four-year-olds will be able to answer 'six' if asked how many objects they will have all together if two objects are added to four. However, the four-year-old's ability to add and subtract successfully is often described as 'concrete', as it is confined to circumstances where physical counting is permitted (by pointing or touching objects, or finger counting) or the objects to be counted are four or less.

Preschool children's addition and subtraction strategies typically follow a predictable progression.[686] When asked to add two sets of objects, children will first rigidly insist on counting all of the items in both sets, starting at one. This strategy, often referred to as the 'sum' strategy, has the potential to lead to correct answers, but frequently fails because of miscounting, particularly when counting higher number sets. As a result, children eventually learn to take mental shortcuts. These shortcuts include the 'max' strategy, which involves starting with the cardinal value from the lowest set and counting forward or the 'min' strategy, whereby counting begins with the largest cardinal value. Once children master the min strategy, they are better able to make use of additive strategies with larger number sets – for example, determining that 18 and 3 equal 21 by adding forward from 18. While some precocious four-year-olds understand the max strategy, it typically does not occur spontaneously until the first or second year of primary school.

None of these strategies are as efficient as fact-retrieval strategies, however, which are stored in the long-term memory through rote practice.[687] While storage of arithmetic facts takes time, it dramatically increases the speed at which children can solve simple arithmetic problems and mentally manipulate more complex numerical information in the working memory. By the end of the fifth year, some children will have memorised several arithmetic facts involving numerosities of 10 or less.[688]

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680 Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, *358*(6389), 749–750.

681 Feigenson L & Carey S. (2003). Tracking individuals via object files: evidence from infants' manual search. *Developmental Science, 6*(5):568–584.

682 Huttenlocher, J., Jordan, N. C., & Levine, S. C. (1994). A mental model for early arithmetic. *Journal of Experimental Psychology: General, 123,* 284–296.

683 Klein, J. S., & Bisanz, J. (2000). Preschoolers doing arithmetic: The concepts are willing but the working memory is weak. *Canadian Journal of Experimental Psychology, 54,* 105–115.

684 Vilette, B. (2002). Do young children grasp the inverse relationship between addition and subtraction? Evidence against early arithmetic. *Cognitive Development, 17,* 1365–1383.

685 Baroody, A. J., & Ginsburg, H. P. (1986). The relationship between initial meaningful and mechanical knowledge of arithmetic. In Hiebert, J. (ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 75–112). Hillsdale, NJ: Erlbaum.

686 Groen, G., & Resnick, L. B. (1977). Can preschool children invent addition algorithms? *Journal of Educational Psychology*, *69*(6), 645.

687 Carpenter, T. P., & Moser, J. M. (1984). The acquisition of addition and subtraction concepts in grades one through three. *Journal for research in Mathematics Education*, 179–202.

688 Ashcraft, M. H., & Christy, K. S. (1995). The frequency of arithmetic facts in elementary texts: Addition and multiplication in grades 1–6. *Journal for Research in Mathematics Education*, 396–421.

Spontaneous focusing on numerosity (SFON)

While some of children's knowledge of counting and arithmetic requires adult instruction, much is learned and practised implicitly during everyday activities.[689,690] For example, conversations taking place during mealtime frequently involve discussions about more or less – hungry eaters always want more, while finicky eaters frequently negotiate for less. Number concepts are also deeply embedded in many popular children's stories. As a case in point, 'Goldilocks and the Three Bears' is essentially a story about ordinality.

Many children's games are also dependent on children's ability to count (such as counting to 10 in a game of hide and seek or counting the dots on a roll of dice). Block play and construction activities additionally reinforce children's understanding of geometry. Researchers are also quick to observe that sharing is essentially a number-based activity – the division of objects (sweets, toy, tokens) draws children's attention to the need for equivalence in terms of numerosity and objects must frequently be counted to verify this equivalence. In this respect, studies have found that children are better able to share once they have acquired the principle of cardinality.[691]

Studies also find that children differ in the degree to which they selectively attend to the numerical aspects of their everyday activities.[692,693] This behaviour, referred to as SFON (spontaneous focussing on numerosity), involves children's non-guided awareness of number and number relationships in their environment. Examples of SFON behaviours include the spontaneous use of numerical words (*I want two biscuits* rather than *I want some biscuits*), the extent to which they focus on issues of number when drawing, or the extent to which numerical relationships feature in children's memory of events or activities.[694]

Studies show that SFON is highly associated with children's ability to count and their mastery of arithmetic principles throughout preschool and primary school.[695,696] While the mechanics of this relationship remain unclear, it is thought that SFON supports children's magnitude discrimination and subitising capabilities which, in turn, facilitate their awareness of number in their environment and subsequently their ability to count.[697]

The transition from informal to formal mathematics

The numerical capabilities described in this section are commonly referred to as *informal* mathematics – that is, number skills that preschool children develop through everyday activities taking place in their homes and at preschool.[698]

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689 Ginsburg, H. P. (2006). Mathematical play and playful mathematics: A guide for early education. *Play= Learning: How play motivates and enhances children's cognitive and social-emotional growth*, 145–165.

690 Hughes, M., Greenhough, P., Yee, W. C., Andrews, J., Winter, J., & Salway, L. (2006). Linking children's home and school mathematics. *Arithmetical Difficulties: Developmental and Instructional Perspectives*, *24*(2), 137.

691 Chernyak, N., Sandham, B., Harris, P. L., & Cordes, S. (2016). Numerical cognition explains age-related changes in third-party fairness. *Developmental Psychology*, *52*(10), 1555.

692 Hannula, M. M., & Lehtinen, E. (2005). Spontaneous focusing on numerosity and mathematical skills of young children. *Learning and Instruction*, *15*(3), 237–256.

693 Sella, F., Berteletti, I., Lucangeli, D., & Zorzi, M. (2016). Spontaneous non-verbal counting in toddlers. *Developmental science*, *19*(2), 329–337.

694 Edens, K. M., & Potter, E. F. (2013). An exploratory look at the relationships among math skills, motivational factors and activity choice. *Early Childhood Education Journal*, *41*(3), 235–243.

695 Hannula-Sormunen, M. M., Lehtinen, E., & Räsänen, P. (2015). Preschool children's spontaneous focusing on numerosity, subitizing, and counting skills as predictors of their mathematical performance seven years later at school. *Mathematical Thinking and Learning*, *17*(2-3), 155–177.

696 Batchelor, S., Inglis, M., & Gilmore, C. (2015). Spontaneous focusing on numerosity and the arithmetic advantage. *Learning and Instruction*, *40*, 79–88.

697 Hannula, M. M., Räsänen, P., & Lehtinen, E. (2007). Development of counting skills: Role of spontaneous focusing on numerosity and subitizing-based enumeration. *Mathematical thinking and learning*, *9*(1), 51–57.

698 Ginsburg, H. (1975). Young children's informal knowledge of mathematics. *Journal of Children's Mathematical Behaviour*. *1*(3), 63–156.

Researchers sometimes group these informal skills into three levels:[699]

- **Level 1: foundational skills** include an awareness of differences between quantities (more; less) and being able to recite the number word sequence.
- **Level 2: meaningful numbering skills,** which include the understanding that specific number words are linked to precise number quantities through the cardinal principle; being able to accurately apply the count list.
- **Level 3: operations on verbal numbers** – being able to perform simple arithmetic through the use of the addition and subtraction verbs, and concepts involving more and less.

An important achievement in early primary school is to link children's informal knowledge of counting and arithmetic to the formal communication of mathematical principles used in school.[700] This transition requires that children have good mastery of informal mathematical principles so that they can then understand how conventional numerical notation (such as Arabic numerals and operational signs '+', '-', '=') can be used to express them. Studies find that a preschool awareness of Arabic numerals facilitates this transition.[701] Studies additionally suggest that difficulties in making this transition – that is, learning how to map the formal numerical symbols to the informal mathematical principles – may be indicative of further mathematical difficulties as children grow older.[702]

Examples of mathematical difficulties include dyscalculia, which is used to describe specific mathematical difficulties occurring in the absence of other cognitive deficits.[703,704] It is thought that dyscalculia affects approximately 7% of the school-aged population, who appear to have specific difficulties in mapping numerical symbols to magnitude quantities.[705] While problems with informal mathematics may also be present during the preschool years, mathematical learning difficulties (MLDs) are not typically diagnosed until primary school, when mathematical symbolic mapping difficulties are first evident.

5.5 What factors influence the development of children's theory of number during the first five years of life?

A variety of genetic and environmental factors are thought to influence children's theory of numbers during their first five years. Drawing conclusions about the relative impact of these factors can be challenging, however. This is because studies vary in how they define and measure these various other factors, as well as the extent to which they include them in statistical models.[706,707] For example, working memory is commonly understood to include

699 Krajewski, K., & Schneider, W. (2009). Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning and instruction*, *19*(6), 513–526.

700 Greenes, C., Ginsburg, H. P., & Balfanz, R. (2004). Big math for little kids. *Early childhood research quarterly*, *19*(1), 159–166.

701 Purpura, D. J., Baroody, A. J., & Lonigan, C. J. (2013). The transition from informal to formal mathematical knowledge: Mediation by numeral knowledge. *Journal of Educational Psychology*, *105*(2), 453.

702 Rousselle, L., & Noël, M. P. (2007). Basic numerical skills in children with mathematics learning disabilities: A comparison of symbolic vs non-symbolic number magnitude processing. *Cognition*, *102*(3), 361–395.

703 Butterworth, B. (2011). Foundational numerical capacities and the origins of dyscalculia. In *Space, Time and Number in the Brain* (pp. 249–265).

704 Geary, D. C. & Hoard, M. K. (2005). Learning disabilities in arithmetic and mathematics: theoretical and empirical perspectives. In Campbell, J. E. (ed.), *Handbook of mathematical cognition*. New York: Psychology Press. (pp. 253–67).

705 Geary, D. C. (2014). The classification and cognitive characteristics of mathematical disabilities in children. In *The Oxford Handbook of Numerical Cognition*.

706 Jordan, J. A., Wylie, J., & Mulhern, G. (2014) Individual Differences in Children's Paths to Arithmetical Development. In *The Oxford Handbook of Numerical Cognition*.

707 Butterworth, B. (2011). Foundational numerical capacities and the origins of dyscalculia. In *Space, Time and Number in the Brain* (pp. 249–265).

five subsystems, although the relative contribution of all five is rarely compared in most studies.[708] While some studies consider phonological and visual working memory processes, others do not. Similar issues are present in the assessment of children's early numerical understanding, with studies differing in the extent to which they consider nonverbal and verbal processes, and the use of standardised tests. Although standardised achievement tests are widely available for children between the ages of three and five, very few validated measures of numerical understanding exist for children who are younger.

It is therefore important to recognise that these variations in methods can dramatically influence a study's findings, and so the following caveats are warranted.

- Relatively little is known about the factors that contribute to individual differences in children's numerical development during infancy and toddlerhood, especially in comparison to the other competencies described in this review, such as language development.
- The influence of environmental factors has been under-studied. This is largely because children's exposure to number is often not included in validated measures of children's home environment.[709]
- Very few studies have considered the longitudinal impact of behaviours present in infancy on children's later numerical understanding.
- While impairments in children's numerical understanding have been identified in primary school (such as dyscalculia), the extent to which they exist during the preschool years has not been routinely tested.[710]

Genetic factors

Findings from twin studies suggest that numerical capabilities may have a stronger heritable component in comparison to some of the other competencies described in this review. It should be noted, however, that most heritability estimates involve children in primary and secondary school, when it is thought that the amplification of gene/environment interactions may be more evident. Indeed, the earliest mathematical heritability that has been measured to date is at age five, with estimates showing relatively low (.18) heritability.[711] However, heritability estimates frequently increase as children grow older.[712,713,714] A recent meta-analysis involving twin studies in the US, UK, Canada, Australia and the Netherlands estimated mathematical heritability at 57% in late primary school. While this is lower than estimates for children's general educational achievement (66%), reading (73%) and language (64%), it is higher than estimates for reading comprehension (49%) and spelling (44%).[715]

708 Meyer, M. L., Salimpoor, V. N., Wu, S. S., Geary, D. C., & Menon, V. (2010). Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. *Learning and Individual Differences*, *20*(2), 101–109.

709 Elliott, L., & Bachman, H. J. (2018). How Do Parents Foster Young Children's Math Skills? *Child Development Perspectives*, *12*(1), 16–21.

710 Butterworth, B. (2011). Foundational numerical capacities and the origins of dyscalculia. In *Space, Time and Number in the Brain* (pp. 249–265).

711 Garon-Carrier, G., Boivin, M., Kovas, Y., Feng, B., Brendgen, M., Vitaro, F., ... & Dionne, G. (2017). Persistent Genetic and Family-Wide Environmental Contributions to Early Number Knowledge and Later Achievement in Mathematics. *Psychological Science*, *28*(12), 1707–1718.

712 Kovas, Y., Voronin, I., Kaydalov, A., Malykh, S. B., Dale, P. S., & Plomin, R. (2013). Literacy and numeracy are more heritable than intelligence in primary school. *Psychological science*, *24*(10), 2048–2056.

713 de Zeeuw, E. L., van Beijsterveldt, C. E., Glasner, T. J., de Geus, E. J., & Boomsma, D. I. (2016). Arithmetic, reading and writing performance has a strong genetic component: A study in primary school children. *Learning and individual differences*, *47*, 156–166.

714 Grasby, K. L., Coventry, W. L., Byrne, B., Olson, R. K., & Medland, S. E. (2016). Genetic and environmental influences on literacy and numeracy performance in Australian school children in Grades 3, 5, 7, and 9. *Behavior Genetics*, *46*(5), 627–648.

715 de Zeeuw, E. L., de Geus, E. J., & Boomsma, D. I. (2015). Meta-analysis of twin studies highlights the importance of genetic variation in primary school educational achievement. *Trends in Neuroscience and Education*, *4*(3), 69–76.

The factors underpinning these heritability estimates remain debated. While some speculate that these estimates reflect amplification from the gene/environment correlations just described, some also suspect that the demands of secondary school maths increasingly draw on genetically-based capabilities.[716,717,718,719] These processes include the efficiency of the working memory and other executive functions, such as attention control and information processing speed.[720] Recent studies have also identified a set of specialist genes that may increase the likelihood of various mathematical difficulties, such as dyscalculia[721]

In sum, convincing arguments have been made that some aspects of children's numerical understanding have a genetic component. However, this evidence should not be interpreted to mean that the child's learning environment does not also contribute – as it clearly does. As we describe in the following sections, environmental influences have been found to strongly contribute to children's numerical understanding during the preschool years, particularly when it comes to counting capabilities and the learning of the Arabic numerals. In addition, studies find that environmental influences may be particularly impactful among children with genetically-linked mathematical difficulties, showing that harsh parenting and chaotic home environments may be especially detrimental.[722]

Antenatal factors

Many of the antenatal factors discussed in previous chapters (for example, chapter 3) also negatively affect children's numerical capabilities. These factors include a very preterm birth (<32 weeks), which appears to be particularly associated with impairments in children's numerical understanding.[723] Studies show that these difficulties are frequently not evident until the end of primary school, however, when numerical tasks become more complex. For example, studies have observed that preterm children are at greater risk of the numerical deficits associated with developmental dyscalculia.[724]

The reasons underpinning mathematical difficulties in preterm children have yet to be fully understood, however. While some studies indicate that an early birth may negatively affect brain cell connectivity in regions associated with number processing, others have not been able to verify this relationship. More conclusive findings suggest that a preterm birth most likely affects many of the more general processes underpinning mathematical performance, including information processing speed and working memory.[725]

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716 Kovas, Y., Haworth, C. M., Dale, P. S., & Plomin, R. (2007). The genetic and environmental origins of learning abilities and disabilities in the early school years. *Monographs of the Society for research in Child Development*, *72*(3), vii–1.

717 Kovas, Y., Petrill, S. A., & Plomin, R. (2007). The origins of diverse domains of mathematics: Generalist genes but specialist environments. *Journal of Educational Psychology*, *99*(1), 128.

718 Krapohl, E., Rimfeld, K., Shakeshaft, N. G., Trzaskowski, M., McMillan, A., Pingault, J. B., ... & Plomin, R. (2014). The high heritability of educational achievement reflects many genetically influenced traits, not just intelligence. *Proceedings of the National Academy of Sciences*, *111*(42), 15273–15278.

719 Decker, S., & Roberts, A. (2015). Specific cognitive predictors of early math problem solving. *Psychology in the Schools, 52*, 477–488.

720 Lukowski, S. L., Soden, B., Hart, S. A., Thompson, L. A., Kovas, Y., & Petrill, S. A. (2014). Etiological distinction of working memory components in relation to mathematics. *Intelligence*, *47*, 54–62.

721 Hart, S. A., Petrill, S. A., Thompson, L. A., & Plomin, R. (2009). The ABCs of math: A genetic analysis of mathematics and its links with reading ability and general cognitive ability. *Journal of educational psychology*, *101*(2), 388.

722 Docherty, S. J., Kovas, Y., & Plomin, R. (2011). Gene-environment interaction in the etiology of mathematical ability using SNP sets. *Behavior genetics*, *41*(1), 141–154.

723 Johnson, S., Strauss, V., Gilmore, C., Jaekel, J., Marlow, N., & Wolke, D. (2016). Learning disabilities among extremely preterm children without neurosensory impairment: Comorbidity, neuropsychological profiles and scholastic outcomes. *Early human development*, *103*, 69–75.

724 Simms, V., Cragg, L., Gilmore, C., Marlow, N., & Johnson, S. (2013). Mathematics difficulties in children born very preterm: current research and future directions. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, fetalneonatal, f1–f7.

725 Rose, S. A., Feldman, J. F., Jankowskl, J. J. (2011). Modeling a cascade of effects: the role of speed and executive functioning in preterm/full-term differences in academic achievement. *Developmental Science, 14*, 1161–75.

Infancy (0–12 months)

Few studies to date have considered the extent to which numerical capabilities during infancy predict later numerical outcomes, although a number of preliminary studies indicate that there may be a developmental association.[726] For example, a recent study observed that ANS magnitude discrimination at age six predicted both magnitude discrimination and cardinal knowledge at age three. Moreover, ANS magnitude discrimination at six months was more strongly associated with the three-year-olds' understanding of number in comparison to concurrent measures of intelligence. Although these findings have yet to be replicated, they suggest that individual differences in children's numerical understanding may already be present during the child's first year and may contribute to consistencies in individual differences as children develop.

Interestingly, a similar association has not been observed for PNS discrimination during the child's first year and his or her later numerical understanding at ages two and five, although very few studies have considered this question specifically.[727] In the one study that has, small number recognition at eight months was not associated with small number recognition skills at 24 months (through an object search task), or their mathematics achievement at five years. However, small number discrimination at 24 months is nevertheless associated with children's mathematics achievement at age five. The study's authors therefore speculate that the lack of an association between infant small number discrimination and later mathematical outcomes may suggest that small number discrimination may not be stable during the child's first year, although more research is clearly necessary before any conclusions can be drawn.

Toddlerhood (12–36 months)

As described in the previous sections, children begin to learn the words associated with numbers during the second year of life. Much of this learning takes place in children's day-to-day conversations with their parents and other family members. It is thought that children's exposure to 'number-talk' particularly supports their mastery of number names and their associated cardinal values. However, studies also observe that it is the *quality* of this talk, not the quantity, which has the biggest impact on children's numerical understanding.

The importance of number-talk was verified in a longitudinal study in 2010 which tracked children's language development from 12 months to five years.[728] Parent–child interaction during everyday activities was recorded on five separate occasions when children were between 14 and 30 months. The quantity and quality of language used during these interactions was then coded, as was the frequency of parent–child number-talk. The study observed that parents differed in terms of the amount of language they used when interacting with their children and their use of number words. While number-talk was relatively infrequent during parent–child interactions, parents who talked more to their children, also talked more about numbers.

The study also observed differences in the nature and quality of number-talk parents used. These differences included the extent to which parents highlighted the cardinal value of number sets and physically counted-out objects or activities with their child.[729] An increased focus on cardinality, in turn, significantly predicted children's 'knower' level at the time of their

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726 Starr, A., Libertus, M. E., & Brannon, E. M. (2013). Number sense in infancy predicts mathematical abilities in childhood. *Proceedings of the National Academy of Sciences*, *110*(45), 18116–18120.

727 Ceulemans, A., Titeca, D., Loeys, T., Hoppenbrouwers, K., Rousseau, S., & Desoete, A. (2015). The sense of small number discrimination: The predictive value in infancy and toddlerhood for numerical competencies in kindergarten. *Learning and Individual Differences*, *39*, 150–157.

728 Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental psychology*, *46*(5), 1309.

729 Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number-talk count more than others: relations between parents' input and children's cardinal-number knowledge. *Developmental science*, *14*(5), 1021–1032.

fourth birthday. Parents also differed in the extent to which they engaged in 'large number-talk' – that is, specifically labelled numerosities greater than four. The study found that large number-talk was, in fact, the strongest predictor of children's knowledge of cardinal numbers 18 months later, and this relationship was independent of other contributing factors, including the parents' non-number-talk and SES (as measured by parental education and income).

While SES was not the strongest predictor of the preschoolers' number knowledge in this study, it was nevertheless a significant predictor. This finding is consistent with findings reported elsewhere, that have similarly observed a strong and persistent link between family income and children's understanding of number already at the time children enter school.[730] While the reasons for this association remain unclear, studies show that parents with higher socioeconomic backgrounds are more likely to set more challenging and developmentally appropriate numerical learning goals for their children, as well as place greater emphasis on mathematical learning more generally.[731]

Ages three to five

Procedural and conceptual knowledge of numbers

Studies consistently show that numerical capabilities at age five strongly predict children's later mathematics achievement.[732] Numerical skills with the greatest predictive value include children's procedural knowledge of counting, their conceptual understanding of cardinality and their familiarity with the Arabic numerals.[733,734,735] These capabilities, in turn, are associated with children's ability to discriminate differences in magnitude, their precise small number recognition and their spontaneous focusing on numerosity (SFON). As discussed in previous sections, children's understanding of number is also associated with more general processes involving working memory and language.[736]

Few studies to date have investigated the relative contribution of these capabilities on children's later mathematical achievement, however. This makes it difficult to draw conclusions about which skills matter the most. The following developmental trends are nevertheless worth noting:

- ANS magnitude discrimination at age four predicts children's mathematics achievement at age six.[737] However, studies show that the strength of this association loses its significance once children's conceptual understanding of cardinality is also taken into account.[738] This suggests that early ANS capabilities may facilitate the understanding of cardinal values, which in turn, predicts children's later mathematical achievement.[739]

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730 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/376216/SFR46_2014_text.pdf

731 Saxe, G. B., Guberman, S. R., Gearhart, M., Gelman, R., Massey, C. M., & Rogoff, B. (1987). Social processes in early number development. *Monographs of the society for research in child development*, i–162.

732 Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*(3), 850–867.

733 Nguyen, T., Watts, T. W., Duncan, G. J., Clements, D. H., Sarama, J. S., Wolfe, C., & Spitler, M. E. (2016). Which preschool mathematics competencies are most predictive of fifth grade achievement? *Early childhood research quarterly*, *36*, 550–560.

734 Aunio, P., & Niemivirta, M. (2010). Predicting children's mathematical performance in grade one by early numeracy. *Learning and individual differences*, *20*(5), 427–435.

735 Purpura, D. J., Baroody, A. J., & Lonigan, C. J. (2013). The transition from informal to formal mathematical knowledge: Mediation by numeral knowledge. *Journal of Educational Psychology*, *105*(2), 453.

736 Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of learning disabilities*, *37*(1), 4–15.

737 Mazzocco, M. M., Feigenson, L., & Halberda, J. (2011). Preschoolers' precision of the approximate number system predicts later school mathematics performance. *PLoS one*, *6*(9), e23749.

738 Chu, F. W., & Geary, D. C. (2015). Early numerical foundations of young children's mathematical development. *Journal of Experimental Child Psychology*, *132*, 205–212.

739 Geary, D. C., & Vanmarle, K. (2016). Young children's core symbolic and nonsymbolic quantitative knowledge in the prediction of later mathematics achievement. *Developmental psychology*, *52*(12), 21–30.

- Studies further observe a reciprocal relationship between small number recognition (PNS) and children's conceptual understanding of cardinal relationships at age four. However, ANS magnitude discrimination, visual working memory and phonological awareness appear to be more strongly associated with children's arithmetic capabilities.[740]
- Working memory consistently contributes to children's mathematical performance at all points of their development.[741,742] As mentioned previously, the relative influence of verbal and visuospatial working memory processes differs, depending on the demands of the numerical task and measures of verbal ability.
- Studies show that during the preschool years, SFON is reciprocally associated with children's understanding of cardinality and ability to map numerical symbols to their estimations of magnitude.[743,744] SFON then remains an independent predictor of children's mathematical achievement throughout the primary school years.[745,746]
- Children's language capabilities are strongly associated with their counting capabilities between the ages of three and five and initial mathematics achievement in Grades 1 and 2.[747] Recent studies show that children's number vocabulary, in particular, is the strongest contributer in these relationships.[748,749]
- Once children enter primary school, children's mathematical achievement is highly associated with their understanding of Arabic numerals and mathematical symbols.[750] Knowledge of numerals and symbols increases children's ability to mentally represent higher numerosities with greater precision and reduces the likelihood of arithmetic mistakes based on procedural counting errors. It is thought the difficulties in this mapping process underpin many of the mathematics learning difficulties observed once children are in primary school.[751] Children's numerical symbol recognition then continues to be strongly associated with children's mathematic achievement throughout the remainder of primary school.
- While the ANS is thought to support the mapping of numerical symbols to specific magnitudes, children's symbolic knowledge of numbers is also influenced by their

740 Soto-Calvo, E., Simmons, F. R., Willis, C., & Adams, A. M. (2015). Identifying the cognitive predictors of early counting and calculation skills: Evidence from a longitudinal study. *Journal of Experimental Child Psychology*, *140*, 16–37.

741 Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: a 5-year longitudinal study. *Developmental psychology*, *47*(6), 1539.

742 Gilmore, C. K., Keeble, S., Richardson, S., & Cragg, L. (2017). The interaction of procedural skill, conceptual understanding and working memory in early mathematics achievement. *Journal of Numerical Cognition, 3*, 400–416.

743 Hannula, M. M., & Lehtinen, E. (2005). Spontaneous focusing on numerosity and mathematical skills of young children. *Learning and Instruction*, *15*(3), 237–256.

744 Batchelor, S., Inglis, M., & Gilmore, C. (2015). Spontaneous focusing on numerosity and the arithmetic advantage. *Learning and Instruction*, *40*, 79–88.

745 Hannula-Sormunen, M. M., Lehtinen, E., & Räsänen, P. (2015). Preschool children's spontaneous focusing on numerosity, subitizing, and counting skills as predictors of their mathematical performance seven years later at school. *Mathematical Thinking and Learning*, *17*(2-3), 155–177.

746 Nanu, C. E., McMullen, J., Munck, P., Hannula-Sormunen, M. M., & Pipari Study Group. (2018). Spontaneous focusing on numerosity in preschool as a predictor of mathematical skills and knowledge in the fifth grade. *Journal of experimental child psychology*, *169*, 42–58.

747 Toll, S. W. M., & Van Luit, J. E. H. (2014). Explaining numeracy development in weak performing kindergartners. *Journal of Experimental Child Psychology, 124,*97–111.

748 Purpura, D. J., & Reid, E. E. (2016). Mathematics and language: Individual and group differences in mathematical language skills in young children. *Early Childhood Research Quarterly*, *36*, 259–268.

749 Toll, S. W. M., & Van Luit, J. E. H. (2014). The developmental relationship between language and low early numeracy skills throughout kindergarten. *Exceptional Children, 81*, 64–78.

750 Xenidou-Dervou, I., Gilmore, C., van der Schoot, M., & van Lieshout, E. C. (2015). The developmental onset of symbolic approximation: beyond nonsymbolic representations, the language of numbers matters. *Frontiers in psychology*, *6*, 487.

751 Butterworth, B. (2011). Foundational numerical capacities and the origins of dyscalculia. In *Space, Time and Number in the Brain* (pp. 249–265).

language capabilities and the quality of their formal educational instruction.[752,753] Findings suggest that children's knowledge of numerals and symbols may supersede their conceptual knowledge of cardinality in predicting mathematical achievement during the first few years of primary school.[754,755]

- There is emerging evidence to suggest that preschool children's *patterning* ability – that is, the ability to recognise predictable patterns in stimuli (see chapter 6) – also supports numerical awareness.[756] Patterning can occur within a single object, within an ordered set of objects or between two ordered sets of objects (such as when things are paired). Although patterning has not historically been identified as a numeracy skill, recent studies indicate it may facilitate children's number line understanding and mapping of numerical symbols to precise numerosities. It is thus thought that patterning works alongside the ANS and PNS in predicting children's later mathematical achievement.[757]

In sum, mastery of the counting principles is a significant milestone during the late preschool years and the ease with which children achieve this milestone is associated with later mathematical competencies. Research additionally suggests that children's mastery of the cardinal principles is associated with processes involving the ANS, PNS, SFON and patterning recognition, although the overlap between these three capabilities has not been explicitly tested. Working memory and language are also thought to increase to the efficiency of these numerical processes when children learn to count and add and subtract quantities.

Children's mastery of the counting and arithmetic principles at the time they enter primary school are strong predictors of their later mathematical achievement. However, being able to precisely match numerical symbols to numerosities higher than five is a critical part of this trajectory. While ANS, PNS, SFON, patterning and working memory processes likely support symbol matching, children's understanding of language and the quality of their education also play a critical role.

The home numeracy environment

Research findings regarding the relationship between the home learning environment and children's early numerical capabilities are equivocal.[758] While some studies observe that the home learning environment, and the 'home numeracy environment' (HNE) in particular, strongly predict children's numerical learning,[759,760,761] others have not been able to verify an association.[762,763] Researchers suspect that this discrepancy has to do with differences

752 Gilmore, C. K., McCarthy, S. E., & Spelke, E. S. (2010). Non-symbolic arithmetic abilities and mathematics achievement in the first year of formal schooling. *Cognition*, *115*(3), 394–406.

753 Purpura, D. J., & Reid, E. E. (2016). Mathematics and language: Individual and group differences in mathematical language skills in young children. *Early Childhood Research Quarterly*, *36*, 259–268.

754 Martin, R. B., Cirino, P. T., Sharp, C., & Barnes, M. (2014). Number and counting skills in kindergarten as predictors of grade 1 mathematical skills. *Learning and individual differences*, *34*, 12–23.

755 Purpura, D. J., Baroody, A. J., & Lonigan, C. J. (2013). The transition from informal to formal mathematical knowledge: Mediation by numeral knowledge. *Journal of Educational Psychology*, *105*(2), 453.

756 Papic, M. M., Mulligan, J. T., & Mitchelmore, M. C. (2011). Assessing the development of preschoolers' mathematical patterning. *Journal for Research in Mathematics Education*, *42*(3), 237–269.

757 Rittle-Johnson, B., Fyfe, E. R., Hofer, K. G., & Farran, D. C. (2017). Early Math Trajectories: Low-Income Children's Mathematics Knowledge from Ages 4 to 11. *Child development*, *88*(5), 1727–1742

758 Elliott, L., & Bachman, H. J. (2018). How Do Parents Foster Young Children's Math Skills? *Child Development Perspectives*, *12*(1), 16–21.

759 Niklas, F., & Schneider, W. (2014). Casting the die before the die is cast: The importance of the home numeracy environment for preschool children. *European Journal of Psychology of Education*, *29*(3), 327–345.

760 Kleemans, T., Peeters, M., Segers, E., & Verhoeven, L. (2012). Child and home predictors of early numeracy skills in kindergarten. *Early Childhood Research Quarterly*, *27*(3), 471–477.

761 Segers, E., Kleemans, T., & Verhoeven, L. (2015). Role of parent literacy and numeracy expectations and activities in predicting early numeracy skills. *Mathematical Thinking and Learning*, *17*(2-3), 219–236

762 Missall, K., Hojnoski, R. L., Caskie, G. I., & Repasky, P. (2015). Home numeracy environments of preschoolers: Examining relations among mathematical activities, parent mathematical beliefs, and early mathematical skills. *Early Education and Development*, *26*(3), 356–376.

763 DeFlorio, L., & Beliakoff, A. (2015). Socioeconomic status and preschoolers' mathematical knowledge: The contribution of home activities and parent beliefs. *Early Education and Development*, *26*(3), 319–341.

in children's age and the specificity with which HNE has been measured. Home numeracy activities also occur relatively infrequently, therefore making it difficult to investigate them during home observations.

Four HNE activities are thought to specifically support children's early number learning:

- informal numerical activities involving maths games, and the application of numerical principles during cooking or shopping
- formal activities that specifically aim to develop numerical skills – counting, sorting and matching, and maths books (connect the dots, workbooks) – and activities that teach children the Arabic numerals.[764]

Studies show that both kinds of activities support children's numerical development and that formal and informal activities correspond with different numerical skills. Specifically, informal activities involving games and play predict children's non-symbolic arithmetic capabilities, whereas formal HNE activities are more strongly associated with children's symbolic knowledge.[765,766] Other factors thought to influence children's numerical development during the late preschool years include their caregivers' active labelling of number sets. Studies find that specifically labelling the number set after counting ('1,2,3,4,5 – that's *five* fingers') is associated with children's understanding of cardinal values.[767,768] Caregiver enthusiasm and positive attitudes towards numerical activities has also been found to predict children's numerical knowledge.[769,770]

Enriching preschool education

A strong and persistent gap in the numerical capabilities of high- and low-income children is present already by the time they enter primary school.[771] This gap is typically *at least* half a standard deviation on mathematics achievement tests, depending on the study.[772] Recent findings from the Early Years Foundation Stage profile observe that in the UK it exists in terms of 15 percentage points, with 66% of children from low income households being assessed at a good level of development (GLD) in their knowledge of numbers in comparison to 81% of children from middle- and upper-income homes.[773]

764 LeFevre, J. A., Skwarchuk, S. L., Smith-Chant, B. L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement*, *41*(2), 55.

765 Skwarchuk, S. L., Sowinski, C., & LeFevre, J. A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of experimental child psychology*, *121*, 63–84.

766 Huntsinger, C. S., Jose, P. E., & Luo, Z. (2016). Parental facilitation of early mathematics and reading skills and knowledge through encouragement of home-based activities. *Early Childhood Research Quarterly*, *37*, 1–15.

767 Casey, B. M., Lombardi, C. M., Thomson, D., Nguyen, H. N., Paz, M., Theriault, C. A., & Dearing, E. (2016). Maternal Support of Children's Early Numerical Concept Learning Predicts Preschool and First-Grade Math Achievement. *Child development*, *89*, 153–173.

768 Mix, K. S., Sandhofer, C. M., Moore, J. A., & Russell, C. (2012). Acquisition of the cardinal word principle: The role of input. *Early Childhood Research Quarterly*, *27*(2), 274–283.

769 Skwarchuk, S. L., Sowinski, C., & LeFevre, J. A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of experimental child psychology*, *121*, 63–84.

770 Missall, K., Hojnoski, R. L., Caskie, G. I., & Repasky, P. (2015). Home numeracy environments of preschoolers: Examining relations among mathematical activities, parent mathematical beliefs, and early mathematical skills. *Early Education and Development*, *26*(3), 356–376.

771 Aubrey, C., Godfrey, R., & Dahl, S. (2006). Early mathematics development and later achievement: Further evidence. *Mathematics Education Research Journal*, *18*(1), 27–46.

772 Duncan, G. J., & Magnuson, K. A. (2005). Can family socioeconomic resources account for racial and ethnic test score gaps? *The Future of Children*, 35–54.

773 See: https://www.gov.uk/government/statistics/early-years-foundation-stage-profile-results-2016-to-2017

The reasons for this gap are unclear, with most studies showing that low-income children have many of the same numerical capabilities as upper-income children do.[774] However, low-income children lag behind middle- and upper-income children in their understanding of counting and arithmetic by the time they enter primary school.[775] Researchers speculate that this gap is due to low-income children receiving less direct home instruction in numeracy-related concepts in comparison to their upper-income peers, as well as differences in parents' use of maths-related language.[776,777]

It was originally thought that enriching educational experiences during the first two years of primary school would enable low-income children to catch up to their middle- and upper-income peers.[778] This assumption is not fully supported by the evidence, however. While some studies observe that accelerated learning can occur during the first several years of primary school, they also observe that it is often not sufficient to make up for initial income-related learning gaps.[779,780]

There is, however, good evidence showing that entering primary school with appropriate maths-readiness skills reduces this gap, as does having sufficient support in the home learning environment.[781] Enriching preschool curriculums have thus been developed to reduce this gap, with some demonstrating substantial short-term improvements in low-income children's numerical learning.[782,783] Unfortunately, studies also find that these initial gains typically fade out during the preschool years.[784,785] The reasons for this fade-out remain debated, with studies suggesting that the benefits of enriching preschool experiences can only be sustained if children's primary and secondary school education is also of high quality.[786]

5.6 How is children's numerical understanding measured during the first five years?

A wide range of measures have been developed to assess preschool children's numerical capabilities. These tools include mathematics-specific screening checklists which can be used alongside omnibus assessments of other cognitive skills, as well as subscales of commonly used IQ tests. However, the vast majority of these measures have only been validated for use with children aged four and older and many have not been norm-referenced

774 Ginsburg, H. P., Lee, J. S., & Boyd, J. S. (2008). Mathematics Education for Young Children: What It Is and How to Promote It. Social Policy Report. Volume 22, Number 1. *Society for Research in Child Development*.

775 Jordan, N. C., Kaplan, D., Olah, L. N., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77*(1), 153–175.

776 Galindo, C., & Sonnenschein, S. (2015). Decreasing the SES math achievement gap: Initial math proficiency and home learning environments. *Contemporary Educational Psychology*, *43*, 25–38.

777 Purpura, D. J., & Reid, E. E. (2016). Mathematics and language: Individual and group differences in mathematical language skills in young children. *Early Childhood Research Quarterly*, *36*, 259–268.

778 Watts, T. W., Duncan, G. J., Siegler, R. S., & Davis-Kean, P. E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher*, *43*(7), 352–360.

779 Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology, 45*(3), 850–867.

780 Jordan, N. C., Kaplan, D., Olah, L. N., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development, 77*(1), 153–175.

781 Galindo, C., & Sonnenschein, S. (2015). Decreasing the SES math achievement gap: Initial math proficiency and home learning environments. *Contemporary Educational Psychology*, *43*, 25–38.

782 Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development*, *84*(6), 2112–2130.

783 Wang, A. H., Shen, F., & Byrnes, J. P. (2013). Does the Opportunity–Propensity Framework predict the early mathematics skills of low-income pre-kindergarten children? *Contemporary Educational Psychology*, *38*(3), 259–270.

784 Watts, T. W., Duncan, G. J., Clements, D. H., & Sarama, J. (2018). What Is the Long-Run Impact of Learning Mathematics During Preschool?. *Child development*, *89*(2), 539–555.

785 Duncan, G. J., & Magnuson, K. (2013). Investing in preschool programs. *Journal of Economic Perspectives*, *27*(2), 109–32.

786 Bailey, D., Duncan, G. J., Odgers, C. L., & Yu, W. (2017). Persistence and fadeout in the impacts of child and adolescent interventions. *Journal of Research on Educational Effectiveness*, *10*(1), 7–39.

within the UK. Table 5.2 provides an overview of some of the more commonly used tools, and further information can be found on the Education Endowment Foundation's website.[787]

It is worth noting that mathematical learning difficulties and dyscalculia are typically not diagnosed until children reach primary school, when difficulties learning the numerical symbols, retrieving mathematical facts and performing mental calculations are first evident.[788,789] However, many of the tools listed in table 5.2 are useful for identifying children who may be at risk, as well as assessing children's numerical capabilities more generally.

787 See: https://educationendowmentfoundation.org.uk/projects-and-evaluation/evaluating-projects/early-years-measure-database/early-years-measures-database/

788 Mazzocco, M. M., & Myers, G. F. (2003). Complexities in identifying and defining mathematics learning disability in the primary school-age years. *Annals of dyslexia*, *53*(1), 218–253.

789 Mazzocco, M. M., & Thompson, R. E. (2005). Kindergarten predictors of math learning disability. *Learning Disabilities Research & Practice*, *20*(3), 142–155.

TABLE 5.2

Commonly used measures of preschool children's theories of numbers (ordered by children's chronological age)

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Ages & Stages Questionnaire (ASQ-3)	The Ages & Stages Questionnaires®, Third Edition (ASQ-3™) pinpoints developmental progress in children between the ages of one month to 5.5 years. It is a developmental screening tool designed for use by early educators and healthcare professionals. It relies on parents as experts. It takes 10–15 minutes for parents to complete and 2–3 minutes for professionals to score. It screens the following areas: communication, gross motor, fine motor, problem-solving, and personal–social. Some number-related questions are included in the Problem Solving section of the questionnaire from 30 months onwards. Questions involving children's Arabic numeral recognition and counting skills are included in the questionnaires for children at 54 and 60 months.	1 month to five years	Practitioner or parent	Screening	No	Ages & Stages
The Ages & Stages of Numeracy Development Checklist	The Ages & Stages of Numeracy Development Checklist is a supplement checklist of skills specific to children's numerical understanding which can be used alongside the ASQ-3, or independently. Its diagnostic and screening capabilities are yet unknown, however.	1 month to five years	Practitioner or parent	Not developed yet	No	Canadian childcare federation
Bayley Scales of infant and toddler development, Third edition (The Bayley-III)	The Bayley-III examines all the facets of a young child's development. Children are assessed in the five key developmental domains of cognition, language, social-emotional, motor and adaptive behaviour. It can be used for children between 1 month and 42 months. It takes from 30 minutes to 90 minutes to complete (depending upon the age of child). The Cognitive Scale has internal consistency reliability of .91 to assess counting and early number skills.	1 to 42 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
The Denver Developmental Screening Test (Denver II)	The Denver II is used by healthcare providers to assess child development. It consists of 125 items (the DDST has 105) divided into four general areas of development: personal–social, fine motor-adaptive, language and gross motor. It screens for developmental delay. It is suitable for children aged 0 to 6 years. It takes from 20 to 60 minutes to complete depending on the stress tolerance of the child. Can be used as a screener for children between the ages of five and six.	0 to 6 years	Practitioner	Screening	Yes	Hogrefe

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Parental Evaluation of Development Status (PEDS)	PEDS screens development, behaviour, social-emotional/mental health and autism in children aged 0–8 years. It elicits and addresses parents' concerns about children's language, motor, self-help, early academic skills, behaviour and social-emotional/mental health. It consists of 6–18 questions. It takes about two minutes to administer and score if conducted as an interview. Less time is required if parents complete the brief questionnaire in waiting or exam rooms or at home prior to an encounter. Maths skills can be assessed in children aged four and older. The tool has not yet been evaluated in the UK.	0 to 8 years	Practitioner	Screening	No	PEDs
The Parent Report of Children's Abilities (PARCA-R)	The PARCA-R is designed to identify preterm children who are at risk for developmental delay. It is used as a neurodevelopmental outcome measure in observational studies and clinical trials and as a screening tool in child development clinics. It takes no more than 15 minutes to complete.	Preterm children aged 2 years	Parent	Screening	No	EPICURE
The Early Math Diagnostic Assessment (EMDA)	The EMDA is a norm-referenced assessment of early number skills for use with children aged 4 years and above. It has not yet been norm-referenced in the UK, however.	Children aged 4 and older	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
KeyMaths3 UK	KeyMaths3 UK is designed to assess the understanding and application of critical maths concepts and skills, from counting through algebraic expressions. It has recently been norm-referenced for use in the UK.	Children aged 4.5 or older	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Brigance Early Childhood Screener III	The Brigance Early Childhood Screen III is a comprehensive assessment of cognitive skills associated with children's preschool achievement. It includes a battery of measures which specifically consider children's counting capabilities, their awareness of the one-to-one principle and cardinality, and their recognition of Arabic numerals.	Children aged 3 to 5	Practitioner	Assessment	Teacher	Curriculum associates international
Number Knowledge test	The Number Knowledge test was designed to measure the intuitive knowledge of number that the average child has available at the age-levels of 4, 6, 8 and 10 years.	Children aged 4 and older	Practitioner	Assessment	Teacher	Amazon AWS

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
British Ability Scales, Third Edition (BAS3)	BAS3 comprises a battery of individually administered tests designed for use by educational and clinical psychologists to assess children or adolescents who have been referred to them for a wide range of reasons, including learning and behavioural difficulties. It enables assessment of different aspects of a child's current intellectual functioning across the age range 3 years (3:00) to 17 years 11 months (17:11). It comprises 20 subtests, each measuring particular types of knowledge, thinking and/or skills. The Early Number Concepts Scale assesses children's ability to recite numbers up to 10, their awareness of one-to-one correspondence, matching and classifying capabilities, their awareness of ordinality and cardinality, and their recognition of Arabic numerals.	3 to 17 years	Practitioner	Diagnostic	Certified professional with graduate qualification	GL Assessment
The Bracken School Readiness Assessment (BSRA)	The Bracken School Readiness Assessment, Third Edition (BSRA-3) helps to determine if a child is ready for school. It includes five subtests to assess basic concepts related to school readiness: colours, letters, numbers/counting, size/comparison and shapes. It is for children aged 3 years to 6 years 11 months. It takes 10–15 minutes to complete.	3 years to 6 years 11 months	Practitioner	Diagnostic	No	Pearson
Wechsler Preschool & Primary Scale of Intelligence – Fourth UK Edition (WPPSI-IV UK)	The WPPSI-IV UK measures cognitive development for children between 2 years 6 months to 7 years 7 months. The Primary Index scales include: verbal comprehension index, visual spatial index, working memory index, fluid reasoning index, processing speed index. The Ancillary Index scales include: vocabulary acquisition index, nonverbal index, general ability index and cognitive proficiency index. It takes 30–60 minutes to administer, depending on the age of the child.	2 years 6 months to 7 years 7 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
The Wechsler Individual Achievement Test –Third Edition (WIAT-III)	The Wechsler Individual Achievement Test -Third Edition is a UK-standardised assessment of numerical operations for use with children aged 4 years and above.	Children aged 4 and above	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson

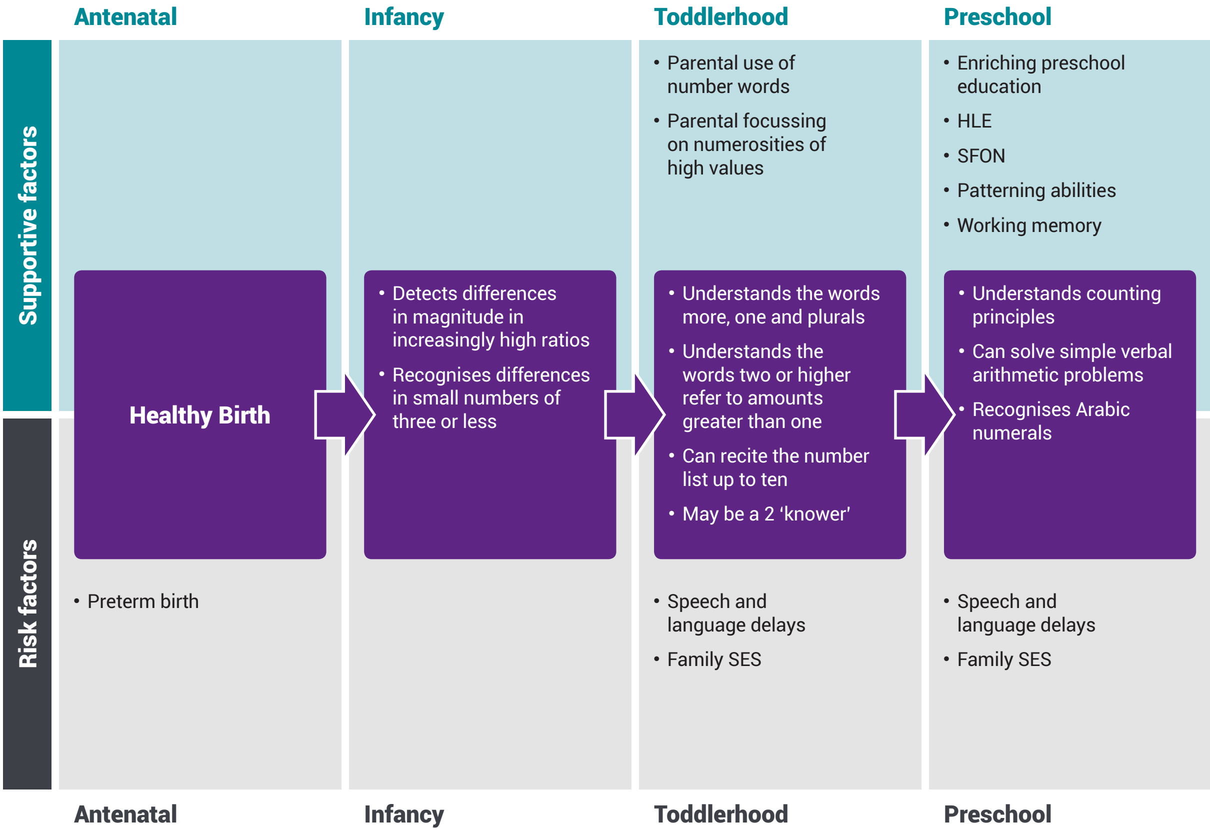
Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Kaufman Assessment Battery for Children, Second Edition (KABC-II)	The Kaufman Assessment Battery for Children, Second Edition (KABC-II) measures cognitive ability and processing skills in children aged 3 years to 18 years. The following scales are included: sequential processing, simultaneous processing, learning ability, planning ability and knowledge. It takes 25–70 minutes to administer, depending on the model chosen.	3 years to 18 years	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Test of Early Mathematics Ability – 3 (Tema-3)	The TEMA-3 measures informal and formal concepts in numbering skills, number-comparison facility, numeral literacy, mastery of number facts, calculation skills, and understanding of concepts. It can be used to screen for readiness, measure progress, or determine specific strengths and weaknesses. Has yet to be norm-referenced in the UK.	Ages 3 to 8	Practitioner	Assessment	Teacher	ATP Assessment
Preschool Early Numeracy Scales (PENS)	The PENS aims to help teachers make more detailed discriminations in children's early numerical skills to inform instruction. Skills measured include one-to-one counting, cardinality, counting subsets, subitising, number comparison, set comparison, number order, numeral identification, set-to-numerals, story problems, number combinations, and verbal counting. It takes approximately 40 minutes to administer.	Ages 3 to 5	Practitioner	Assessment	Practitioners with training in the measure	Publication explaining validity and use
Tools for Assessment in Early Mathematics (TEAM)	Tools for Early Assessment in Math (TEAM) is an assessment screening tool for students in Grades PreK-5. It is meant to be used in conjunction with mathematics curriculums to assess early numerical progress.	Ages 3 to 10	Practitioner	Curriculum based assessment	Teacher	McGraw-Hill
Early Years Foundation Stage Profile (EYFSP)	A summary of educational attainment taking place at the end of reception. The teacher provides an individual assessment of the child's level of attainment in communication and language, physical development, personal and social emotional development, literacy, mathematics, understanding the world and expressive arts and design. The section on mathematics (ELOs 11 & 12) is particularly relevant to this competency, particularly when it comes to assessing children's counting and arithmetic capabilities.	Children who will be 5 on or before the last day of the academic year	Practitioner	Educational assessment	Practitioners at registered early years providers	Government website

5.7 Implications for practice and commissioning

Figure 5.6 provides an overview of the key competencies involved in the development of children's numerical understanding and the processes which support or interfere with its development. More details about this trajectory and age-appropriate methods for assessing progress are summarised further in table 5.3 at the end of this chapter.

FIGURE 5.6

Key competencies in the development of children's theories of number and processes which support or interfere with typical development



Source: EIF

Summary of key messages

Key messages: genetic and antenatal factors

- The extent to which processes occurring during the antenatal period specifically influence children's later numerical development has yet to be fully understood.
- There is some evidence showing that a preterm birth may create specific risks to children's numerical understanding, although mathematical difficulties may not be detected until the primary school years.
- Few twin studies have specifically considered the heritability of children's numerical capabilities during preschool. Those that have observe it to be low (.18). Estimates involving the heritability of mathematics achievement in older primary school-aged children observe it to be relatively high, (.57), although the extent to which such estimates reflect gene/environment correlations remains debated.

Key messages: infancy

- The majority of infants are born with competencies sufficient for them to detect differences in continuous magnitude and small numbers. These capabilities are present at birth and become increasingly more precise throughout the early years and childhood.
- There is *preliminary* evidence from a single study to suggest that individual differences in magnitude discrimination in infancy is associated with children's magnitude discrimination and verbal counting capabilities at age 3.5.

Key messages: toddlerhood

- Children begin to learn the words associated with numbers during the second year of life. Researchers believe that the acquisition of number language increases children's awareness of numerosity and precise number discrimination.
- Number-related words learned during the second and third years include 'more', 'one', 'all gone' and specific numerosities (e.g. two, three, four). Some precocious toddlers are also able to recognise specific Arabic numerals.
- Initially, toddlers will recognise number words as referring to numerosities greater than one, but they will not associate the word with a specific numerosity.
- There is preliminary evidence to suggest that toddlers' ability to discriminate differences in small amounts at age two is predictive of their counting capabilities at age five.
- During the end of the third year, some children will gradually come to understand cardinal number values by associating the number names with specific numerosities, starting with sets of two, followed by three and then four.
- Parents and others support this process by highlighting the cardinal value of number sets and increased use of large number-talk (e.g. emphasising the value of larger numerosities).
- Parents' use of number words is consistently associated with family income.
- Counting skills are consistently associated with children's verbal ability, although this relationship is likely explained by children's more specific understanding of number words.

Key messages: ages three to five

- Between the ages of three and five, most children master the principles associated with counting and can solve verbal arithmetic problems. Many children will also be able to recognise the Arabic numerals associated with number by the end of their fourth year.
- Children's knowledge of the counting principles and arithmetic is associated with their small and large number discrimination capabilities, as well as the extent to which they spontaneously focus on numerosity within their environments.
- Counting and arithmetic problem-solving capabilities are also consistently associated with the executive functions and working memory in particular.
- Children's awareness of number words, number symbols and the counting principles is consistently associated with the quality of the home *numeracy* environment. Number games and other formal numerical learning activities are specifically associated with children's understanding of the counting principles and numeral recognition.
- Studies consistently show that children's verbal ability, and knowledge of number words in particular, strongly predicts their mastery of the counting principles and recognition of Arabic numerals.

- Knowledge of the principles associated with counting and awareness of the Arabic numerals during the fifth year is consistently found to be a strong predictor of children's later achievement in mathematics during primary and secondary school.
- Learning gaps in children's understanding of mathematical principles present at the beginning of primary school tend to remain throughout children's education.
- Child-level signals of risk associated with children's numerical understanding may be present between the ages of four and five but are not reliably diagnosed until children enter primary school.
- The quality of the home numeracy environment is consistently associated with family income and parent education, in particular.
- Enriching mathematics curriculums embedded in the preschool offered to low-income children are consistently associated with short-term gains in preschool children's mathematics achievement.

What are the implications for early intervention?

The evidence presented in this chapter consistently confirms a strong and persistent income-related gap in children's early numeracy development. This gap is present at the time children enter primary school and persists until they enter the workforce. At the age of five, this gap principally reflects differences in high- and low-income children's understanding of counting and arithmetic principles. While the reasons for this gap remain debated, studies suggest that much can be explained by differences in low- and high-income children's home numeracy environments.

There is also evidence showing that some differences in early numerical understanding may be associated with differences in children's ability to discriminate differences in numerosity, as well as processes involving the executive functions (working memory in particular) and language capabilities. However, these difficulties are not reliably detected until children enter primary school. Early intervention activities targeting the early years are therefore likely to provide the greatest benefits if offered to low-income families at the targeted-selective level.

Universal

There is good evidence to suggest that an increased focus on numbers in the home environment is positively associated with children's understanding of the principles associated with counting and arithmetic. However, studies also show that number-talk occurs relatively rarely in parent–child conversations in comparison to other topics. **All families are therefore likely to benefit from messages which raise parents' awareness of the importance of number-talk during the early years.**

While parents already receive some of these messages (for instance, common advice is to engage children in counting rhymes), more specific advice aimed at increasing children's awareness of numerosity is likely to be especially helpful. For example, parents might be provided with tips for engaging their children in small number-talk (three biscuits, six cars, two cups, and so on) and large number-talk (such as counting up and down larger numerosities involving steps or money). Parents should also be made aware of various numeracy activities which will increase preschool children's awareness of formal mathematics, including their recognition of Arabic numerals and the purpose of number signs. Activities known to increase children's formal numerical knowledge include number games and sticker books, as highlighted at the end of this review.

Messages about the importance of parent–child number-talk can be promoted through health visiting, children's centres, nurseries and preschools. The Educational Endowment Foundation

Early Years Toolkit[790] observes that many preschool curriculums targeting children's early numeracy are relatively low-cost, but can provide benefits of up to six months when offered to all children universally. While these interventions typically benefit all children, they are likely to provide the greatest impact when offered to low-income children, as described below.

Targeted-selective

The evidence described in this chapter highlights the need for enriching early numeracy curriculums for low-income preschool children. The *Foundations for Life* review did not identify any interventions which provided specific advice on parent–child number-talk, although it was clear that this was a component of some of the evidence-based two-generation programmes identified during the initial literature review.[791] For example, evaluations of the Head Start programme in the United States consistently demonstrate short-term improvements in children's understanding of numerical concepts, particularly when offered to younger preschool children (aged 3) in comparison to older preschool children (aged 4).[792]

There is no specific Head Start mathematics curriculum, as individual charters are free to decide which curriculums they make available, although many make use of evidence-based options. While EIF has not yet evaluated the evidence underpinning early mathematics curriculums, two preschool programmes identified as having good evidence through the US What Works Clearinghouse include Pre-K Mathematics[793] and Building Blocks for Math.[794,795] Both curriculums are teacher-led and can be readily embedded into existing preschool curriculums. Both programmes also include content which aims to bridge children's informal and formal numerical knowledge through hands-on activities at school, as well as components which help parents promote numeracy within their homes.

Targeted-indicated

As mentioned previously, dyscalculia and other MLDs are not reliably diagnosed until children enter primary school.[796,797] However, late preschool represents a time when potential risks may first become apparent.[798] Such risks include difficulties recognising or remembering precise small number amounts, and/or mastering the counting principles. Should difficulties be apparent, practitioners should also consider whether other cognitive difficulties commonly associated with children's numerical understanding are additionally present. Examples of associated capabilities include children's working memory, attention control and verbal ability.[799] Further recommendations about how children's numerical understanding can be supported through health visiting, children's centres, childcare and nursery are provided at the end of this review.

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790 See: https://educationendowmentfoundation.org.uk/evidence-summaries/early-years-toolkit/early-numeracy-approaches/

791 Asmussen, K., Feinstein, L., Martin, J., & Chowdhry, H. (2016) *Foundations for Life: What works to support parent-child interaction in the early years?* Early Intervention Foundation. https://www.eif.org.uk/report/foundations-for-life-what-works-to-support-parent-child-interaction-in-the-early-years

792 US Department of Health and Human Services (2010). *Head Start impact study final report: Executive summary*. https://www.acf.hhs.gov/sites/default/files/opre/executive_summary_final.pdf

793 See: https://ies.ed.gov/ncee/wwc/Intervention/425

794 Clements, D. H., Sarama, J. H., Spitler, M. E., Lange, A. A., & Wolfe, C. B. (2011). Mathematics learned by young children in an intervention based on learning trajectories: A large-scale cluster randomized trial. Journal for Research in Mathematics Education, 4, 127–166.

795 See: https://ies.ed.gov/ncee/wwc/Intervention/425

796 Kaufmann, L., Mazzocco, M. M., Dowker, A., von Aster, M., Goebel, S., Grabner, R., ... & Rubinsten, O. (2013). Dyscalculia from a developmental and differential perspective. *Frontiers in psychology*, *4*, 516.

797 Butterworth, B. (2005). The development of arithmetical abilities. *Journal of Child Psychology and Psychiatry*, *46*(1), 3–18.

798 Kaufmann, L., & von Aster, M. (2012). The diagnosis and management of dyscalculia. *Deutsches Ärzteblatt International*, *109*(45), 767.

799 Mazzocco, M. M., & Myers, G. F. (2003). Complexities in identifying and defining mathematics learning disability in the primary school-age years. *Annals of dyslexia*, *53*(1), 218–253.

TABLE 5.3

Developmental competencies – associated risks and methods of assessing children's theory of numbers

Age	Developmental competency	Manifestation/context	Factors which make a difference	Assessment
0–12 months	Discriminates differences in magnitude in ratios of 4:3 Can recognise differences in number in number sets of three or less Recognises differences in ordinality Is aware of similarities in number across modalities	Perceptual awareness during daily activities		
12–24 months	Understands the word one and terms such as 'all gone' Understands various determiners Will search for missing objects in sets of three or less	Parent–child interaction		The Ages & Stages of Numeracy Development Checklist
24–36 months	Can recite the count sequence up to 10 Knows that number words refer to numerosities Begins to associate number words with cardinal values	Parent–child interaction Number games and number activities	Parental use of large and small number-talk Speech and language delays Family SES	The Ages & Stages of Numeracy Development Checklist
36–60 months	Learns to understand the cardinal values 2–4 Can perform simple addition and subtraction operations Can recognise Arabic numerals and accurately associate them with specific values under 10	Parent–child interaction Number games and number activities Formal mathematics learning at home and at school	Opportunities to engage in formal and informal mathematics learning Working memory capabilities Speech and language delays Family SES	A wide variety of validated measures exist for assessing children's numerical understanding between the ages of 3 and 5

Part 3: Language development

In the previous chapters, we introduced three core knowledge systems which allow children' to understand the basic properties of objects, the intentions of others and principles associated with counting and numerical relationships. In this section, we discuss children's early understanding of language.

Depending on where one sits on the nativist/constructivist divide, language might be viewed as another core system, which is governed by a dedicated language acquisition device (LAD) which allows humans to impose a grammar on to the things they see and hear around them to form meaningful representations that also serve a communicative purpose.[800] A pure nativist view thus maintains that all children are born with this device and require little more than exposure to language to understand how to put it into use. Those on the constructivist side (or social-interactionists in the case of language), by contrast, acknowledge that while infants are biologically prepared to learn language, much more than exposure is required for them to sufficiently master it.[801] In this respect, children benefit immensely from adult scaffolding that simplifies the complexities of language and provides them with opportunities to use and master it.[802]

While we do not take sides in these arguments, we do believe that it is useful to recognise the unique role language plays in children's cognitive development. From this perspective, we consider language to be a biologically primary system that is both exclusive and universal to all human beings.[803] We also view language to be cognitively transformative, by providing children with an efficient means to represent and combine information from the environment in a way that can be communicated with others.[804,805] We therefore recognise that while language develops as a result of the core knowledge systems described in this review, it also fundamentally changes them by providing children with words to describe and think about the concepts learned within each system.

For most children, this transformation occurs at the end of the first year, when the child comes to understand that words are associated with objects and those words can be used to share information with others.

- As we described in chapter 3, children's knowledge of object words permits a conceptual understanding of an object's essential nature which then can be abstracted and manipulated to make predictions and solve problems about object relationships.
- As described in chapter 4, the acquisition of language also modifies children's understanding of thought processes by giving children a means to talk to others about what they think, know and feel. Understanding the intentions, thoughts and feelings of others is assumed to lay the foundation for cooperation and other prosocial behaviours once children enter school.

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800 Chomsky, N. (2002). *Syntactic structures*. Walter de Gruyter.

801 Bruner, J. (1983). *Child's talk: Learning to use language*. New York: W.W. Norton.

802 Tomasello, M. (2009). *Constructing a language*. Harvard University Press.

803 Lenneberg, E. H. (1967). The biological foundations of language. *Hospital Practice*, *2*(12), 59–67.

804 Spelke, E. S. (2017). Core knowledge, language, and number. *Language Learning and Development*, *13*(2), 147–170.

805 Waxman, S. R., & Lidz, J. L. (2006). Early world learning. *Handbook of child psychology*.

- As we described in chapter 5, knowledge of the words associated with numbers also helps children to understand precise cardinal values higher than three, thereby enabling them to understand differences of more and less involving higher number values with great precision. These skills are also strongly associated with children's mathematical understanding once they enter school.

In chapter 6 we first describe the key components of language and how they relate to other aspects of children's development. We then describe the different stages of language development, factors that support children's language development or place it at risk, and the potential impact of children's language development on later-life outcomes.

6. Language development during the first five years

6.1 What is it?

It has been argued that language development is one of the most complex and important achievements of childhood. Language is the medium through which people form and maintain relationships, learn and develop cognitive skills, create and define a sense of identity, and navigate the world. Children entering school with robust oral language abilities have significantly improved chances of positive long-term outcomes in literacy development, educational attainment, mental health, employment and social inclusion.[806,807,808,809]

Language can be defined as the systematic and conventional use of sounds, signs or written symbols used for the purpose of communication or self-expression.[810] It is *symbolic* in that it can represent an object, sound, event or idea which is fully independent of any specific features associated with its entities. It is *systematic* in that it entails a set of rules or patterns with which to encode meaning. It is *conventional* in that it is an essentially arbitrary system which is shared or 'agreed' by a particular group or society. There are more than 6,000 languages spoken around the world and so children growing up in each of these different language communities must learn the specific conventions of the language or languages spoken in that social group.

Language is traditionally described in terms of four separate components.[811]

1. **Phonology:** the system of contrastive relationships between sounds in a language which convey meaning (that 'cat' differs in meaning from 'hat', 'pat' and 'sat'); and the rules which govern their combination (that 'pling' is a possible word in English but 'gnilp' is not).
2. **Semantics:** words and their meanings (also referred to as lexicon).
3. **Pragmatics:** the child's understanding of how to use language in social situations (also referred to as discourse), as summarised in box 6.1.
4. **Grammar:** involving morphology and syntax:
   - morphology – parts of words which convey meaning, often grammatical (such as plural endings, past tense markers and auxiliaries);
   - syntax – the rules which govern how words are put together to form sentences (for example, the knowledge that 'the cat eats the fish' means something different from 'the fish eats the cat').

806 Duncan, G., Dowsett, C., Classens, A., Magnuson, K., Huston, A., Klebanov, P., Pagani, L., Feinstein, L., Engel, Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School Readiness and Later Achievement. *Developmental Psychology, 43*, 1428–1446.

807 Law, J., Garrett, Z., & Nye, C., 2003/09, Speech and language therapy interventions for children with primary speech and language delay or disorder. *Cochrane Database of Systematic Reviews*, 2003 (Issue 3, updated 2009) (Online), CD004110– CD004110.

808 Schoon, I., Parsons, S., Rush, R., & Law, J. (2010) Childhood language problems and adult literacy: a twenty nine year follow-up study. *Pediatrics*, *125*(3), 459–466.

809 Tomblin, J. B. (2008). Validating diagnostic standards for SLI using adolescent outcomes. In Norbury, C. F., Tomblin, J. B., & Bishop, D. V. M. (eds), *Understanding Developmental Language Disorders* (pp. 93–114). Hove: Psychology Press

810 Crystal, D. (1995). *The Cambridge Encyclopedia of the English Language*. London: BCA.

811 Saxton, M. (2010). *Child language: Acquisition and development*. Sage.

Each one of the language components includes a receptive and expressive element. Receptive elements pertain to children's understanding of language, whereas expressive elements involve children's ability to reproduce and communicate with language.

Box 6.1: Seven functions of language

- **Instrumental:** Using language to express a need (e.g. 'more juice')
- **Regulatory:** Using language to ask or tell someone what to do (e.g. 'get me juice')
- **Interactional:** Using language as a way to communicate and form relationships with others (e.g. 'I love you')
- **Personal:** Using language as a form of communicating information about the self (e.g. 'I am a big boy'), including feelings, thoughts and desires
- **Heuristic:** Using language to gain knowledge about the environment (e.g. 'what is that?')
- **Imaginative:** Using language to tell stories and joke and talk about things that are imagined
- **Representational:** Using language to convey facts and information

Source: Halliday, M. A. K. (1973). *Explorations in the Functions of Language*. London: Edward Arnold

6.2 What other competencies are associated with children's language development?

In its broadest sense, language acquisition can be seen as the mapping of sounds or gestures on to meanings.[812] Children must therefore be able to infer the communicative intentions of their communicative partner in order to derive meaning from verbal interactions, as well as differentiate individual sounds and sound sequences. These two activities are commonly referred to as *intention-reading* and *pattern-finding,* as we describe below.

Intention reading

As described in chapter 4, children are born with certain biases which allow them to detect or read the intentions of others. These biases include a discernible preference for human faces and voices and the ability to track another person's gaze.[813] By four months, most infants can discern, within 250 metres, whether a person's eye-gaze is towards or away from them and whether the individual is behaving in a socially contingent way.[814] In fact, if caregivers do not respond to the infant's gaze through changes in facial expression that infants can detect, infants often become very distressed.[815]

Early parent–child interactions help infants learn the basic rules of reciprocal social interaction. However, it is not until the parent and caregiver share their attention towards a third object that true word learning begins. As described in chapter 3, this typically occurs when the infant is between nine and 10 months of age. These 'triadic' interactions not only

812 Tomasello, M. (2009). *Constructing a language*. Harvard University Press.

813 Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Faraguna, D., & Csibra, G. (2005). Newborns' preference for face-relevant stimuli: Effects of contrast polarity. *Proceedings of the National Academy of Sciences of the United States of America, 102*(47), 17245–17250.

814 Striano, T., Henning, A. and Stahl, D. (2005), Sensitivity to social contingencies between 1 and 3 months of age. *Developmental Science, 8*, 509–518.

815 Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child psychiatry, 17*(1), 1–13.

require that caregiver and child attend the same object or event – each partner must also *know* that the other is attending to the same object or event. This knowledge can only be achieved if one is aware of the direction of the other individual's eye gaze and is able to interpret the others' facial expressions and vocalisations as a form of social engagement. The child can then connect or 'map' the adult's word or phrase to the specific object of the shared attention.[816,817]

Not all communicative intentions are simple to interpret, however. For this reason, infants also rely on knowledge of social routines to ensure that their mappings of meanings are accurate and rich. Infants do this by creating a broad, joint attentional frame around the contexts in which caregiver utterances occur. In this respect, an utterance and point to an object in one joint attentional frame (such as getting dressed) may be interpreted differently from another (such as eating lunch).[818]

The infant's ability to imitate others also facilitates their acquisition of language. During the second year, toddlers can imitate the speech, actions and gestures of others to the extent that it can be viewed as a form of 'over-imitation.'[819] This over-imitation often includes unimportant and extraneous actions that are thought to reflect the infant's lack of certainty over which aspects of social interaction and language are important, and which are not. Over-imitation may nevertheless serve children well in acquiring cultural conventions of their family and friends.

Pattern-finding

Understanding where the words produced through adult speech begin and end is a daunting task. Figure 6.1 provides a spectrogram of the adult sentence 'show me the money'. Although the sentence consists of four words, the sound waves form anywhere between 1 or 10 segments (depending on how you view them) and these do not correspond neatly with the individual words. Spectrograms involving normal adult speech show, in fact, that there are more breaks within words than there are between them.[820]

FIGURE 6.1

A spectrogram from the sentence 'Show me the money'

Source: Reproduced from Turner, D., (no date) 'PSY 369: Psycholinguistics, Language Comprehension, Speech recognition', presentation. https://slideplayer.com/slide/8251809/

816 Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants.in C. Moore and PJ Dunham Eds. *Joint attention: Its origins and role in development.* Hillsdale, NJ: Erlbaum.

817 Bates, E., Benigni, L., Bretherton, I., Camaioni, L., & Volterra, V. (1979). *The emergence of symbols: Communication and cognition in infancy.* New York: Academic.

818 Liebal, K., Behne, T., Carpenter, M., & Tomasello, M. (2009). Infants use shared experience to interpret pointing gestures. *Developmental science, 12*(2), 264–271.

819 Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. Proceedings of the National Academy of Sciences, 104(50), 19751–19756.

820 Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274*(5294), 1926–1928.

Infants must therefore figure out which sound breaks are important and the extent to which they correspond with specific words. Researchers assume infants do this through a form of pattern recognition (also referred to as statistical learning) which allows them to keep track of how often syllables follow one another and then use this information to determine which sequences are meaningful.[821]

Determining where word breaks occur is simply the first of many patterns that infants must recognise. Table 6.1 summarises the sequences and rules children must recognise in order to perceive words and understand the grammatical rules which organise them. It is worth recognising that this list is not exhaustive and for every example, the process of pattern finding is not sufficient on its own for language development to occur. It must work in concert with the other competencies described in this report, including children's implicit theories of objects and their ability to anticipate the intentions of others.

TABLE 6.1

The patterns infants must find when learning their first words and sentences

First words	When learning their first words, infants must first 'spot' sequences of sounds which reoccur (where's your **milk**; you want some **milk** now? Mummy's got your **milk** for you).
Early words	When learning early word combinations, infants must identify reoccurring 'frames' which permit varying items in their 'slots' (more milk; more juice; more grapes; shoes on; hat on; coat on). As described in chapter 3, children do this by linking object categories to specific verbs and adjectives.
Simple sentences	Children come to understand the grammatical structure of simple sentences by identifying similarities between sentences even when different words are used. In other words, children must implicitly recognise the role of the subject, verb and object (mummy eat banana; daddy throw ball; dog lick hand).
Grammatical morphology	Children come to understand grammatical morphology through the use of verb and noun categories, theories regarding how grammatical morphemes are used differently. This is achieved in part by using the distributional regularities of speech, so noticing that 'the' and 'a' come before nouns; that -ing and -ed are attached to verbs.
Grammatical rule use	In order for children to learn not to **overgeneralise** rules they must be sensitive to the frequency with which they hear specific word and morphological combinations including the *absence* of some structures in the input which they might hypothesise should occur ('the girl giggled' but not 'the girl giggled the teddy'; 'I ate my dinner' but not 'I eated my dinner').

6.3 How does language impact children's development over time?

As we have described in previous chapters, children's language acquisition fundamentally transforms how information acquired through the other core knowledge systems is stored and applied. Once children reach primary school, language also becomes the medium through which all learning takes place. Without oral – and subsequently written language – the transmission of knowledge from one individual to another would not be possible. It is thought that language also facilitates the development of metacognitive skills, which allow children to reflect upon their own learning in ways which potentially increase learning efficiency.

[821] Saxton, M. (2010). *Child language: Acquisition and development*. Sage.

There is now also consistent evidence showing that linguistic differences in vocabulary and grammar predict differences in the ways in which perceptual information is processed.[822,823] For example, the English and Russian language differ in the number of words used to describe various shades of light blue, with Russian including many more terms. Studies show that Russian adults can detect differences in shades of blue much more quickly than English-speaking adults, but detect differences at the same rate when it comes to other colours. Researchers therefore suspect that culturally specific distinctions in language contribute to culturally-specific differences in perception.[824]

A similar phenomenon has been observed with respect to the adult processing of spatial relationships. For example, the English language makes a distinction between containment (put in) versus surface placement (put on). The Korean language also makes this distinction, but also has words (*kkita*) for describing tight-fitting containment (for instance, slotting in – as with a Lego brick).[825] Studies show that this distinction contributes to how young children perceive relationships between objects at the time they acquire language. However, non-Korean-speaking adults have great difficulty understanding this distinction, presumably as a result of 'inattentional blindness' stemming from their overreliance on the English spatial distinctions which do not align with the Korean.[826]

As we have described in previous chapters, children's ability to store and retrieve information in their long-term memory is also highly reliant on their language skills.[827,828] Researchers suspect that the acquisition of language helps children remember events and discuss them with others.[829,830] Such discussions are also associated with children's theory of mind capabilities, as conversations about shared memories often highlight differences in others' perspectives and feelings.[831] Similarly, children's language capabilities predict their autobiographical memories, which inform their representations of themselves and influence their behaviour within social relationships. Children's verbal skills are also thought to underpin the self-talk they use to regulate their feelings and behaviour.[832] In this respect, studies show that early language difficulties increase the risk of behavioural difficulties, whereas precocious linguistic skills decrease the risk.[833,834]

As we described in our report, *Language as a child wellbeing indicator*,[835] child language is also strongly associated with children's school readiness at the time they enter primary

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822 Regier, T., & Kay, P. (2009). Language, thought, and color: Whorf was half right. *Trends in cognitive sciences*, *13*(10), 439–446.

823 Roberson, D., Davies, I., & Davidoff, J. (2000). Color categories are not universal: replications and new evidence from a stone-age culture. *Journal of Experimental Psychology: General,* 129(3), 369.

824 Winawer, J., Witthoft, N., Frank, M. C., Wu, L., Wade, A. R., & Boroditsky, L. (2007). Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences*, *104*(19), 7780–7785.

825 Choi, S., McDonough, L., Bowerman, M., & Mandler, J. M. (1999). Early sensitivity to language-specific spatial categories in English and Korean. *Cognitive Development*, *14*(2), 241–268.

826 Mack, A., & Rock, I. (1998). Inattentional blindness: Perception without attention. *Visual Attention, 8*, 55–76.

827 Simcock, G., & Hayne, H. (2002). Breaking the barrier? Children fail to translate their preverbal memories into language. *Psychological Science, 13*(3), 225–231.

828 Simcock, G., & Hayne, H. (2002). Breaking the barrier? Children fail to translate their preverbal memories into language. *Psychological Science, 13*(3), 225–231.

829 Friedman, W. J. (2004). Time in autobiographical memory. *Social Cognition, 22*, 591–605.

830 Friedman, W. J. (2005). Developmental and cognitive perspectives on humans' sense of the times of past and future events. *Learning and Motivation, 36*(2), 145–158.

831 Carpendale, J. I., & Lewis, C. (2004). Constructing an understanding of mind: The development of children's social understanding within social interaction. *Behavioral and Brain Sciences, 27*(01), 79–96.

832 Cole, P. M., Armstrong, L. M., & Pemberton, C. K. (2010). *The role of language in the development of emotion regulation.*

833 Conway, L. J., Levickis, P. A., Mensah, F., McKean, C., Smith, K., & Reilly, S. (2017). Associations between expressive and receptive language and internalizing and externalizing behaviours in a community-based prospective study of slow-to-talk toddlers. *International journal of language & communication disorders*, *52*(6), 839–853.

834 Valloton, C. and Ayoub, C. (2011) Use your words: the role of language in the development of toddlers' self-regulation. Early Childhood Research Quarterly, 26(2), 169–181.

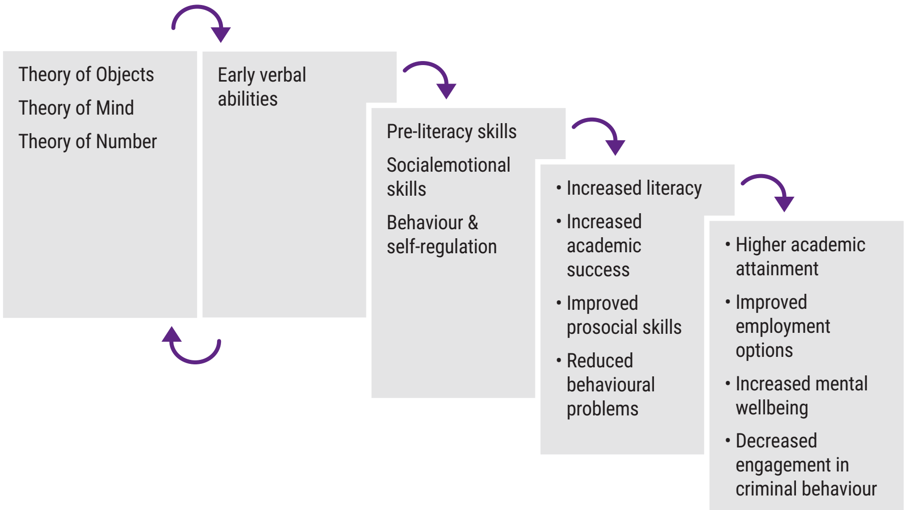
835 Law, J., Charlton, J., & Asmussen, K. (2017). *Language as a child wellbeing indicator*. Early Intervention Foundation. https://www.eif.org.uk/report/language-as-a-child-wellbeing-indicator

school. Once in school, language difficulties then predict a wide variety of poor educational and behavioural outcomes.[836] For example, a 2011 Australian cohort study observed that language difficulties present at age four were associated with language difficulties at age seven.[837] These language difficulties, in turn, predicted a wide variety of other school-related problems, including low literacy and social and emotional difficulties.[838] UK-based studies additionally show that language difficulties present at age seven continue to remain with children throughout their academic careers, as well as reduce their employment opportunities once they leave school.[839,840,841]

In sum, a wide body of evidence shows that children's early language capabilities are highly associated with later academic, social, emotional and behavioural outcomes. As illustrated in figure 6.2, early verbal abilities are built upon children's development within the three core knowledge domains described in previous chapters. Children's language skills and core knowledge within these domains then reciprocally influence each other to support the skills associated with children's school readiness, which in turn continue to influence children's academic outcomes for the entirety of primary and secondary school.

FIGURE 6.2

Potential developmental cascades involving children's early language development



Source: EIF

836 Bishop, D. V., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of child psychology and psychiatry*, *31*(7), 1027–1050.

837 Prior, M. Bavin, E., and Ong, B. (2011). Predictors of school readiness in five- to six-year-old children from an Australian longitudinal community sample, *Educational Psychology, 31*, 3–16.

838 McKean C, Reilly S, Bavin E, Bretherton L, Cini E, Conway L, Cook F, Eadie P, Prior M, Wake M, Mensah F. (2017). Language outcomes at 7 years: early predictors and co-occurring difficulties. *Pediatrics, 139*(3), e20161684.

839 Tomblin, J. B. (2008). Validating diagnostic standards for specific language impairment using adolescent outcomes. In Norbury, C. F., Tomblin, J. B., & Bishop, D. V. M. (eds), *Understanding developmental language disorders: from theory to practice*. Hove: Psychology Press.

840 Snowling, M. J., Adams, J., Bishop, D. V. M., & Stothard, S. E. (2001). Educational attainments of school leavers with a preschool history of speech-language impairments. *International Journal of Language & Communication Disorders, 36*(2), 173–183.

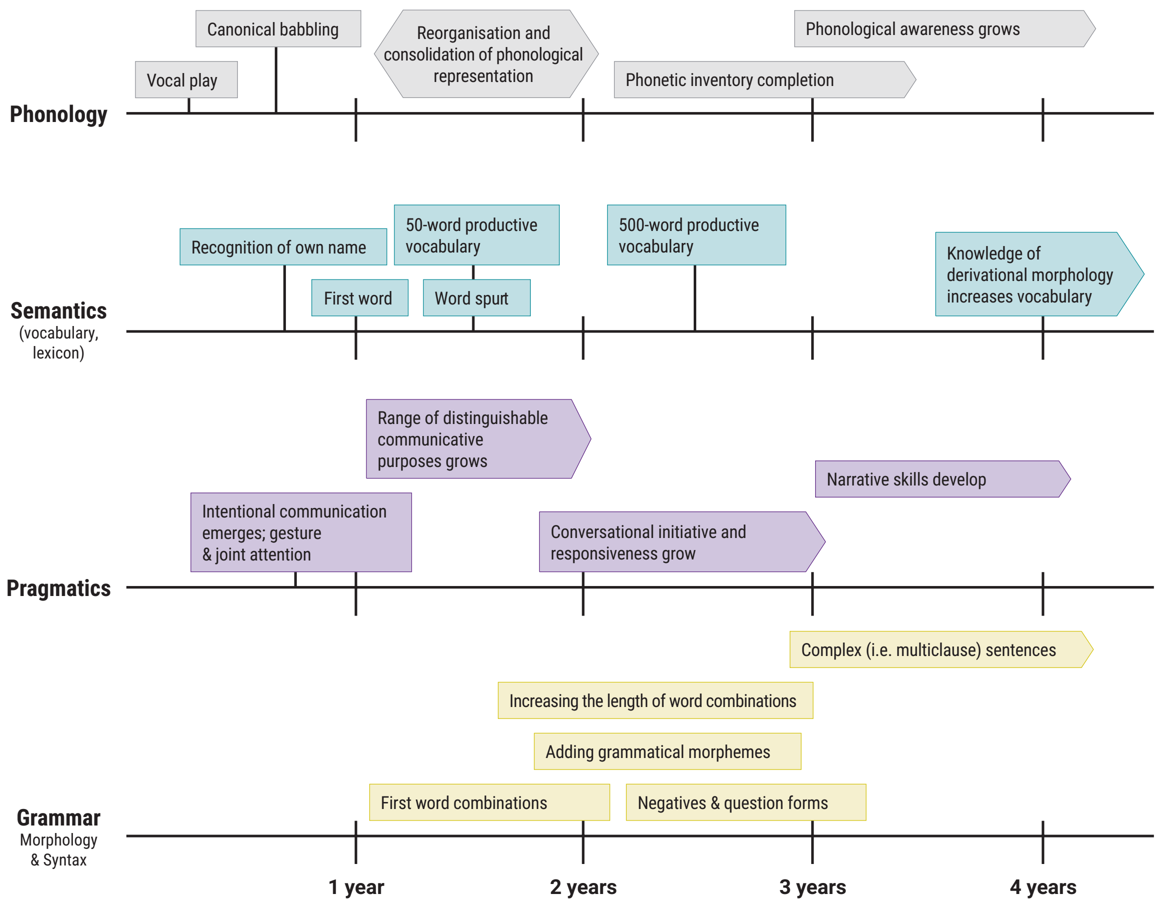
841 Snowling, M. J., Bishop, D. V. M., Stothard, S. E., Chipchase, B., & Kaplan, C. (2006). Psychosocial outcomes at 15 years of children with a preschool history of speech-language impairment. *Journal of Child Psychology and Psychiatry, 47*(8), 759–765.

6.4 How does children's understanding and use of language develop during the first five years of life?

Language learning is an extremely complex process, involving the child's ability to perceive, derive meaning from and reproduce the verbal information in his or her environment. Figure 6.3 provides a summary of key milestones occurring within the four linguistic components described at the beginning of this chapter: phonology, semantics, pragmatics and grammar. Although the development of these four components takes place in a predictable sequence, they are highly interdependent and involve both receptive and expressive elements. Below, we describe in greater detail how these four components develop during early childhood within the periods of infancy, toddlerhood and preschool.

FIGURE 6.3

Milestones in the development of children's language during the first five years



Source: Reproduced from Bjorklund, D. F., & Causey, K. B. (2017). *Children's thinking: Cognitive development and individual differences*. London: Sage Publishing

Infancy (0–12 months)

Phonology

Phonology refers to the systematic organisation of sounds, which is both a perceptual and cognitive process. As described in section 6.2, children must learn to distinguish differences in the speech sounds (phonemes) of their native language, recognise patterns within these sounds and map these patterns on to meanings. Children's must then also understand how these sounds can be produced with their mouths and vocal chords in a way that is meaningful to others. Much of the language learning that takes place during the child's first year thus involves the refinement of phonological perception and reproduction.

Phonological processes begin when the infant is still in the womb.

- By 23 weeks, the foetus can hear the muffled tones of the mothers' voice.[842]
- By 29 weeks, the foetus can discriminate differences in syllables (such as 'ga and ba').[843]
- Within hours of birth, infants show a clear bias for human speech and measurable preference for their mother's voice.[844,845]
- Within days of birth, infants can also discriminate differences between the language of their mother and another language.[846,847]

It is thought that the foetus/infant makes these discriminations on the basis of prosody, involving differences in the stress patterns, syllable shapes and intonation of various language systems.

Remarkably, during the first few months of life, infants appear to be able to perceive most, if not all, of the phonemes present in *all* human languages.[848] Some have therefore argued that the human brain is biologically hard-wired to recognise phonemic differences in human speech.[849] However, during the first six months of life, infants gradually lose this capability through a process referred to as 'perceptual narrowing', which increases infants' proficiency in their own language, but decreases their ability to discriminate phonological differences in others. The reasons for perceptual narrowing remain debated, but its occurrence is frequently provided as evidence of the 'use it or lose it' synaptic pruning processes taking place during the child's first two years (see chapter 2 for further discussion).[850] From an evolutionary standpoint, it is believed that perceptual narrowing is a fundamentally adaptive process, as it provides infants with the flexibility to master skills which provide the greatest value within their given social group.[851]

Interestingly, infants exposed to more than one language retain phonological flexibility for much longer periods of time in comparison to infants raised in monolinguistic homes. This flexibility allows infants to remain sensitive to a wide variety of phonemic contrasts, while at the same time recognising differences between two or more phonological systems.[852,853] Infants raised in multilingual homes can therefore master more than one language in roughly the same period of time as infants raised in monolinguistic homes.[854]

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842 Moore, J. K., & Linthicum Jr, F. H. (2007). The human auditory system: a timeline of development. *International Journal of Audiology*, *46*(9), 460–478.

843 Mahmoudzadeh, M., Dehaene-Lambertz, G., Fournier, M., Kongolo, G., Goudjil, S., Dubois, J., ... & Wallois, F. (2013). Syllabic discrimination in premature human infants prior to complete formation of cortical layers. *Proceedings of the National Academy of Sciences*, *110*(12), 4846–4851.

844 Vouloumanos, A., & Werker, J. F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. *Developmental science*, *10*(2), 159–164.

845 DeCasper, A. J., and Fifer, W. P. (1980). Of human bonding: newborns prefer their mothers' voices. *Science*, 6, 1174–1176.

846 Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29,* 143–178

847 Moon, C., Cooper, R., & Fifer, W. (1993). Two-day-olds prefer their native language. *Infant Behavior and Development, 16*, 495–500.

848 Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science, 171*, 971–974.

849 Trehub, S. E. (1976). The discrimination of foreign speech contrasts by infants and adults. *Child Development*, *47*, 466–472.

850 Phillips, D. A., & Shonkoff, J. P. (eds) (2000). *From neurons to neighborhoods: The science of early childhood development*. National Academies Press.

851 Pascalis, O., Loevenbruck, H., Quinn, P. C., Kandel, S., Tanaka, J. W., & Lee, K. (2014). On the links among face processing, language processing, and narrowing during development. *Child Development Perspectives*, *8*, 65–70.

852 Bosch, L., & Sebastián-Gallés, N. (2001). Evidence of early language discrimination abilities in infants from bilingual environments. *Infancy*, *2*(1), 29–49.

853 Petitto, L. A., Katerelos, M., Levy, B. G., Gauna, K., Tetreault, K., & Ferraro, V. (2001). Bilingual signed and spoken language acquisition from birth: Implications for the mechanisms underlying early bilingual language acquisition. *Journal of child language*, *28*(2), 453–496.

854 Werker, J. F., Byers-Heinlein, K., & Fennell, C. T. (2009). Bilingual beginnings to learning words. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1536), 3649–3663.

Much of this initial phonological learning takes place through listening.[855] However, sensitive caregivers also make speech perception easier through their use of infant-directed speech (IDS; also referred to as child-direct speech, or 'motherese'). As described in chapter 2, IDS is a form of exaggerated adult speech involving a higher pitch, a wider range of vocal tones, a slower rate and shorter phrases.[856,857,858] Studies observe that the use of IDS is associated with infants' awareness of phonemes which, over time, eventually facilitates the learning of new words.[859,860,861] Studies show that infants exposed to higher levels of IDS during their first year typically master their first words before those exposed to less IDS.[862]

When it comes to reproducing the sounds of language, children must learn to control their mouth, tongue and larynx to form sounds which are meaningful for others. Learning to speak benefits from practice, as well as feedback from sensitive caregivers. Most of the sounds made by the newborn infant are believed to be reflexive. By two months, however, infants are making more purposeful sounds which are interpreted as meaningful by others. These extended vowel-like vocalisations, often referred to as 'cooing', can often be heard during parent–infant face play.[863] During these games, the infant's coos and gurgles are frequently acknowledged by a smile or comment from the parent, which both reinforces the sound and conveys the message that the infant is someone worth communicating with. Early parent–infant interactions thus serve both a phonological and pragmatic purpose.

As the infant acquires greater vocal control, the range of vowel sounds become increasingly more varied to include consonants, raspberries, growls and squeals. By sixteen weeks, most infants will begin to utter single syllables with prolonged vowel or consonant sounds in a way that is viewed as true babbling. Infant babbling then continues throughout the first year until the child replaces babbling with words.

At around six months, *reduplicative* babbling (also referred to as *canonical* babbling) begins to emerge.[864,865] Reduplicative babbling is characterised by repeated syllables on a string ('bababa', 'dadada') which frequently resemble the consonant-vowel combinations used in the parents' language. So, English-speaking infants babble in English and Chinese-speaking infants babble in Chinese. Reduplicative babbling may occur during parent–child interactions but can also occur on its own. Some researchers therefore view reduplicative babbling as a form of linguistic 'practice' that paves the way for the production of the first words. Interestingly, deaf children do not engage in reduplicative babbling, but will similarly gesture if exposed to sign language in their homes.[866]

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855 Vouloumanos, A., & Waxman, S. R. (2014). Listen up! Speech is for thinking during infancy. *Trends in Cognitive Sciences*, *18*(12), 642–646.

856 Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Development*, 1497–1510.

857 Fernald, A., Taeschner, T., Dunn, J., Papousek, M., de Boysson-Bardies, B., & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of child language*, *16*(3), 477–501.

858 Song, J. Y., Demuth, K., & Morgan, J. (2010). Effects of the acoustic properties of infant-directed speech on infant word recognition. *The Journal of the Acoustical Society of America*, *128*(1), 389–400.

859 Kuhl, P.K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., et al. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science,277*(5326), 684–686.

860 Ma, W., Golinkoff, R. M., Houston, D., & Hirsh-Pasek, A., (2011). Word Learning in Infant- and Adult-Directed Speech, *Language Learning and Development, 7*, 209–225.

861 Graf Estes, K., & Hurley, K. (2013). Infant-directed prosody helps infants map sounds to meanings. *Infancy*, *18*(5), 797–824.

862 Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological science*, *24*(11), 2143–2152.

863 Oller, D. K. (2000). The Emergence of the Speech Capacity, Lawrence Erlbaum Associates, Mahwah, New Jersey.

864 Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech*. San Diego, CA: Singular Publishing.

865 Thelen E. (1991). Motor aspects of emergent speech: A dynamic approach. In Krasnegor, N. A., Rumbaugh, D. M., Schiefelbusch, R.L., & Studdert-Kennedy, M. (eds), *Biological and behavioral determinants of language development* (pp. 339–362). Hillsdale, NJ: Erlbaum.

866 Petitto, L. A. (2000). On the Biological Foundations of Human. *The signs of language revisited: An anthology to honor Ursula Bellugi and Edward Klima*, 447–471.

Between 10 and 14 months a variegated form of *non-reduplicative* babbling begins to emerge ('badabu', 'gabugee') which mimics some of the intonations and rhythms used in adult speech.[867,868] Infants can be heard engaging in this kind of babbling as if they are participating in some kind of conversation with themselves. However, infants will also modify this babbling in response to contingent feedback from their caregivers.[869] During this same period, some infants also begin to use *protowords* involving sound sequences that are consistently used in the presence of a specific object or situation, but do not resemble a specific word.[870]

Communicative (pragmatic) development

Pragmatics refers to knowledge about appropriate uses of language within differing social contexts. As summarised in box 6.1, language has many uses, depending upon the situation, the needs of the speaker and the capabilities of the listener. During the second half of the first year, infants begin to learn the parameters of these uses. For example, crying might lead to being picked up or held; cooing or laughing might lead to positive parent–child interaction, and so on.

Sometime at around eight or nine months, infants begin to use gestures (reaching, pointing) to serve a communicative purpose. At first, reaching for something or pointing might be used to indicate that the infant wants something. This kind of pointing behaviour is referred to as *protoimperative* to imply that the infant is issuing some form of a command. A point towards a cup is thus interpreted as a command for a drink; raising the arms is a command to be picked up, and so on.

Protoimperative points serve an instrumental, cause and effect, purpose which is different from the symbolic purpose of the *protodeclarative* point, which also becomes evident at around nine or so months. As described in chapters 3 and 4, protodeclarative pointing is used by infants to indicate that they want to share or gain information with their caregiver about an object or event. The use of the protodeclarative point is considered by many to represent a pivotal moment in communicative development, as it suggests that the infant understands that language can be used to represent something (an object, an event, and so on) and communicate about it.[871] Studies show that utterances frequently accompany these gestures, indicating that the infant is aware that sounds and gestures serve a communicative purpose.[872]

Protodeclarative pointing frequently takes place during triadic interactions involving the infant, caregiver and objects. Studies increasingly show that triadic parent–infant–object play also provides the context in which much early word learning takes place.[873,874] Joint attention activities additionally perform an important pragmatic function, as infants develop strategies for directing the conversation, taking turns and asking for information.[875]

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867 Kent, R. D., & Read, C. (1992). *The acoustic analysis of speech*. San Diego, CA: Singular Publishing.

868 Thelen E. (1991). Motor aspects of emergent speech: A dynamic approach. In: Krasnegor, N. A., Rumbaugh, D. M., Schiefelbusch, R. L., Studdert-Kennedy, M. (eds.), *Biological and behavioral determinants of language development* (pp. 339–362). Hillsdale, NJ: Erlbaum.

869 Goldstein, M. H., & Schwade, J. A. (2008). Social feedback to infants' babbling facilitates rapid phonological learning. *Psychological science*, *19*(5), 515–523.

870 Bates, E., Camaioni, L., & Volterra, V. (1975). The acquisition of performatives prior to speech. *Merrill-Palmer Quarterly of Behavior and Development*, *21*(3), 205–226.

871 Tomasello, M., Carpenter, M., & Liszkowski, U. (2007). A new look at infant pointing. *Child Development*, *78*(3), 705–722.

872 Esteve-Gibert, N., & Prieto, P. (2014). Infants temporally coordinate gesture-speech combinations before they produce their first words. *Speech Communication*, *57*, 301–316.

873 Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development*, *57*, 1454–1463.

874 Goldstein, M. H., Schwade, J., Briesch, J., & Syal, S. (2010). Learning while babbling: Prelinguistic object-directed vocalizations indicate a readiness to learn. *Infancy*, *15*(4), 362–391

875 Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development*, *57*, 1454–1463.

Semantic development

Semantics refer to the specific meaning of language terms, which is otherwise described as vocabulary. The words that occur at the time of the child's first birthday represent the culmination of all of the babbling and gesturing taking place beforehand and are therefore viewed as an important milestone in children's *expressive* language development. By the time these first words appear, most infants will already have a *receptive* vocabulary of 80 to 100 words.[876] An important milestone in children's receptive vocabulary comes at around six months when they first recognise their names.[877] Infants then learn the names of other members of their family and household objects steadily thereafter.[878]

Toddlerhood (12–36 months)

Phonology

While the child's first words are typically understood by most adults, they frequently represent 'baby talk' in terms of their simplicity and similarity to babbling. From this perspective, common first words such as 'mama' and 'dada' can be viewed as an extension of reduplicative babbling with meaning attached to them. Within a relatively short period of time, however, toddlers' words become increasingly more sophisticated and adult-like as they include more varied consonant and syllable combinations.

It is thought that children's phonological development occurs alongside their learning of vocabulary, as the learning of words increases their awareness of word sounds.[879] For example, studies have found that the size of the child's vocabulary during the second year of life is associated with their phonological awareness and preliteracy skills throughout their later development.[880] Children typically learn words that are easier to pronounce before those that are more difficult.[881] Simpler sounds are also mastered before more difficult sounds, although sound 'simplicity' is often associated with the frequency in which it occurs in the child's language. English-speaking children typically master the consonants 'p', 'b', 'd', 'm', 'n', 'j', 'w' and 'h' before they can pronounce 't', 'k', 'g' and 'f'.

Age norms are not always particularly useful for understanding a child's phonological development, as pronunciation is influenced by a wide variety of factors in addition to children's exposure to the sound. These factors include the child's hearing and perceptual capabilities, the maturation of the mouth, tongue and larynx and the position of the consonant within a word.[882] For example, simple consonants are much easier to pronounce than are consonant clusters (such as 'sp', 'sk', 'spl'), and consonants are frequently easier to pronounce at the beginning of a word than they are at the end.[883] There is also evidence to suggest that some toddlers prefer some consonant and vowel combinations over others, so will repeat them over and over again.

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876 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

877 Bortfeld, H., Morgan, J. L., Golinkoff, R. M., & Rathbun, K. (2005). Mommy and Me: Familiar Names Help Launch Babies Into Speech-Stream Segmentation. *Psychological Science, 16*(4), 298–304.

878 Bergelson, E., & Swingley, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, *109*(9), 3253–3258.

879 Vihman, M & Croft, W (2007). Phonological development: toward a "radical" templatic phonology, *Linguistics. 45*, 683–725.

880 Duff, F. J., Reen, G., Plunkett, K., & Nation, K. (2015). Do infant vocabulary skills predict school-age language and literacy outcomes? *Journal of Child Psychology and Psychiatry*, *56*(8), 848–856.

881 Ingram, D. (1999). Phonological acquisition. *The Development of Language*, 73–97.

882 Hoff, E. (2013). *Language Development*. Cengage Learning.

883 McLeod, S., Van Doorn, J., & Reed, V. A. (2001). Normal acquisition of consonant clusters. *American Journal of Speech-Language Pathology*, *10*(2), 99–110.

While children's phonological proficiency continues to improve throughout the child's second and third years, it typically does not reach the acuity of that of adults until the age of seven or eight. Phonological acuity throughout late preschool and early primary school is consistently associated with children's ability to read and write.[884,885,886]

Semantic development

Children's vocabulary develops rapidly during the second year of life. At 12 months, most children say fewer than 10 words, but by 24 months, say over 300.[887] Word learning is initially slow at the beginning of the first year, involving the words children hear through their daily experiences (table 6.2). Despite their relatively small vocabularies, most toddlers can nevertheless express a wide variety of ideas through body gestures and one-word phrases (table 6.3). Factors associated with the rate at which toddlers acquire new words include their exposure to language in the home, the degree to which toddlers engage in shared attention activities with their caregivers, and their social disposition.[888,889,890,891]

TABLE 6.2

Topics in children's earliest vocabularies

Topic	Examples
Food and drink	Juice, milk, biscuit, banana
Family	Mummy, daddy
Animals	Dog, cow, bunny
Parts of the body	Nose, tummy, hair, hand
Clothes	Pants, socks, hat
Vehicles	Car, train, bike
Games and routines	Peek-a-boo; Round and round the garden; Night night
Toys	Book, ball, teddy
Familiar objects	Cup, chair, flower
Actions	Eat, up, sit down
Descriptives	Hot, dirty
Sounds	Mmmmm, ow, moo

884 Bryant, P. E., MacLean, M., Bradley, L. L., & Crossland, J. (1990). Rhyme and alliteration, phoneme detection, and learning to read. *Developmental Psychology*, *26*(3), 429.

885 Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological bulletin*, *131*(1), 3.

886 Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*(3), 848–872.

887 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, i–185.

888 Newman, R., Ratner, N. B., Jusczyk, A. M., Jusczyk, P. W., & Dow, K. A. (2006). Infants' early ability to segment the conversational speech signal predicts later language development: a retrospective analysis. *Developmental Psychology*, *42*(4), 643.

889 Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive Psychology*, *61*(4), 343–365.

890 Slomkowski, C. L., Nelson, K., Dunn, J., & Plomin, R. (1992). Temperament and language: Relations from toddlerhood to middle childhood. *Developmental Psychology*, *28*(6), 1090.

891 Bloom, L., & Capatides, J. B. (1987). Expression of affect and the emergence of language. *Child Development*, 1513–1522.

TABLE 6.3

Speech acts at the one-word stage

Speech act	Examples
Labelling	Touches own nose and says 'nose'
Repeating	Hears father say 'mummy's home' and says 'mummy'
Answering	Adult asks 'what's that?', pointing to toy cow child says 'moo'
Requesting an action	Can't get shoes off and looks at mother while saying 'off'
Requesting	Points at juice and looks at mother and says 'juice?' with rising intonation
Calling	Shouts 'mummy' across the room and waits for a response
Greeting	Says 'hi' when a new person enters the room
Protesting	Vocalises and resists or says 'no' when mum tries to wash face
Practising	Use of word in absence of specific object or event and not addressed to adult

Source: Chapman, R., & Miller, J. F. (1981). Exploring children's communicative intents. Assessing language production in children. In Miller, J. F. *Assessing Language Production in Children: Experimental Procedures* (pp. 111–136). Baltimore, MD: University Park Press.

At around 18 months, many children's vocabulary undergoes a spurt that takes their vocabulary from 50 to 300 words within a six-month period of time. This means that some children are learning words at a rate of 10 to 20 new words per day.[892] It is thought that this word spurt occurs through a process of 'fast mapping' where the child only needs to hear the word once or twice to have learned it. Experiments involving the invented words of 'lep' or 'dax' exemplify of how fast mapping is assumed to occur. During these experiments, toddlers (between the ages of 16 and 20 months) are shown an array of four or five familiar objects and one unfamiliar object (typically an unusual kitchen utensil, such as a garlic press). Researchers then ask the toddlers if they can pass them the various objects, including the unfamiliar object – referred to as a 'lep' or 'dax'. Studies show that most toddlers during this age will immediately deduce that the lep is the unfamiliar utensil and will remember the name after only one or two trials.[893] Researchers assume that toddlers have thereby rapidly mapped the unfamiliar word to the unfamiliar object in a way that can be easily remembered when encountering the object again under a new set of circumstances.

Various theories have been put forth to explain why and how this fast mapping occurs. Some assume that it occurs at the point that children's object permanence (based on Piaget's sensorimotor stages; see chapter 3) is fully developed and so reflects an awareness of objects existing separately in space and time.[894] Others argue that it occurs at the point when children first realise that all objects have names.[895] Still others suggest that it is a product of children's categorical object representations which happen during the second year (see chapter 3).[896] A fourth explanation assumes that the word spurt occurs at the point when children are fully able to perceptually segment all words from their parents' running speech.[897] Indeed, studies consistently observe an association between the speed

[892] Reznick, J. S., & Goldfield, B. A. (1992). Rapid change in lexical development in comprehension and production. *Developmental Psychology,28*, 406

[893] Mervis, C. B., & Bertrand, J. (1994). Acquisition of the novel name–nameless category (N3C) principle. *Child Development*, *65*(6), 1646–1662.

[894] Lifter, K., & Bloom, L. (1989). Object knowledge and the emergence of language. *Infant Behavior & Development, 12*, 395–423.

[895] Dore, J., Franklin, M. B., Miller, R. T., & Ramer, A. L. H. (1976). Transitional phenomena in early language acquisition. *Journal of Child Language, 3*, 13–28.

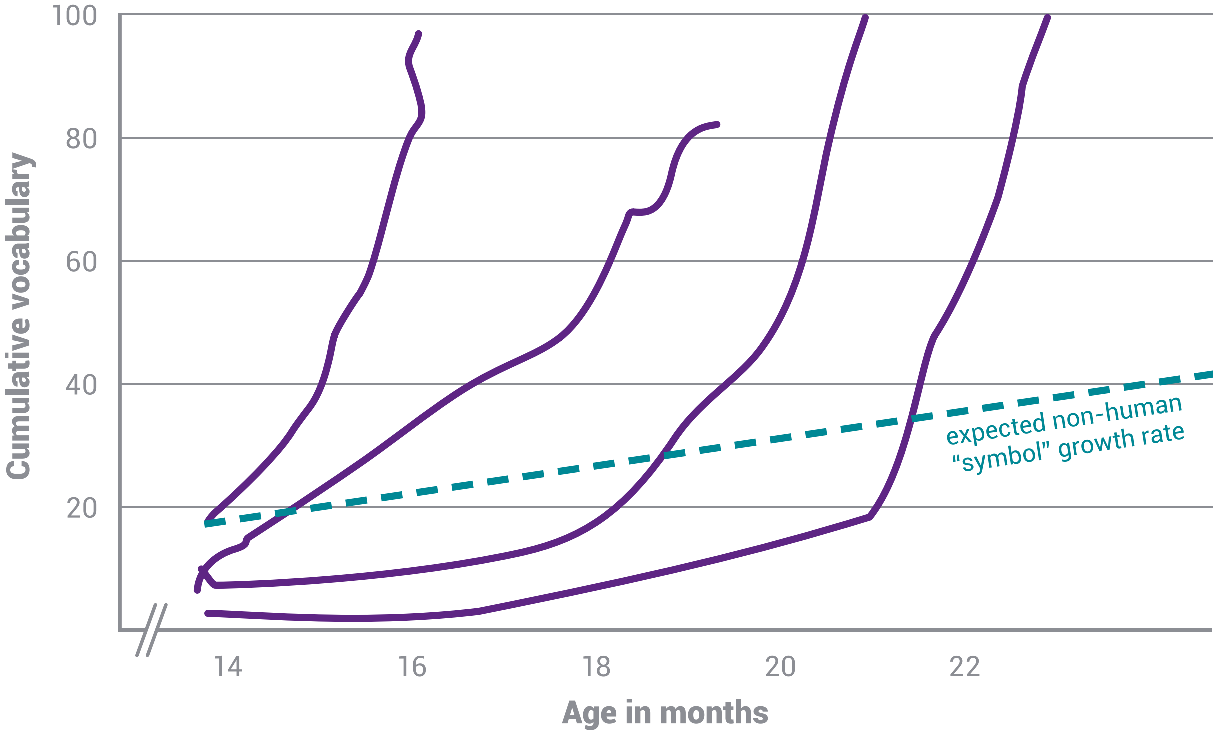
[896] Gopnik, A., & Meltzoff, A. (1987). The development of categorization in the second year and its relations to other cognitive and linguistic developments. *Child Development, 58*, 1523–1531.

[897] Plunkett, K. (1993). Lexical segmentation and vocabulary growth in early language acquisition. *Journal of Child Language, 20,* 43–60.

at which children process adult speech and the rate of their vocabulary growth throughout the second year.[898] It is also worth noting that this spurt does not occur universally in all children (figure 6.4), causing some to question whether it actually represents a developmental shift in children's conceptual understanding.[899,900]

FIGURE 6.4

Individual variation in children's lexical growth



Source: Reproduced from Goldfield, B. A., & Reznick, J. S. (1990). Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of child language, 17*(1), 171–183

Grammar – syntax and morphology

Grammar involves children's understanding of syntax and use of morphemes (referred to as morphology). Syntax refers to the structure of sentences and morphology refers to the structure of words. Issues pertaining to syntax involve the order of words in a sentence. For example, the phrase 'the cat chased the rabbit' means something entirely different to 'the rabbit chased the cat'.

Morphology refers to changes made to individual words which change their meaning. A morpheme is the smallest grammatical unit (see box 6.2). It may be a single root word, but can also be a 'bound' morpheme, which qualifies a root word. Examples of bound morphemes include 's' or 'es' added to the end of a word to signify amount or 'ed' or 'ing' to signify tense. To speak effectively, children need to master both the syntax and morphology of their native language.

[898] Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental psychology*, *42*(1), 98.

[899] Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

[900] Ganger, J., & Brent, M. R. (2004). Reexamining the vocabulary spurt. *Developmental psychology*, *40*(4), 621.

Box 6.2: Measuring young children's use of grammar through their mean length of utterance

The complexity of children's grammar is typically understood through the MLUs used in children's everyday speech. MLUs represent units of speech as follows:[901]

Mummy	+	kiss	+	ed	+	my	+	Daddy	=	5
1	+	1	+	1	+	1	+	1		

MLUs are assessed in stages and are categorised as follows for English-speaking children:

- **Stage I:** (MLU = 1–1.99) Children are beginning to combine words
- **Stage II:** (MLU = 2–2.49) Children begin to add morphemes to word combinations
- **Stage III**: (MLU = 2.5–3) Children are adding tonalities to phrases to indicate a question or negative (see below)
- **Stage IV:** (MLU = 3.00 and up) Children are using complex sentences
- **Stage V:** Children use greater variety of complex sentences with embedded clauses.

Stages 1–3 are considered as reliable indicators of the complexity of children's expressive grammar. However, after that point, the length of utterance may or may not reflect the complexity of the child's grammar, so the MLU is a less reliable indicator of the child's understanding. Other measures appropriate for children with more complex grammar include the Index of Productive Syntax (IPSyn) and the MacArthur Inventories (see section 6.6).

Children typically begin to learn the rules of grammar during their second year, when they create sentences that combine two words together. Initially, these sentences are very simple, involving two nouns (e.g. 'Sally biscuit') a noun and an adjective (e.g. 'little boy') or a noun and a verb (e.g. 'daddy walk'). By the end of the second year, most children are also adding negative markers to sentences ('I no want bed') and questions.

During early speech, it is not uncommon for sentences to contain morphemic *overregularisations*, such as the use of the 'ed' to express that something has occurred in the past. Hence, toddlers will say 'I drinked' rather than I 'drank', 'I runned' rather than 'I ran' or 'mices' rather than mice. Another common error is the omission of finiteness clauses in sentences, involving verbs which indicate tense. The sentence 'Johnny is walking' is an example of a finiteness clause indicating the walking presently occurring. It is not uncommon for young children to omit finiteness clauses when first learning syntax – using sentences such as 'Johnny walk' instead of 'Johnny is walking'. By the end of the third year, however, these grammatical errors begin to fade and sentences become increasingly correct and complex. Table 6.4 summarises the key milestones which occur in children's production of syntax and morphology between the ages of two and four.

901 Williamson, G. (2014) Mean length of utterance. Available at https://www.sltinfo.com/mean-length-of-utterance/

TABLE 6.4

Production of morphology and syntax

18–24 months	Early two-word combinations: 'gone juice', 'more milk'
21–35 months	Three-word combinations First grammatical morphemes begin to be used but not yet consistently: drink-*ing*, shoe-*s*
24–41 months	Questions and negative sentences begin to be used
28–36 months	Increasing consistency until 'mastery' reached of early grammatical markers: -*ing*, plural -*s*, in, on
26–50 months	Increasing consistency until 'mastery' reached of finiteness markers: past-tense -*ed*, possessive -*s*, is
28–45 months	First complex sentences used: 'daddy went shopping and mummy did tea', 'we went swimming after I falled'
24–30 months	Commands are most frequent sentence type
30–34 months	Questions become the most frequent sentence type
46 months	Most complex sentence types are used, including coordination (*and, but, if, because*) and subordination (*after, although, while, when, who, which, that*)

Sources: Synthesis from Hoff (2013)[902]; Vasilyeva et al (2008)[903]; Brown (1973)[904]; Miller and Chapman (1981)[905]

Young children vary dramatically in the complexity of their grammar. While some 18-month-old children speak in complete sentences, others are just beginning to combine two words. Individual differences in the complexity of children's grammar are commonly understood in terms of the *mean length of utterance* (MLU) of the child's spontaneous speech (see box 6.2). Longer utterances typically include more morphemes, and so reflect greater grammatical complexity.

It is worth noting that children's utterances do not always reflect what the child does and does not understand.[906] This is because young children's language also includes phrases they have learned by rote or through meanings which are derived from the context.[907] For example, a toddler may seemingly understand the phrase 'time to get out of the bath now' because they have come to associate the phrase with getting out of the bath, not because they understand the grammar or every single word.

Pragmatic development during toddlerhood

Between the ages of two and three, toddlers become increasingly more adept at using language for a variety of different communicative purposes.[908] As described in the previous section, infants can already use language in an imperative and declarative way by the end of their first year. By the end of their second year, children use language for a variety of reasons – including asking questions and negating others. Table 6.5 provides an overview of the communicative intentions typically expressed by 18-month-old children.

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902 Hoff, E. (2013). *Language development*. Cengage Learning

903 Vasilyeva, M., Waterfall, H., & Huttenlocher, J. (2008). Emergence of syntax: Commonalities and differences across children. Developmental science, 11(1), 84–97.

904 Brown, R. (1973). *A first language: The early stages*. Harvard University Press.

905 Miller, J. F., & Chapman, R. S. (1981). The relation between age and mean length of utterance in morphemes. Journal of *Speech, Language, and Hearing Research, 24*(2), 154–161.

906 Hirsh-Pasek, K., & Golinkoff, R. (1991). Language Comprehension: A New Look at Some Old Themes. *Biological and Behavioral Determinants for Language Development*, 301.

907 Hoff, E. (2013). *Language development*. Cengage Learning.

908 Snow, C. E., Pan, B. A., Imbens-Bailey, A., & Herman, J. (1996). Learning how to say what one means: A longitudinal study of children's speech act use. *Social Development*, *5*(1), 56–84.

TABLE 6.5

Examples of communicative intentions expressed by 18-month-old children

Call hearer to attend speaker	Agree with a proposition
Greet on meeting	Disagree with a proposition
Request/propose the initiation of a new activity	Correct an utterance
Request/propose the continuation of a new activity	Ask a yes–no question requesting clarification of utterance
Request/propose the repetition of an action	Give an affirmative answer to yes/no question
Propose object to act on; action known	Give a negative answer to a yes/no question
Propose an act on a known object	Make a verbal move in telephone game
Propose a location for a known at on a known object	Make a verbal move in peek-a-boo game
Agree to do as requested	Mark object transfer
Refuse to do as requested	Mark completion of action
Propose the ending of an activity	Mark the falling of an object
Make a statement discussing a joint focus of attention	Exclaim in disapproval
Make a statement discussing a recent event	Exclaim distress
Make a statement discussing a past or future event	Exclaim in surprise or enthusiasm

Sources: Ninio (1995), reproduced in Hoff (2013)[909,910]

Studies also show that by the age of two, toddlers are fairly skilled at initiating conversations and responding to conversations initiated by adults.[911] However, most toddlers are not yet able to respond to adult-led conversations in a way that is *linguistically contingent* (that is, which linguistically references what the adult has said).[912] This is exemplified in the following conversation:

Adult: 'Where are your mittens?'

Toddler: (retrieves them) 'Here.'

While the toddler has responded appropriately to the adult's question, his or her verbal response does not fully align with the language used in the question. A more linguistically contingent response would instead be 'they are in the closet'. This response references the adult's speech by using the word 'they' for mittens, but also linguistically elaborates the information in a way that is decontextualised from the situation. It is also far more grammatically complex than is the simpler response of 'here'.

Linguistically contingent speech requires that the child fully comprehends what the adult has said and has the grammatical understanding to expand upon it. Studies show that caregivers help their children do this by asking them questions which push them to state their response more fully and provide more information which will maintain or elaborate the conversation.[913] It is thought that this caregiver scaffolding not only helps children understand the dynamics

909 Ninio, A. (1995). Expression of communicative intents in the single-word period and the vocabulary spurt. *Children's language*, *8*, 103–124.

910 Hoff, E. (2013). *Language development*. Cengage Learning

911 Shatz, M. (1978). On the development of communicative understandings: An early strategy for interpreting and responding to messages. *Cognitive Psychology*, *10*(3), 271–301.

912 Bloom, L., Rocissano, L., & Hood, L. (1976). Adult-child discourse: Developmental interaction between information processing and linguistic knowledge. *Cognitive Psychology*, *8*(4), 521–552.

913 Hoff-Ginsberg, E. (1987). Topic relations in mother-child conversation. *First Language*, *7*(20), 145–158.

of effective communication (such as linguistic contingency), but also facilitates the development of their grammar and vocabulary.[914]

Ages three to five

Between the ages of three and five, children's language becomes increasingly more sophisticated – their phonological awareness steadily improves, the complexity of their grammar continues to increase, and their vocabulary continues to grow at a fast pace. At age two, children typically understand 300 words – by the age of five, most will understand more than 10,000.[915]

The preschool child's improved language capabilities facilitate a wide variety of cognitive processes that also continue to develop during the preschool years. These processes include the analogical reasoning skills described in chapter 3, the ability to lie and predict others' false beliefs as described in chapter 4, and the ability to count and perform verbal arithmetic as described in chapter 5. While it is beyond the scope of this review to describe the development of all of the language milestones taking place during the later preschool years, three processes associated with children's early school achievement are worth mentioning here: the advent and use of inner speech, the development of narrative discourse, and the emergence of preliteracy skills.

Inner speech

Inner speech (also referred to as private speech, solitary speech, inner monologue, egocentric speech, verbal thinking, covert thought) refers to the self-talk children and adults use when reflecting or problem-solving.[916] Adult self-talk is typically not spoken, but young children can often be heard talking to themselves out loud. For example, it is not uncommon to hear preschoolers engaging in audible monologues when playing by themselves or alongside their peers. Inner speech is normally first heard at the age of two, when toddlers are just starting to put words together in sentences. It then steadily increases throughout the later preschool years until the age of five, when it peaks and then becomes less prominent as it is internalised into unspoken thought processes.

Developmental psychologists offer a variety of different explanations as to why inner speech occurs. Piaget first used it as an example of the young child's inability to engage in true conversation with others.[917] More recently, researchers have come to view it as a form of language play or practice, with some also seeing parallels between inner speech and the function of the phonological loop in children's working memory (see chapter 5).[918,919] The theory that has the most traction, however, comes from Vygotsky, who maintained that inner speech is indicative of how children's thought processes begin through social interactions which then become internalised over time.[920,921] For example, children can often be heard 'instructing' themselves when problem-solving. Vygotsky viewed this as the child internalising the external support he or she receives from his or her caregivers, thus also suggesting that inner speech plays an important self-regulatory role.

914 Hoff-Ginsberg, E. (1990). Maternal speech and the child's development of syntax: A further look. *Journal of child language*, *17*(1), 85–99.

915 Anglin, J. M., Miller, G. A., & Wakefield, P. C. (1993). Vocabulary development: A morphological analysis. *Monographs of the Society for Research in Child Development*, i–186

916 Alderson-Day, B., & Fernyhough, C. (2015). Inner speech: development, cognitive functions, phenomenology, and neurobiology. *Psychological Bulletin*, *141*(5), 931.

917 Piaget, J. (2005). *Language and Thought of the Child: Selected Works vol 5*. London: Routledge.

918 Gallagher, T. M., & Craig, H. K. (1978). Structural characteristics of monologues in the speech of normal children: Semantic and conversational aspects. *Journal of Speech, Language, and Hearing Research*, *21*(1), 103–117.

919 Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*, 158–173.

920 Vygotsky, L.S. (1962). *Thought and language*. Cambridge, MA: MIT Press.

921 Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

There is good evidence to support each of these theories, with studies showing that inner speech is instrumental in a variety of cognitive processes. These processes include the executive functions (especially those involving memory and attention), metacognitive skills used when planning and learning, and children's emotional and behavioural self-regulation. Specifically, it is thought that the quality of inner speech helps children determine their emotional and behavioural response to various social situations.[922,923] In this respect, several language-focused interventions have shown promise in improving the behaviour of preschool children identified as having a language delay.[924,925,926]

Narrative discourse

As the complexity of children's language improves, they become increasingly able to engage in lengthy conversations with others about events decontextualised from their immediate circumstances. These events include experiences occurring in the past or future, events occurring in other places and circumstances which are fantastic or imagined.[927,928] During these discussions, children begin to learn how to describe these events in a coherent, narrative manner which involves a beginning, middle and end. Throughout the later preschool years, children's narratives become increasingly rich in terms of their content and structure.[929] Children's ability to comprehend and produce story narratives at age five has been found to predict their reading comprehension at age eight.[930]

The narratives of English-speaking children have been observed to go through a predictable sequence between the ages of two and five. Table 6.6 summarises this sequence, as first described by Applebee in 1978, although it is worth noting that a variety of narrative assessment schemes have been developed since then.[931] Schemes used to assess children's narratives frequently consider the complexity of the child's language (the microstructure), as well the narrative's structure and content (the macrostructure).[932]

Studies have additionally identified three phases in children's reliance on adults and conventional scripts when producing their narratives:[933]

1. **Dependency on adult participation:** In this first phase, adults most typically initiate and scaffold the conversation by introducing the topic ('Did you go to Sally's birthday party last week?') and then keeping the conversation going by asking relevant questions.
2. **Common elements:** Over time, children take greater control over their narratives, but they tend to be quite general and rely on conventional scripts. So, a phase 2 explanation about a birthday party might just include elements shared by most birthday parties (games; presents; cake) but provide no details of the specific event.

922 Gross, J. J. (1998). The emerging field of emotion regulation: an integrative review. *Review of general psychology*, *2*(3), 271.

923 Cole, P. M., Zahn-Waxler, C., Fox, N. A., Usher, B. A., & Welsh, J. D. (1996). Individual differences in emotion regulation and behavior problems in preschool children. *Journal of Abnormal Psychology, 105*(4), 518–529.

924 Roberts, M. Y., & Kaiser, A. P. (2011). The effectiveness of parent-implemented language interventions: A meta-analysis. *American Journal of Speech-Language Pathology, 20*, 180–199.

925 Roberts, M. Y., & Kaiser, A. P. (2015). Early intervention for toddlers with language delays: A randomized controlled trial. *Pediatrics, 135*, 686–693.

926 Curtis, P. R., Kaiser, A. P., Estabrook, R., & Roberts, M. Y. (2017). The Longitudinal Effects of Early Language Intervention on Children's Problem Behaviors. *Child Development*.

927 Umiker-Sebeok, D. J. (1979). Preschool children's intraconversational narratives. *Journal of Child Language*, *6*(1), 91–109.

928 Snow, C. (1983). Literacy and language: Relationships during the preschool years. *Harvard Educational Review*, *53*(2), 165–189.

929 Haden, C. A., Haine, R. A., & Fivush, R. (1997). Developing narrative structure in parent–child reminiscing across the preschool years. *Developmental Psychology*, *33*(2), 295.

930 Griffin, T. M., Hemphill, L., Camp, L., & Wolf, D. P. (2004). Oral discourse in the preschool years and later literacy skills. *First language*, *24*(2), 123–147.

931 Berman, R. A., & Slobin, D. I. (2013). *Relating events in narrative: A crosslinguistic developmental study*. Psychology Press.

932 Heilmann, J., Miller, J. F., & Nockerts, A. (2010). Sensitivity of narrative organization measures using narrative retells produced by young school-age children. *Language Testing, 27*, 603–626.

933 Eisenberg, A. R. (1985). Learning to describe past experiences in conversation. *Discourse Processes*, *8*(2), 177–204.

3. **Unique occurrences:** More advanced narratives are less reliant on prompting and conventional narratives. Hence, a description of someone's birthday party might include details about who was there, the type of games played and the kinds of presents the birthday child received. Such stories might also include information about the child's opinion of the event based on his or her specific experience.

Studies find that children's first narratives typically involve events with high emotional content, including happy occasions (such as birthday parties) and events when someone has been punished or injured.[934] As a result, researchers assume that children's narrative capabilities may support their autobiographical understanding of themselves, as well as provide a linguistic vehicle for sharing information about themselves with others.[935]

TABLE 6.6

Applebee's stages of narrative development

Stage	Age	Description	Example
Heaps	2	Children may communicate a group of unrelated ideas with topic switches frequently.	'The girl is eating cookies. The man is going in the car. The baby is sleeping.'
Sequences	2–3	Children begin to tell a story with arbitrary links between elements such as characters, setting or topic.	'She has a doll. The doll is eating soup. I don't like to eat soup because it tastes yucky.'
Primitive narratives	3–4	Stories contain characters, setting and a topic, with events following a central theme. Cause and effect relationships emerge.	'My dad went to work. My mom stayed at home. My kitty cat came up to me and I pet him, then I started to cry because he bit me. So mom came in and I got a bandaid.'
Focused chains	4–5	Stories contain all relevant elements, such as characters, setting and a topic. Stories are told in a logical sequence, but the listener may still need to have additional knowledge to interpret the ending correctly.	'Once upon a time there was a mommy named Christie and a daddy named Tom. They had a little boy and his name was Peter. Mommy told Peter to go outside to play, and then he came in and said, "Mommy, our dog's outside and he's barking." Mommy said, "He wants to come in."'
True narratives	5–7	These stories contain a true plot, including a problem in the story which is resolved at the end. It follows a logical sequence of events and includes character development by connecting the motivations and goals of the character with the plot.	'One day there was a boy named Bobby and a girl named Sharon. They found a cat in their front yard and they brought it into the house. They fed the cat and they gave it some milk. They played with it and then a little while after a lady called and asked if anyone had seen her cat. And then they said that they had it at their house. And she gave them each five dollars for finding the cat, taking care of it and feeding it milk.'

Source: Applebee, A. N. (1978). *The child's concept of story: Ages two to seventeen*. https://talkingtogetherdotca.files.wordpress.com/2016/05/stages-of-narrative-development1.pdf

934 Miller, P. J., & Sperry, L. L. (1988). Early talk about the past: The origins of conversational stories of personal experience. *Journal of Child Language*, *15*(2), 293–315.

935 Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A social cultural developmental theory. *Psychological Review*, *111*(2), 486.

Preliteracy skills

Children learn language spontaneously. While adult scaffolding significantly influences the rate and proficiency with which children learn language, virtually all children learn to talk. This is not the case when it comes to reading and writing, however. As described at the beginning of this report, reading is considered a biologically secondary function which has high cultural value, but requires direct instruction and practice in order to be mastered.

Early language skills lay the foundation for children's later literacy.[936] Children's phonological awareness, knowledge of vocabulary, use of syntax and morphology jointly and independently predict children's decoding skills, word recognition and reading comprehension.[937,938,939] For example, children's phonological awareness is believed to support children's ability to link sounds to the letters of the alphabet. These skills, in turn, support the phonological decoding (sounding out) and recoding that takes place when children are learning to read.[940,941,942] Phonological awareness is also associated with children's vocabulary, which further facilitates their word recognition and reading comprehension.[943,944] Some studies suggest that phonological awareness supports the word decoding that is learned at the beginning of primary school, whereas vocabulary facilitates reading comprehension typically required in the middle primary school.[945,946,947]

Children's understanding of decontextualised language is also associated with their ability to read. Decontextualised language refers to discussions about ideas and events removed from the child's immediate circumstances.[948,949] Children's narrative conversations are an example of one form of decontextualised use of language, conversations about factual information are an example of another. Studies show that oral storytelling and conversations during book sharing also facilitate children's understanding of how to use language in a decontextualised way.[950]

Other factors thought to contribute to children's reading and writing capabilities include their knowledge of the alphabet letters, written words, books and other printed materials.[951]

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936 National Early Literacy Panel (US), & National Center for Family Literacy. (2008). The National Early Literacy Panel. In Lonigan, C.J., Schatschneider, C., & Westberg, L. (eds), *Developing early literacy*. Washington, DC.: National Institute for Literacy.

937 Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E. S., & Poe, M. D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. *Journal of Educational Psychology*, *95*(3), 465.

938 NICHD Early Childcare Research Network. (2005). Pathways to reading: the role of oral language in the transition to reading. *Developmental Psychology*, *41*(2), 428.

939 Dickinson, D. K., Golinkoff, R. M., & Hirsh-Pasek, K. (2010). Speaking out for language: Why language is central to reading development. *Educational Researcher*, *39*(4), 305–310.

940 Anthony, J. L., & Francis, D. J. (2005). Development of phonological awareness. *Current Directions in Psychological Science*, *14*(5), 255–259.

941 Bishop, D. V., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of child psychology and psychiatry*, *31*(7), 1027–1050.

942 Stringer, H. (2017). *The Newcastle Intervention for Phonological Awareness (NIPA)* (Third edition). Newcastle upon Tyne, UK: Newcastle University, School of Education, Communication and Language Sciences.

943 Biemiller, A. (2006). Vocabulary development and instruction: A prerequisite for school learning. *Handbook of early literacy research*, *2*, 41–51.

944 Hoff, E. (2013). *Language development*. Cengage Learning.

945 Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental psychology*, *38*(6), 934.

946 Sénéchal, M., Ouellette, G., & Rodney, D. (2006). The misunderstood giant: On the predictive role of early vocabulary to future reading. *Handbook of early literacy research*, *2*, 173–182.

947 Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of educational psychology*, *98*(3), 554.

948 Snow, C. (1983). Literacy and language: Relationships during the preschool years. *Harvard Educational Review*, *53*(2), 165–189.

949 Tannen, D. (ed.) (1982). *Spoken and written language: Exploring orality and literacy* (Vol. 32). ABLEX Publishing Corporation.

950 Bus, A. G., Van Ijzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of educational research*, *65*(1), 1–21.

951 Mol, S. E., & Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychological Bulletin*, *137*(2), 267.

Collectively, these skills are described as children's emergent literacy milestones (as summarised in table 6.7) and contigent upon the quality of the child's learning environments.

TABLE 6.7

Key milestones in children's emergent literacy

Birth to 3 years
• Recognises specific books by cover
• Pretends to read
• Enjoys word play, rhyming
• Listens to stories
• Begins to produce some letter-like forms in own 'writing'
3 to 4 years
• Knows that alphabet letters have names and are different from pictures
• Recognises some environmental print (such as STOP and EXIT signs)
• Pays attention to separate sounds in language (such as notices rhyming words and alliteration, as in 'Peter, Peter, pumpkin eater')
• Shows interest in books and reading
• Connects events in stories to life experiences
• Writes (scribbles) own messages
Age 5
• Recognises and can name all uppercase and lowercase letters
• Understands that the sequence of letters in a written word represents the sequence of sounds in the spoken word (the alphabetic principle)
• Can name some book titles and authors
• Makes predictions based on illustrations or portions of stories
• Uses invented spelling to write own messages
• Can write own name
• Can write most letters and some words when they are dictated
Age 6
• Can accurately decode (sound out) regular single-syllable words
• Recognises common, irregularly spelled words by sight (have, said, where, two)
• Predicts and justifies what will happen next in stories
• Monitors own comprehension when reading; notices when simple texts fail to make sense
• Creates own written texts for others to read

Sources: Hoff (2013)[952] based on Snow et al (1998)[953]

While studies consistently find that emergent literacy skills are highly predictive of children's reading and writing achievement in primary school, researchers caution that an overemphasis on emergent literacy in preschool environments could restrict children's engagement in other processes known to contribute to their language development.[954,955] Specifically, some have

952 Hoff, E. (2013). *Language development.* Cengage Learning.

953 Snow, C. E., Burns, M. S., & Griffin, P. (1998). *Preventing reading difficulties in young children.* Washington, DC: National Academy Press.

954 Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*(3), 848–872.

955 Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: implications for closing achievement gaps. *Developmental psychology*, *49*(1), 4.

expressed concern that the emphasis on books and reading may eclipse other important learning opportunities involving parent–child conversations and free and unstructured child play.[956] We now consider how parent–child conversations, book sharing and a variety of other processes affect children's early language development during the first five years.

6.5 What factors influence the development of children's language and communication skills during the first five years of life?

A wide variety of influences are associated with individual differences in children's language development. These influences include heritable processes, complications during pregnancy and childbirth, and factors associated with the family and home. While the relative impact of these influences is often difficult to determine, a number of consistent messages are evident across the literature. Here, we summarise findings which are consistently observed in large-scale cohort studies, as well as smaller, seminal studies that illustrate key points.

Genetic factors

Heritability

Studies show that the heritability of language follows a trajectory similar to the other competencies described in this report. Specifically, the heritability of language is observed to be relatively low between the ages of two and four (.24) and then steadily increases throughout middle childhood and adolescence, with studies placing it at between .47–.57 by age 12.[957]

The explanations provided for this increase in language heritability are similar for those provided for children's cognitive development more generally, as described in chapters 3 and 5.

- It is probable that genetic and environmental correlations *amplify* the contribution of potential heritable effects. For example, more linguistically proficient children seek out environmental opportunities to use language and increase their proficiency at it. In this respect, researchers suspect that environmental opportunities may amplify initial, but fundamentally small genetically-driven language capabilities. For example, studies show that children's interest in reading is facilitated by potentially heritable differences in decoding skills, that in turn increase the enjoyment of reading, which then further reinforces children's reading capabilities, and so on.[958,959]
- Studies show that children's language capabilities are associated with a variety of other cognitive skills that are also thought to have a genetic component, such as the executive functions.[960] Some therefore speculate that *innovation* in domain-general capabilities occurring in late preschool and early primary school may also contribute to the increases in heritability estimates observed in older children's language.[961,962]

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956 Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E. S., & Poe, M. D. (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. *Journal of Educational Psychology*, *95*(3), 465.

957 Hayiou-Thomas, M. E., Dale, P. S., & Plomin, R. (2012). The etiology of variation in language skills changes with development: A longitudinal twin study of language from 2 to 12 years. *Developmental Science*, *15*(2), 233–249.

958 Bast, J., & Reitsma, P. (1998). Analyzing the development of individual differences in terms of Matthew effects in reading: Results from a Dutch longitudinal study. *Developmental Psychology*, *34*(6), 1373.

959 Mol, S. E., & Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychological Bulletin*, *137*(2), 267.

960 Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2009). A cognitive approach to the development of early language. *Child Development*, *80*(1), 134–150.

961 Colledge, E., Bishop, D. V., Koeppen-Schomerus, G., Price, T. S., Happé, F. G., Eley, T. C., ... & Plomin, R. (2002). The structure of language abilities at 4 years: a twin study. *Developmental Psychology*, *38*(5), 749.

962 Haworth, C. M., Wright, M. J., Luciano, M., Martin, N. G., de Geus, E. J., van Beijsterveldt, C. E., ... & Kovas, Y. (2010). The heritability of general cognitive ability increases linearly from childhood to young adulthood. *Molecular Psychiatry*, *15*(11), 1112.

- There is also some evidence showing that innovation in domain-specific processes involving language development may additionally contribute to increases in heritability estimates involving language skills during adolescence.[963,964]
- National curriculum standards may increase the homogeneity of childrens shared and non-shared learning environments, thus making genetically-based differences more salient in heritability estimates involving the primary and secondary school years.

Specific language impairments

It is estimated that approximately 8% of all UK children will be identified as having a specific language impairment (SLI) by the time they enter primary school.[965] Specific language impairments are traditionally defined as delays in children's language performance relative to their peers in the absence of any clear explanation, such as hearing loss or other cognitive impariments.[966]

Findings from a comprehensive review of over 100 genetic studies observed that heritability estimates typically fall between .50 to .60 for children identified as having an SLI, suggesting that many impairments likely involve a heritable basis.[967] This review further observed that children's awareness of phonology and syntax are more likely to be affiliated with heritable processes in comparison to children's understanding of vocabulary. It is also clear that a number of genetically-driven disabilities, including autism spectrum conditions (ASCs), may also negatively impact children's pragmatic use of language (see chapter 4).

A key finding in the literature is that children seemingly grow in and out of language difficulties. This apparent inconsistency is likely related to the nature of the language delay, the period of development during which it is assessed, and the type of assessment tool used. For example, studies show that children with delays in mean length of utterance at age two typically catch up to their peers by age seven, wherease difficulties with finiteness markers are more likely to endure throughout childhood as are initial delays in children's vocabulary.[968,969] While there is evidence showing that all three aspects of language development are influenced by genetic processes, finiteness omissions and MLU delays have been found to have a strong genetic component, whereas vocabulary growth appears to be more strongly associated with the child's environment.

For these reasons, it is not surprising that studies observe that language difficulties are not reliably predicted until chidren are four years or older, and even then, there remains a fair amount of developmental change.[970] For example, a recent analysis of the TEDS study observed that between the ages of 4 and 12, one-third of the children had appeared to grow out of language problems, while one-third appeared to have grown into them and the authors attributed this to the nature of language problems as children developed. For example, there

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963 Hayiou-Thomas, M. E., Dale, P. S., & Plomin, R. (2014). Language impairment from 4 to 12 years: Prediction and etiology. *Journal of Speech, Language, and Hearing Research*, *57*(3), 850–864.

964 Dale, P. S., McMillan, A. J., Hayiou-Thomas, M. E., & Plomin, R. (2014). Illusory recovery: Are recovered children with early language delay at continuing elevated risk? *American Journal of Speech-Language Pathology*, *23*(3), 437–447.

965 Law, J., Charlton, J., & Asmussen, K. (2017). *Language as a child wellbeing indicator*. Early Intervention Foundation. https://www.eif.org.uk/report/language-as-a-child-wellbeing-indicator

966 Tomblin, J. B., Zhang, X., Buckwalter, P., & O'Brien, M. (2003). The stability of primary language disorder: Four years after kindergarten diagnosis. *Journal of Speech, Language, and Hearing Research*, *46*(6), 1283–1296.

967 Stromswold, K. (2001). The heritability of language: A review and metaanalysis of twin, adoption, and linkage studies. *Language*, *77*(4), 647–723.

968 Rice, M. L. (2013). Language growth and genetics of specific language impairment. *International Journal of Speech-Language Pathology*, *15*(3), 223–233.

969 Byrne, B., Coventry, W. L., Olson, R. K., Samuelsson, S., Corley, R., Willcutt, E. G., ... & DeFries, J. C. (2009). Genetic and environmental influences on aspects of literacy and language in early childhood: Continuity and change from preschool to Grade 2. *Journal of Neurolinguistics*, *22*(3), 219–236.

970 Hayiou-Thomas, M. E., Dale, P. S., & Plomin, R. (2014). Language impairment from 4 to 12 years: Prediction and etiology. *Journal of Speech, Language, and Hearing Research*, *57*(3), 850–864.

was evidence of problems of expressive language in preschool resolving themselves by primary school, while issues involving complex syntax increase as children grow older. Researchers have therefore interpreted these findings to suggest that genetically-based factors may potentially switch on and off throughout children's development, making some problems difficult to anticipate.

Gender

Studies consistently observe small, but reliable differences in the language capabilities of girls and boys during the preschool years.[971,972,973] During infancy, girls have been found to vocalise more, especially when they are in the presence of others.[974] During toddlerhood, girls have been found to use more gestures and acquire vocabulary at a faster rate.[975,976] In later preschool, girls are more likely to engage in narrative discourse.[977] Some studies also observe more variability in the language capabilities of boys, suggesting that they may be more susceptible to language delays.[978,979] While some attribute this 'girl advantage' to differences in the ways in which adults engage boy and girl infants in conversations – a large-scale, cross national study in 2012 found little support for this assumption.[980] So, the factors that may contribute to gender-related differences in language currently remain unknown.

Little is also known about the potential impact of gender differences on children's language development, although studies consistently find that the differences are relatively small.[981] A recent meta-analysis observed that while gender differences may differentially impact children's early achievement in preschool, these differences do not appear to influence later outcomes occurring in primary or secondary school.[982] On the other hand, studies also show that boys may be more vulnerable to the impacts of language delays when they do occur. For example, a recent analysis of the MCS sample observed that language delays were associated with behavioural problems in boys during preschool, but not for girls.[983] Studies additionally observe that social disadvantage may have a greater impact on boys' language development than it does for girls.[984]

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971 Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press.

972 Bornstein, M., Hahn, C. S., & Haynes, O. (2004). Specific and general language performance across early childhood: Stability and gender considerations. *First Language*, *24*(3), 267–304.

973 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

974 Lewis, M., & Freedle, R. (1973). Mother–infant dyad: The cradle of meaning. In *Communication and affect: Language and thought* (pp. 127–155).

975 Ozçalişkan, S., & Goldin-Meadow, S. (2010). Sex differences in language first appear in gesture. *Developmental Science, 13*, 752–760.

976 Eriksson, M., Marschik, P. B., Tulviste, T., Almgren, M., Pérez Pereira, M., Wehberg, S., ... & Gallego, C. (2012). Differences between girls and boys in emerging language skills: evidence from 10 language communities. *British Journal of Developmental Psychology*, *30*(2), 326–343.

977 Haden, C. A., & Ornstein, P. A. (2009). Research on talking about the past: The past, present, and future. *Journal of Cognition and Development*, *10*(3), 135–142.

978 Galsworthy, M., Dionne, G., Dale, P., & Plomin, R. (2000). Sex differences in early verbal and non-verbal cognitive development. *Developmental Science*, *3*, 206–215.

979 Law, J., Boyle, J., Harris, F., Harkness, A., & Nye, C. (1998). Screening for speech and language delay: A systematic review of the literature. *Health Technology Assessment*, *2*(9).

980 Eriksson, M., Marschik, P. B., Tulviste, T., Almgren, M., Pérez Pereira, M., Wehberg, S., ... & Gallego, C. (2012). Differences between girls and boys in emerging language skills: evidence from 10 language communities. *British Journal of Developmental Psychology*, *30*(2), 326–343.

981 Berglund, E., Eriksson, M., and Westerlund, M. (2005). Communicative skills in relation to gender, birth order, childcare and socioeconomic status in 18-month-old children. *Scandinavian Journal of Pychology, 46*, 485–491.

982 Magnuson, K. A., Kelchen, R., Duncan, G. J., Schindler, H. S., Shager, H., & Yoshikawa, H. (2016). Do the effects of early childhood education programs differ by gender? A meta-analysis. *Early childhood research quarterly*, *36*, 521–536.

983 Gibson, J. (2018). 'The interplay between linguistics and social development'. Presentation at the Public Health England East of England CYP Commissioner Forum. Cambridge, 19 April 2018.

984 Barbu, S., Nardy, A., Chevrot, J. P., Guellaï, B., Glas, L., Juhel, J., & Lemasson, A. (2015). Sex differences in language across early childhood: Family socioeconomic status does not impact boys and girls equally. *Frontiers in psychology*, *6*, 1874.

Antenatal factors

Preterm birth

Speech and language problems are common among children born prematurely. Findings from a recent analysis of the Norwegian Mother and Child Cohort Study observed that late preterm infants (34 to 36 weeks gestation) had 74% greater odds of having communication impairments at 18 months, while those born at early term (37 to 38 weeks gestation) had 27% greater odds of language impairments.[985] These findings are similar to those reported elsewhere, showing that many preterm children outgrow these difficulties, thus suggesting that initial impairments may not be permanent.[986,987]

It is thought that initial language delays in premature children may be related to disruptions to the development of the auditory cortex, which is responsible for children's hearing and phonological awareness.[988] As described in the previous section, children are able to discriminate sounds in the womb. A preterm birth may therefore disrupt this process by exposing the infant to sounds not typically heard in the womb, while simultaneously decreasing his or her exposure to the mother's voice and other important ambient sounds. For example, studies observe that infants typically hear much less in neonatal units than they do in their mother's womb.[989]

Exposure to harmful substances

Exposure to harmful substances negatively impacts children's early language capabilities similarly to the other cognitive outcomes described in this review.[990] However, the impact of children's exposure to tobacco in the womb and later language development remains unclear. Historically, studies involving children born in the 1980s have shown that exposure to cigarette smoke in the womb is strongly associated with a number of negative language and cognitive outcomes, even after other sociodemographic variables, including maternal education, have been statistically considered.[991,992,993]

These findings have not, however, been observed in more recent cohort studies involving children born in the 1990s and later. For example, findings involving the Danish National Birth Cohort found that the negative effects of cigarette smoke in the womb on later language outcomes became non-significant once maternal education was also statistically considered

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985 Stene-Larsen, K., Brandlistuen, R. E., Lang, A. M., Landolt, M. A., Latal, B., & Vollrath, M. E. Communication Impairments in Early Term and Late Preterm Children: A Prospective Cohort Study following Children to Age 36 Months. *Journal of Pediatrics, 165*, 6, 1123–1128.

986 Zambrana, I. M., Vollrath, M. E., Sengpiel, V., Jacobsson, B., & Ystrom, E. (2015). Preterm delivery and risk for early language delays: a sibling-control cohort study. *International journal of epidemiology*, *45*(1), 151–159.

987 Guarini, A., Sansavini, A., Fabbri, C., Alessandroni, R., Faldella, G., & Karmiloff-Smith, A. (2009). Reconsidering the impact of preterm birth on language outcome. *Early Human Development*, *85*(10), 639–645.

988 Monson, B. B., Eaton-Rosen, Z., Kapur, K., Liebenthal, E., Brownell, A., Smyser, C. D., ... & Neil, J. J. (2018). Differential rates of perinatal maturation of human primary and nonprimary auditory cortex. *eNeuro*, *5*(1), ENEURO-0380.

989 Pineda, R., Durant, P., Mathur, A., Inder, T., Wallendorf, M., & Schlaggar, B. L. (2017). Auditory exposure in the neonatal intensive care unit: room type and other predictors. *The Journal of pediatrics*, *183*, 56–66.

990 Mamluk, L., Edwards, H. B., Savović, J., Leach, V., Jones, T., Moore, T. H., ... & Smith, G. D. (2017). Low alcohol consumption and pregnancy and childhood outcomes: time to change guidelines indicating apparently 'safe' levels of alcohol during pregnancy? A systematic review and meta-analyses. *BMJ open*, *7*(7), e015410.

991 Fried, P. A., Watkinson, B., & Gray, R. (2003). Differential effects on cognitive functioning in 13- to 16-year-olds prenatally exposed to cigarettes and marihuana. *Neurotoxicology and Teratology, 25*, 427–436.

992 Mortensen, E., Michaelsen, K., Sanders, S., & Reinisch, J. (2005). A dose-response relationship between maternal smoking during late pregnancy and adult intelligence in male offspring. *Paediatric and Perinatal Epidemiology, 19*, 4–11.

993 Olds, D. L., Henderson, C. R., Jr., & Tatelbaum, R. (1994). Intellectual impairment in children of women who smoke cigarettes during pregnancy. *Pediatrics, 93*, 221–227.

and this finding is similar to that observed in cohort studies undertaken in Australia, New Zealand, Canada, the United States and England.[994,995,996,997,998,999,1000]

The differences in these findings may be explained by changes over time in the number of cigarettes pregnant mothers report smoking. For example, the mothers participating in one of the original US studies taking place in the 1980s were more likely to smoke over 15 cigarettes per day, in comparison to the mothers in the more recent Danish study who reported an average of less than 10 cigarettes per day. These findings should nevertheless not be interpreted to mean that lower amounts of cigarette smoke in the womb are safe, as studies continue to confirm an association between antenatal exposure to nicotine and other negative child outcomes not described in this review.[1001]

Other substances thought to negatively impact children's language development include Selective Serotonin Reuptake Inhibitors (SSRIs) taken to reduce symptoms of depression. Several studies have now verified a link between prolonged maternal use of SSRIs during pregnancy and later child language difficulties.[1002,1003] For example, an analysis involving the Norwegian Mother and Child Cohort Study observed that children whose mothers who reported using SSRIs throughout their pregnancies were less likely to speak in complete sentences by age three and a half in comparison with the children born to mothers who did not take antidepressants.[1004] However, this study also observed that symptoms of depression and anxiety during pregnancy also negatively impacted children's language outcomes, even when SSRIs were not taken. Considered together, these findings suggest a need for nonpharmaceutical treatments for mothers experiencing mental health problems during their pregnancies, as we highlight in EIF's report, *What works to enhance the effectiveness of the Healthy Child Programme*.[1005]

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994 Falgreen Eriksen, H. L., Kesmodel, U. S., Wimberley, T., Underbjerg, M., Kilburn, T. R., & Mortensen, E. L. (2012). Effects of tobacco smoking in pregnancy on offspring intelligence at the age of 5. *Journal of Pregnancy*, *2012*.

995 Baghurst, P. A., Tong, S. L., Woodward, A., & McMichael, A. J. (1992). Effects of maternal smoking upon neuropsychological development in early childhood: Importance of taking account of social and environmental factors. *Paediatric and Perinatal Epidemiology, 6*, 403–415.

996 Breslau, N., Paneth, N., Lucia, V. C., & Paneth-Pollak, R. (2005). Maternal smoking during pregnancy and offspring IQ. International *Journal of Epidemiology, 34,* 1047–1053.

997 Fergusson, D. M., & Lloyd, M. (1991). Smoking during pregnancy and its effects on child cognitive ability from the ages 8 to 12 years. *Paediatric and Perinatal Epidemiology, 5*, 189–200.

998 Lawlor, D. A., Najman, J. M., Batty, G. D., O'Callaghan, M. J., Williams, G. M., & Bor, W. (2006). Early life predictors of childhood intelligence: Findings from the Mater- University study of pregnancy and its outcomes. *Paediatric and Perinatal Epidemiology, 20*, 148–162.

999 MacArthur, C., Knox, E. G., & Lancashire, R. J. (2001). Effects at age nine of maternal smoking in pregnancy: Experimental and observational findings. *British Journal of Obstetrics and Gynaecology, 108*, 67–73.

1000 Huijbregts, S. C. J., Seguin, J. R., Zocccolillo, M., Boivin, M., & Tremblay, R. E. (2008). Maternal prenatal smoking, parental antisocial behavior, and early childhood physical aggression. *Development and Psychopathology, 20*(2), 437–453.

1001 Asmussen, K., & Brims, L. (2018). *What works to enhance the effectiveness of the Healthy Child Programme: An evidence update*. Early Intervention Foundation. https://www.eif.org.uk/report/what-works-to-enhance-the-effectiveness-of-the-healthy-child-programme-an-evidence-update/

1002 Weikum, W. M., Oberlander, T. F., Hensch, T. K., & Werker, J. F. (2012). Prenatal exposure to antidepressants and depressed maternal mood alter trajectory of infant speech perception. *Proceedings of the National Academy of Sciences*, *109*(Supplement 2), 17221–17227.

1003 O'Connor, E., Rossom, R. C., Henninger, M., Groom, H. C., & Burda, B. U. (2016). Primary care screening for and treatment of depression in pregnant and postpartum women: evidence report and systematic review for the US Preventive Services Task Force. *Jama*, *315*(4), 388–406.

1004 Skurtveit, S., Selmer, R., Roth, C., Hernandez-Diaz, S., and Handal, M. (2014). Prenatal exposure to antidepressants and language competence at age three: results from a large population-based pregnancy cohort in Norway. *BJOG; 121*, 1621–1632.

1005 Asmussen, K., & Brims, L. (2018). *What works to enhance the effectiveness of the Healthy Child Programme: An evidence update*. Early Intervention Foundation. https://www.eif.org.uk/report/what-works-to-enhance-the-effectiveness-of-the-healthy-child-programme-an-evidence-update/

Maternal age

Recent findings involving the MCS observed that maternal age at the time of the child's birth is positively associated with children's linguistic capabilities at age five.[1006] Specifically, children whose mothers were between the ages of 30 and 40 at the time they gave birth to their first child were more likely to achieve higher vocabulary scores on the British Ability Scales in comparison to children who were born to mothers under the age of 30 when they had their first child. This study further observed that maternal age remained a significant predictor of children's vocabulary after statistically controlling for maternal education, relationship status, and household income. More specifically, the highest scores were observed for children whose mothers were between the ages of 30 and 34, although these were not significantly higher than the scores observed for children whose mothers were between the ages of 35 and 39. Interestingly, the vocabulary scores of children born to mothers over 40 were also lower, although not significantly so in comparison to children born to mothers who had their first child between the ages of 30 and 39. Studies also consistently suggest that adolescent parenthood is a risk for children's language development, although this is likely to do with the high overlap between adolescent parenthood and family income (see below).[1007,1008]

Infancy (0–12 months)

Phonological awareness

As described in previous sections, much of the language learning that takes place during the first year involves the infant's ability to distinguish phonemes and individual words from long streams of adult speech. Several studies have recently observed that phonemic awareness and word detection at 4–7 months is associated with the size of a child's expressive vocabulary between 24 and 36 months.[1009,1010,1011,1012] Studies also observe an association between reduplicative babbling and index-finger pointing during infancy and children's vocabulary at 18 months, although it appears as though these behaviours may be differentially associated with children's expressive and receptive capabilities.[1013] While reduplicative babbling is associated with the age at which infants acquired their first words, index-finger pointing is not. Reduplicative babbling is also associated with children's expressive vocabulary at 18 months, but not with their receptive vocabulary, when index-finger pointing is.

Gestures and object play

The results reported above are consistent with findings described elsewhere, observing that infant pointing behaviours and word acquisition are positively associated between 12 and 24 months, but not beforehand.[1014,1015] After 12 months, however, index-finger pointing and other

1006 Goisis, A. (2015). How are children of older mothers doing? evidence from the United Kingdom. *Biodemography and social biology*, *61*(3), 231–251.

1007 Lacroix, V., Pomerleau, A., & Malcuit, G. (2002). Properties of adult and adolescent mothers' speech, children's verbal performance and cognitive development in different socioeconomic groups: a longitudinal study. *First Language*, *22*(2), 173–196.

1008 Oxford, M., & Spieker, S. (2006). Preschool language development among children of adolescent mothers. *Journal of Applied Developmental Psychology*, *27*(2), 165–182.

1009 Tsao, F. M., Liu, H. M., & Kuhl, P. K. (2004). Speech perception in infancy predicts language development in the second year of life: A longitudinal study. *Child Development*, *75*(4), 1067–1084.

1010 Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature Reviews. Neuroscience*, *5*(11), 831.

1011 Newman, R., Ratner, N. B., Jusczyk, A. M., Jusczyk, P. W., & Dow, K. A. (2006). Infants' early ability to segment the conversational speech signal predicts later language development: a retrospective analysis. *Developmental Psychology*, *42*(4), 643.

1012 Cristia, A., Seidl, A., Junge, C., Soderstrom, M., & Hagoort, P. (2014). Predicting individual variation in language from infant speech perception measures. *Child Development*, *85*(4), 1330–1345.

1013 McGillion, M., Herbert, J. S., Pine, J., Vihman, M., DePaolis, R., Keren-Portnoy, T., & Matthews, D. (2017). What paves the way to conventional language? The predictive value of babble, pointing, and socioeconomic status. *Child Development*, *88*(1), 156–166.

1014 Colonnesi, C., Stams, G. J. J. M., Koster, I., & Noom, M. J. (2010). The relation between pointing and language development: A meta-analysis. *Developmental Review, 30*, 353–366.

1015 Hsu, H. C., & Iyer, S. N. (2016). Early gesture, early vocabulary, and risk of language impairment in preschoolers. *Research in Developmental Disabilities*, *57*, 201–210.

gestures are consistently associated with children's word learning during the second year. For example, an analysis involving the Early Language in Victoria Study observed that infant gesturing at 12 months was a better predictor of children's vocabulary at age two than was gesturing behaviour at eight months.[1016]

This study also observed that children's interaction with objects during infancy was a stronger predictor of their receptive vocabulary in comparison to their pointing behaviour. Additionally, gestures and object play were strongly associated with their parents' use of gesture. This observation is consistent with findings reported in other studies which show that increased parental gesturing is associated with increased child gesturing.[1017,1018,1019] However, studies also show that parent gestures are not directly associated with children's vocabulary when compared to their children's use of gesture.[1020] Thus, while pointing behaviours and object play are positively associated with children's understanding and use of words, the direction of causality remains unclear.

Joint attention

Object play frequently takes place during joint attention activities involving the caregiver and child. Studies show that infants vary in their interest and ability to engage in shared attention activities and these differences, in turn, predict their language acquisition during the second year of life.[1021] Specifically, children's vocabulary at 24 months is found to be associated with their ability to initiate and respond to their parents' bids for attention when children are between six and 12 months.[1022,1023] Studies also find that the amount of time spent in joint attention activities during infancy predicts vocabulary size in toddlerhood.[1024] Specifically, increases in maternal labelling behaviours in response to the infant's focus of attention are particularly predictive of vocabulary size at 15 months.

Infant-directed speech and maternal responsiveness

Studies suggest that the prosody and exaggerated emphasis on sounds and words used by parents when talking to their infants may help them discriminate sounds and remember specific words.[1025,1026,1027] For example, a small-scale US study involving lengthy recordings of caregiver–infant interactions observed that infants receiving higher levels of infant-directed speech (IDS) at 11 months understood over twice as many words at 24 months in

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1016 Bavin, E. L., Prior, M., Reilly, S., Williams, J., Eadie, P., Barrett, Y., & Ukoumunne, O. C. (2008). The Early Language in Victoria Study: predicting vocabulary at age 1 and 2 years from gesture and object use. *Journal of Child Language, 35*, 687–701.

1017 Iverson JM, Capirci O, Longobardi E, Caselli MC. (1999). Gesturing in mother--child interactions. *Cognitive Development, 14,* 57–75.

1018 Namy, L. L., Acredolo, L. P., Goodwyn, S. W. (2000). Verbal labels and gestural routines in parental communication with young children. *Journal of Nonverbal Behavior*. 24, 63–79.

1019 Rowe, M. L. (2000). Pointing and talk by low-income mothers and their 14-month-old children. *First Language. 20*, 305–30.

1020 Rowe, M. L., Özçalışkan, Ş., & Goldin-Meadow, S. (2008). Learning words by hand: Gesture's role in predicting vocabulary development. *First language*, *28*(2), 182–199.

1021 Farrant, B. M. and Zubrick, S. R. (2013). Parent–child book reading across early childhood and child vocabulary in the early school years: Findings from the Longitudinal Study of Australian Children. *First Language 33*(3) 280–293.

1022 Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development*, *78*(3), 938–954.

1023 Morales, M., Mundy, P., Delgado, C. E., Yale, M., Messinger, D., Neal, R., & Schwartz, H. K. (2000). Responding to joint attention across the 6-through 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology*, *21*(3), 283–298.

1024 Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, i–174.

1025 Thiessen, E. D., Hill, E. A., & Saffran, J. R. (2005). Infant-directed speech facilitates word segmentation. *Infancy*, *7*(1), 53–71.

1026 Singh, L., Nestor, S., Parikh, C., & Yull, A. (2009). Influences of infant-directed speech on early word recognition. *Infancy*, *14*(6), 654–666.

1027 Liu, H. M., Kuhl, P. K., & Tsao, F. M. (2003). An association between mothers' speech clarity and infants' speech discrimination skills. *Developmental Science*, *6*(3).

comparison with children receiving less IDS.[1028] The study further observed that it was not the amount of words heard, but the quality of the IDS during one-to-one interactions which specifically predicted the increases in children's vocabulary.

The study additionally found that caregiver IDS occurred more frequently in higher-income households. However, once family income was controlled for, the quality of the IDS and the frequency of the one-to-one interactions continued to predict differences in children's vocabulary at 24 months. So, the quality of caregiver IDS appeared to mediate any negative impact associated with family income.

Finally, this study observed that IDS occurred more frequently when infants were babbling, although it was not possible to determine any direction of causality. It is therefore possible that infant babbling may trigger increases in caregiver IDS, or the reverse – that increases in IDS may encourage increased infant babbling. Regardless, this relationship is consistent with findings reported in other, larger-scale studies showing that responsive and sensitive caregiving behaviours are strongly associated with the rate at which children achieve their first language milestones, independently of any association with family income or other socioeconomic factors.[1029]

Studies also show that consistency in the caregiver responsiveness and IDS over time is a key part of this relationship. For example, an analysis involving the US National Institute for Child Health and Human Development (NICHD) Study of Early Childcare and Youth Development observed that while sensitive parenting at age six months was associated with children's expressive language and academic achievement at age five, it was the stability in the mother's sensitivity over time (measured at multiple points during the first five years) which best explained this association. This study further observed that increased sensitivity from other childcare providers also predicted their expressive language capabilities once they entered school.[1030,1031]

Maternal depression

Historically, studies have observed an association between maternal depression and children's language development. This assumption is based on findings suggesting that depression and other mental illnesses may restrict mothers' ability to respond sensitively to their infants and engage in joint attention activities.[1032,1033] More recent studies show, however, that this relationship is not always upheld when other important variables, such as family income or social isolation are statistically taken into account.[1034,1035,1036] Once these other factors have also been considered, the association between maternal depression and child language delays often disappears, or remains only in circumstances involving extreme

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1028 Ramírez-Esparza, N., García-Sierra, A., & Kuhl, P. K. (2014). Look who's talking: speech style and social context in language input to infants are linked to concurrent and future speech development. *Developmental Science*, *17*(6), 880–891.

1029 Tamis-LeMonda, C. S., Bornstein, M. H., & Baumwell, L. (2001). Maternal responsiveness and children's achievement of language milestones. *Child Development*, *72*(3), 748–767.

1030 Hirsh-Pasek, K., & Burchinal, M. (2006). Mother and caregiver sensitivity over time: Predicting language and academic outcomes with variable-and person-centered approaches. *Merrill-Palmer Quarterly*, *52*(3), 449–485.

1031 Raviv, T., Kessenich, M., & Morrison, F. J. (2004). A mediational model of the association between socioeconomic status and three-year-old language abilities: The role of parenting factors. *Early Childhood Research Quarterly*, *19*(4), 528–547.

1032 Sohr-Preston, S. L., & Scaramella, L. V. (2006). Implications of timing of maternal depressive symptoms for early cognitive and language development. *Clinical child and family psychology review*, *9*(1), 65–83.

1033 Murray, L., Fiori-Cowley, A., Hooper, R., & Cooper, P. (1996). The impact of postnatal depression and associated adversity on early mother-infant interactions and later infant outcome. *Child Development*, *67*(5), 2512–2526.

1034 Lucci, T. K., & Otta, E. (2013). Postpartum depression and child development in first year of life. *Estudos de Psicologia (Campinas)*, *30*(1), 7–17.

1035 Goodman, S. H., Rouse, M. H., Connell, A. M., Broth, M. R., Hall, C. M., & Heyward, D. (2011). Maternal depression and child psychopathology: A meta-analytic review. *Clinical child and family psychology review*, *14*(1), 1–27.

1036 Sohr-Preston, S. L., & Scaramella, L. V. (2006). Implications of timing of maternal depressive symptoms for early cognitive and language development. *Clinical child and family psychology review*, *9*(1), 65–83.

disadvantage.[1037,1038,1039] Studies additionally find that depression does not universally impair mothers' ability to respond appropriately to their child.[1040,1041,1042,1043] However, these findings should not be interpreted to mean that maternal depression does not negatively predict children's development in other important ways. For example, studies consistently confirm strong associations between maternal depression and child behavioural problems.[1044]

Toddlerhood (12–36 months)

Caregiver language and income

Individual differences in English-speaking children's vocabulary acquisition between the ages of two and three years have been extensively studied. Although much of this research involves small samples and a limited set of contributing variables, the findings across studies are broadly similar.[1045]

- Individual differences in children's word processing skills are evident by 18 months.[1046]
- Individual differences in children's word processing skills at 25 months have been found to predict vocabulary and working memory at eight years.[1047]
- The quality and amount of IDS toddlers hear during their second year is associated with their receptive and expressive vocabularies at age two.[1048,1049] Caregiver's responsiveness to child behaviours, their gestures, the diversity of their language and use of one-word utterances to name objects have all been found to predict the size of their children's vocabularies and the speed with which they process language.[1050,1051,1052,1053,1054]

1037 Paulson, J. F., Keefe, H. A., & Leiferman, J. A. (2009). Early parental depression and child language development. *Journal of Child Psychology and Psychiatry*, *50*(3), 254–262.

1038 Quevedo, L. A., Silva, R. A., Godoy, R., Jansen, K., Matos, M. B., Tavares Pinheiro, K. A., & Pinheiro, R. T. (2012). The impact of maternal post-partum depression on the language development of children at 12 months. *Child: care, health and development*, *38*(3), 420–424.

1039 Grace, S. L., Evindar, A., & Stewart, D. E. (2003). The effect of postpartum depression on child cognitive development and behavior: a review and critical analysis of the literature. *Archives of Women's Mental Health*, *6*(4), 263–274.

1040 Murray, L. (1992). The impact of postnatal depression on infant development. *Journal of child psychology and psychiatry*, *33*(3), 543–561.

1041 Wang, Y., & Dix, T. (2013). Patterns of depressive parenting: Why they occur and their role in early developmental risk. *Journal of Family Psychology, 27*(6), 884–895.

1042 Annie Yoon, S., A. Kelso, G., Lock, A., & Lyons-Ruth, K. (2014). Mother–Infant Joint Attention and Sharing: Relations to Disorganized Attachment and Maternal Disrupted Communication. *The Journal of genetic psychology*, *175*(6), 494–510

1043 Henderson, E. N., & Jennings, K. D. (2003). Maternal depression and the ability to facilitate joint attention with 18-month-olds. *Infancy*, *4*(1), 27–46.

1044 Goodman, S. H., Rouse, M. H., Connell, A. M., Broth, M. R., Hall, C. M., & Heyward, D. (2011). Maternal depression and child psychopathology: A meta-analytic review. *Clinical child and family psychology review*, *14*(1), 1–27.

1045 Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: implications for closing achievement gaps. *Developmental psychology*, *49*(1), 4.

1046 Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental psychology*, *42*(1), 98–116.

1047 Marchman, V. A., & Fernald, A. (2008). Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental Science*, *11*(3).

1048 Ma, W., Golinkoff, R. M., Houston, D. M., & Hirsh-Pasek, K. (2011). Word learning in infant-and adult-directed speech. *Language Learning and Development*, *7*(3), 185–201.

1049 Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology*, *27*(2), 236.

1050 Hurtado, N., Marchman, V. A., & Fernald, A. (2008). Does input influence uptake? Links between maternal talk, processing speed and vocabulary size in Spanish-learning children. *Developmental Science*, *11*(6).

1051 Swingley, D., & Humphrey, C. (2018). Quantitative linguistic predictors of infants' learning of specific english words. *Child development*, *89*(4), 1247–1267.

1052 Lacroix, V., Pomerleau, A., & Malcuit, G. (2002). Properties of adult and adolescent mothers' speech, children's verbal performance and cognitive development in different socioeconomic groups: a longitudinal study. *First Language*, *22*(2), 173–196.

1053 Cartmill, E. A., Armstrong, B. F., Gleitman, L. R., Goldin-Meadow, S., Medina, T. N., & Trueswell, J. C. (2013). Quality of early parent input predicts child vocabulary 3 years later. *Proceedings of the National Academy of Sciences*, *110*(28), 11278–11283.

1054 Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*(5), 1762–1774.

However, the amount of adult-directed speech (ADS) that children hear in their homes (adult conversations, television, and so on) is not associated with individual differences in children's language development.[1055]

- There is now preliminary evidence showing that frequent interruptions (for example, through the use of mobile phones) may diminish the quality of children's language learning during parent–child interactions.[1056]
- The amount and quality of caregiver IDS is highly associated with maternal education and family income.[1057] This finding has been observed in multiple, robust studies and is reported consistently throughout the literature.[1058] In fact, studies observe that income-related differences in children's language are best predicted by income-related differences in mothers' use of language, not by income itself.[1059]
- Income-related differences in children's language processing are already apparent at 18 months.[1060]

In sum, income-related differences are present in children's word processing capabilities at 18 months, and these differences are consistently associated with differences in the amount and quality of the language children hear in their homes. Caregiver behaviours found to support early word learning in toddlerhood include the continued use of IDS that is responsive to the child's specific interests, and the use of a diverse and rich vocabulary. The implications of these findings for early intervention are discussed further at the end of this chapter.

Book sharing

The quality of the home learning environment, and the availability of books specifically, are consistently associated with children's early language development. Indeed, toys and other objects provide ideal opportunities for shared attention and book sharing can facilitate the learning of new words.[1061] Several meta-analyses confirm that shared book reading is consistently and significantly associated with children's vocabulary size at all points of early development.[1062,1063] Questions remain, however, about how much book reading is enough, as well as the relative value of book sharing in comparison with other kinds of parent–child interaction.

A 2012 analysis of the Longitudinal Study of Australian Children (LSAC) cohort considered these questions specifically by comparing joint attention activities and book sharing during infancy to children's language development until the age of five. The analysis found that children's participation in shared attention activities at nine months and the frequency of book sharing during the first three years jointly predicted children's vocabulary at age three,

1055 Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science*, *24*(11), 2143–2152.

1056 Reed, J., Hirsh-Pasek, K., & Golinkoff, R. M. (2017). Learning on hold: Cell phones sidetrack parent-child interactions. *Developmental Psychology*, *53*(8), 1428.

1057 National Institute of Child Health and Human Development Early Childcare Research Network. (2003). Social functioning in first grade: Associations with earlier home and childcare predictors and with current classroom experiences. *Child Development,74*, 1639–1662.

1058 For a review, see: Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: implications for closing achievement gaps. *Developmental psychology*, *49*(1), 4.

1059 Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development*, *74*(5), 1368–1378.

1060 Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science*, *16*(2), 234–248.

1061 Hoff, E. (2010). Context effects on young children's language use: The influence of conversational setting and partner. *First Language*, *30*(3-4), 461–472.

1062 Bus, A. G., Van Ijzendoorn, M. H., & Pellegrini, A. D. (1995). Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of Educational Research*, *65*(1), 1–21.

1063 Mol, S. E., Bus, A. G., De Jong, M. T., & Smeets, D. J. (2008). Added value of dialogic parent–child book readings: A meta-analysis. *Early Education and Development*, *19*(1), 7–26.

over and above their gender and mothers' education.[1064] Joint attention during infancy and parent–child book sharing then continued to predict children's language skills at the time the children were ready for school. Specifically, low levels of book sharing (10 minutes a day or less) throughout the first five years more than doubled the likelihood of children scoring in the lowest 20th percentile in comparison with children who were read to for longer periods per day.[1065] The analysis additionally observed that the number of books in the home was a good indicator of the frequency of parent–child book reading and thus also predicted children's vocabulary at age five.

These findings are consistent with those reported elsewhere showing that daily book sharing activities are strongly associated with children's vocabulary at age two, and may possibly attenuate any negative impacts associated with family income.[1066] Studies also find that frequent book sharing during infancy and toddlerhood may have a 'snowballing' effect on children's emergent literacy. In other words, enjoyable reading experiences during the very early years are thought to contribute to an increased interest in books which, in turn, increases children's participation in reading as they develop.[1067,1068]

Birth order and siblings

Language development may be accelerated in firstborn children, with studies showing that firstborn children frequently acquire their first 50 words up to a month before their siblings.[1069,1070,1071] Researchers assume that this occurs because firstborn children are more likely to receive one-to-one attention from their parents in the form of triadic play and book sharing.[1072,1073,1074] However, studies also find that the magnitude of these differences are small and typically fade after children learn their first 50 words.[1075] Studies also show that when it comes to learning pronouns, younger siblings may have a small advantage. Researchers believe this may occur because second and subsequent siblings are more frequently involved in conversations with multiple family members where the terms 'he', 'she', 'you' and 'me' are used.[1076]

1064 Farrant, B. M., & Zubrick, S. R. (2012). Early vocabulary development: The importance of joint attention and parent-child book reading. *First Language*, *32*(3), 343–364.

1065 Farrant, B. M. and Zubrick, S. R. (2013). Parent–child book reading across early childhood and child vocabulary in the early school years: Findings from the Longitudinal Study of Australian Children. *First Language, 33*(3) 280–293.

1066 Raikes, H., Alexander Pan, B., Luze, G., Tamis-LeMonda, C. S., Brooks-Gunn, J., Constantine, J., ... & Rodriguez, E. T. (2006). Mother–child bookreading in low-income families: Correlates and outcomes during the first three years of life. *Child Development*, *77*(4), 924–953.

1067 Deckner, D. F., Adamson, L. B. & Bakeman, R. (2006). Child and maternal contributions to shared reading: Effects on language and literacy development. *Journal of Applied Developmental Psychology*, 27(1), 31–41.

1068 Raikes, H., Pan, B. A., Luze, G., Tamis-LeMonda, C. S., Brooks-Gunn, J., Constantine, J., et al. (2006). Mother-child bookreading in low-income families: Correlates and outcomes during the first three years of life. *Child Development, 77*(4), 924–953.

1069 Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., ... & Stiles, J. (1994). Variability in early communicative development. *Monographs of the society for research in child development*, i–185.

1070 Pine, J. M. (1995). Variation in vocabulary development as a function of birth-order. *Child Development, 66,* 272–281.

1071 Zambrana, I. M., Ystrom, E., & Pons, F. (2012). Impact of gender, maternal education, and birth order on the development of language comprehension: a longitudinal study from 18 to 36 months of age. *Journal of Developmental & Behavioral Pediatrics*, *33*(2), 146–155.

1072 Westerlund, M., & Lagerberg, D. (2008). Expressive vocabulary in 18-month-old children in relation to demographic factors, mother and child characteristics, communication style and shared reading. *Childcare Health & Development,* 34, 257–266.

1073 Raikes, H., Alexander Pan, B., Luze, G., Tamis-LeMonda, C. S., Brooks-Gunn, J., Constantine, J., ... & Rodriguez, E. T. (2006). Mother–child bookreading in low-income families: Correlates and outcomes during the first three years of life. *Child Development*, *77*(4), 924–953.

1074 Hoff-Ginsberg, E. (1998). The relation of birth order and socioeconomic status to children's language experience and language development. *Applied Psycholinguistics*, *19*(4), 603–629.

1075 Berglund, E., Eriksson, M., and Westerlund, M. (2005). Communicative skills in relation to gender, birth order, childcare and socioeconomic status in 18-month-old children. *Scandinavian Journal of Pychology, 46*, 485–491.

1076 Oshima-Takane, Y., Goodz, E., and Derevensky, J. L. (1996). Birth order effects on early language development: do secondborn children learn from overheard speech? *Child Development,* 67, 621–634.

Additional evidence suggests that language milestones are slightly delayed in families where there are many siblings, with some studies observing an inverse relationship between children's language development and the number of siblings in the home.[1077] This delay has been attributed to the fact that children raised in large families receive less one-to-one attention from their parents and may have to compete with their siblings for toys and other learning materials.[1078] Nevertheless, it is worth noting that studies also find that having siblings provides other benefits, especially when it comes to development of ToM and other social skills, as described in chapter 4.[1079]

Childcare

Childcare varies dramatically in terms of its quality and the amount children receive, making it difficult to draw conclusions about its overall impact. Factors found to be associated with the effectiveness of childcare include the age at which children first attend (for instance, before or after the age of two), the type of childcare (such as child-minding vs centre-based; group vs individual), the amount of time spent in childcare (> 12 hours per week), and the quality of childcare (for example, certified teachers vs untrained childminders or creche workers).[1080]

- Findings from the Study of Early Education and Development (SEED) observed a positive association between children's participation in childcare and vocabulary at ages two and three, regardless of income.[1081] However, it is worth noting that these findings were observed only among children receiving care from childminders or relatives – not those participating in group care.
- As described in chapter 3, an analysis involving the Families, Children and Childcare (FCCC) study observed that out-of-home group care (> 12 hours per week) before the age of two predicted gains in children's vocabulary at age five in comparison with children not receiving childcare. Looking at verbal skills at 51 months (based on the verbal comprehension and vocabulary scales of the BAS), greater amounts of group care over the preschool period did not predict higher BAS scores, however, while starting at an earlier age did.[1082,1083]
- Findings from the US NICHD study have also confirmed short-term gains in children's language development, although these gains were found to have faded by the time children were five years old.[1084,1085]
- Findings from a recent Dutch childcare study observed that centre-based care lasting 12 hours per week or more was associated with improvements in children's language development, *provided that it was offered after the age of two*.[1086] When offered before the

1077 Downey, D. B. (2001). Number of siblings and intellectual development – The resource dilution explanation. *American Psychologist, 56,* 497–504.

1078 Downey, D. B. (1995). When bigger is not better: Family size, parental resources, and children's educational performance. *American sociological review*, 746–761.

1079 Downey, D. B., Condron, D. J., & Yucel, D. (2015). Number of siblings and social skills revisited among American fifth graders. *Journal of Family Issues*, *36*(2), 273–296.

1080 Melhuish, E., Ereky-Stevens, K., Petrogiannis, K., Ariescu, A., Penderi, E., Rentzou, K., ... & Leseman, P. (2015). *A review of research on the effects of Early Childhood Education and Care (ECEC) upon child development*.

1081 Morris, S. P., Melhuish, E., & Gardiner, J. (2017). Study of early education and development (SEED): Impact study on early education use and child outcomes up to age three. Department for Education.

1082 Sylva, K., Stein, A., Leach, P., Barnes, J., Malmberg, L. E., & FCCC-team. (2011). Effects of early child-care on cognition, language, and task-related behaviours at 18 months: An English study. *British Journal of Developmental Psychology*, *29*(1), 18–45.

1083 Barnes, J., & Melhuish, E. C. (2017). Amount and timing of group-based childcare from birth and cognitive development at 51 months: A UK study. *International Journal of Behavioral Development*, *41*(3), 360–370.

1084 NICHD ECCRN (2000). The relation of childcare to cognitive and language development. *Child Development, 71*, 960–980.

1085 NICHD ECCRN (2004). Type of childcare and children's development at 54 months. *Early Childhood Research Quarterly,* 19, 203–230.

1086 Luijuk, M. P. C. M., Linting, M. Henrichs, J., and van Ijendoorn, M. H. (2015). Hours in non-parental childcare are related to language development in a longitudinal cohort study: Childcare and language development. *Childcare Health and Development 41(6).* 1188–1198.

age of two, centre-based care was associated with decreases in language proficiency at 18 months, although these children's language skills nevertheless caught up to that of their peers by the age of five. This study further observed that the benefits of centre-based care were independent of family income – in other words, all children benefited – although it should be noted that the Dutch sample was likely to have been more homogeneous in comparison to the sample participating in the UK or US studies.

More specifically, studies that consider the impact of childcare on the language development of disadvantage children generally confirm a positive association. For example, findings involving the MCS observed a small, but significant benefit for disadvantaged children attending centre-based childcare at the assessments made at ages 3, 5 and 7.[1087] The Canadian National Longitudinal Survey of Children and Youth has observed similar benefits for disadvantaged preschoolers attending regular group-based childcare.[1088]

Ages three to five

Prior language capabilities

Studies consistently show that children's language capabilities at age three are significantly associated with language and other school readiness outcomes by the time they enter primary school. For example, all of the cohort studies included in this review that collected data on the language capabilities of children age three (and in some cases age two) observed a significant association between children's language capabilities at ages two, three, five and later points in children's development when measured.[1089,1090,1091,1092,1093,1094] While these findings should not be interpreted to mean that children's language capabilities are set in stone by the age of three (indeed, change continues to be observed in children at the individual level, as described previously), such findings reveal remarkable stability in early language development when considered at the population level.

These studies also show that children's language capabilities at age three predict a variety of other important competencies when children are older. For example, a recent analysis of the MCS sample observed that children's vocabulary at age three was significantly associated with their ability to make friends at school in Year 1.[1095] Findings from a separate analysis further verified that children's behaviour and language at age three jointly predict behavioural difficulties at age five, further confirming that for some children, early language delays may increase the risk of later behavioural problems.[1096]

1087 Côté, S. M., Doyle, O., Petitclerc, A. & Timmins, L. (2013) Childcare in infancy and cognitive performance until middle childhood in the millennium cohort study. *Child Development*, *84*, 1191–1208.

1088 Geoffroy, M.-C., Côté, S. M., Borge, A. I. H., Larouche, F., Séguin, J. R. & Rutter, M. (2007) Association between nonmaternal care in the first year of life and children's receptive language skills prior to school entry: the moderating role of socioeconomic status. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *48*, 490–497.

1089 Hernández-Alava, M., & Popli, G. (2017). Children's Development and Parental Input: Evidence from the UK Millennium Cohort Study. *Demography*, *54*(2), 485–511.

1090 Melhuish, E. (2010) *Growing Up in Scotland: Impact of the home learning environment on child cognitive development*. Edinburgh: Scottish Government.

1091 Bradshaw, P. (2011) *Growing Up in Scotland: Changes in child cognitive ability in the pre-school years*. Edinburgh: Scottish Government.

1092 Gardner-Neblett, N., DeCoster, J., & Hamre, B. K. (2014). Linking preschool language and sustained attention with adolescent achievement through classroom self-reliance. *Journal of Applied Developmental Psychology*, *35*(6), 457–467.

1093 Prior, M., Bavin, E., & Ong, B. (2011). Predictors of school readiness in five-to six-year-old children from an Australian longitudinal community sample. *Educational Psychology*, *31*(1), 3–16.

1094 Roulstone, S., Law, J., Rush, R., Clegg, J., & Peters, T. (2011). Investigating the role of language in children's early educational outcomes. Department for Education.

1095 Girard, L. C., Pingault, J. B., Doyle, O., Falissard, B., & Tremblay, R. E. (2017). Expressive language and prosocial behaviour in early childhood: Longitudinal associations in the UK Millennium Cohort Study. *European Journal of Developmental Psychology*, *14*(4), 381–398.

1096 Girard, L. C., Pingault, J. B., Doyle, O., Falissard, B., & Tremblay, R. E. (2016). Developmental associations between conduct problems and expressive language in early childhood: A population-based study. *Journal of Abnormal Child Psychology*, *44*(6), 1033–1043.

Family income and parental education

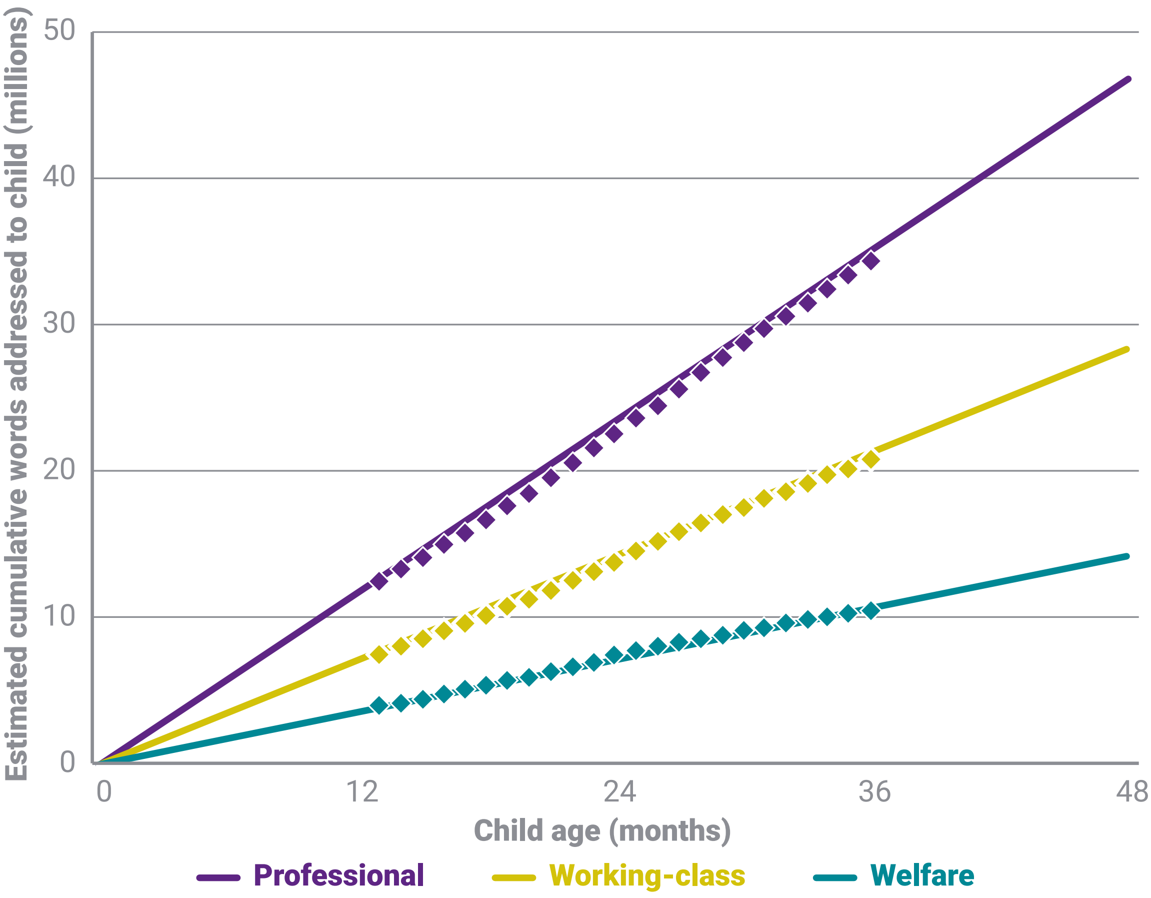
Between the ages of three and five, children's language development continues to be strongly associated with their parents' socioeconomic status. The magnitude of this relationship is best exemplified by Hart and Risley's famous '30 million-word gap' study which showed that by the time of their third birthday, children raised by professional parents had heard 30 million more words than children whose parents were receiving state benefits (see figure 6.5).[1097] More specifically:

- children raised in workless households heard an average of **616 words per hour**
- children raised by working class parents heard an average of **1,251 words per hour**
- children raised by professional parents heard an average of **2,153 words per hour**.

Over a year's time, these figures amounted to a difference of almost 8 million words between the three groups; after three years' time, this difference represented a gap of over 32 million words.

FIGURE 6.5

SES-related differences in the number of words heard per hour during the first three years of life



Source: Hart and Risley 1995; reproduced from Law et al 2013.

In a follow-up study, Hart and Risley further observed that children raised by professional parents were exposed to a greater variety of words, which reflected increased grammatical complexity. Professional parents were also more likely to ask their children more questions and push them to provide more elaborate answers. Hart and Risley suspected that this

1097 Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Paul H Brookes Publishing.

linguistic scaffolding additionally contributed to children's language acquisition as children grew older, observing that the amount of language children heard at age three predicted their achievement and reading capabilities when they were age nine.

Although Hart and Risley's original sample was small, many larger-scale studies have since replicated their findings. These subsequent studies consistently observe that parents with professional skills and qualifications are more likely to speak to their child in a way that is responsive to the child's age and verbal capabilities. In this respect, professional parents more frequently label words when talking to their one-year-old child, but then switch to longer and more structured narratives when their children are between the age of three and five.[1098,1099] Researchers believe that these behaviours are ultimately adaptive towards their children's developmental needs, reflecting that the quantity of input is the most useful during the child's second year, the diversity and complexity of the vocabulary most important during the third year, and the use of structured narratives and decontextualised conversations are the most important during the fourth year.

Many studies have also replicated Hart and Risley's longitudinal findings, showing that SES-related gaps existing at the age of three persist and grow larger throughout primary and secondary school.[1100,1101] For example, analyses involving each wave of the MCS data also observed an SES-related language gap which became increasingly wider as children grew older. Findings from a very recent analysis involving the MCS data observe that this gap is best explained by parents' educational level, and their vocabulary in particular, in comparison to family and the number of books in the home.[1102] More specifically, this study made the following observations:

- Children who have at least one parent with a bachelor's or higher qualification have roughly a three-fold advantage in language capabilities (as measured by vocabulary) at age 14 in comparison to children whose parents have no qualifications.
- Exposure to books in the home plays an important mediating role in this relationship. It amplifies the effects of parental vocabulary in homes where one or both parents have higher qualifications and improves language outcomes among children whose parents have no qualifications.
- Children's verbal abilities at age five significantly predict their verbal abilities at age 14, although their parents' vocabulary continues to predict adolescent's language capabilities. Parental education and children's exposure to books also remain important factors, although the relationship between reading to the child at age three is no longer predictive of adolescent language, as its effect is fully explained by the child's language scores at age five.
- While children's vocabulary at age 14 is strongly correlated with their parents' vocabulary, it is nevertheless significantly better than their parents, suggesting some cause for optimism regarding the potential benefits of education for reducing generational inequalities.

The association between parent qualifications and child language has led some to examine whether increases in parents' educational level might contribute to improvements in

1098 Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*(5), 1762–1774.

1099 Hoff-Ginsberg, E. (1998). The relation of birth order and socioeconomic status to children's language experience and language development. *Applied Psycholinguistics,19,* 603–629.

1100 Taylor, C. L., Christensen, D., Lawrence, D., Mitrou, F., & Zubrick, S. R. (2013). Risk factors for children's receptive vocabulary development from four to eight years in the Longitudinal Study of Australian Children. *PLOS one*, *8*(9), e73046.

1101 Law, J., Rush, R., Anandan, C., Cox, M., & Wood, R. (2012). Predicting Language Change Between 3 and 5 Years and Its Implications for Early Identification. *Pediatrics, 2012*, 130–132.

1102 Sullivan, A., Moulton, V. & Fitzsimons, E. (2017). The intergenerational transmission of vocabulary. Centre for Longitudinal Studies. Working paper 2017/14.

their children's language development during the preschool years. Findings involving the NICHD cohort suggest that such improvements are possible, through associations with improvements in parent–child interaction and the home-learning environment, including increases in number of books available in the home.[1103]

Unfortunately, studies consistently show that disadvantaged children are more likely to experience decreases in the quality of the home learning environment rather than increases.[1104] When improvements in the home learning environment do occur, they occur more frequently in households led by parents with higher qualifications.[1105] Although these improvements are often paralleled by increases in children's language capabilities, studies also find that they are typically not sufficient for children to catch up to peers who experienced an enriching home learning environment from the first year of life.

Early years education

As described in previous chapters, enriching early years education offered to disadvantaged children between the ages of three and five is consistently associated with a variety of improvements in children's learning, including their understanding of objects and numbers. Similar benefits have been observed for children's language development, with studies showing at least a quarter of a standard deviation of improvement on validated language measures.[1106] Although these benefits frequently fade out within two years, findings from the most recent Head Start impact study observed that some benefits involving children's oral comprehension and receptive vocabulary were retained.[1107]

The consistency of these findings have led some to argue that preschool education has the potential to reduce income-related gaps in children's early language development, by allowing disadvantaged children to catch up to their more advantaged peers.[1108,1109] A recent analysis of the MCS data set observed that while participation in early preschool education is associated with improvements in children's early language development, its impact does not appear to be sufficient for them to catch up to more advantaged peers, as the language skills of these children also continue to improve.[1110] Participation in preschool between the ages of three and five nevertheless appears to perform a protective function, by keeping disadvantaged children's language from falling further behind.

Bilingual language acquisition

Many children throughout the world are exposed to more than one language while growing up. While for many children this exposure occurs right from birth, it is also not uncommon for children to be exposed to a second language when they first enter school.

1103 Magnuson, K. A., Sexton, H. R., Davis-Kean, P. E., and Huston, A. C. (2009). Increases in Maternal Education and Young Children's Language Skills. *Merrill-Palmer Quarterly, 55*(3), 319–350.

1104 Rodriguez, E. T. and Tamis-LeMonda, C. S. (2011), Trajectories of the home learning environment across the first 5 years: Associations with children's vocabulary and literacy skills at prekindergarten. *Child Development, 82*, 1058–1075.

1105 Son, S. H., & Morrison, F. J. (2010). The nature and impact of changes in home learning environment on development of language and academic skills in preschool children. *Developmental Psychology*, *46*(5), 1103.

1106 Barnett, W. S., Lamy, C., & Jung, K. (2005). *The effects of state prekindergarten programs on young children's school readiness in five states*. New Brunswick, NJ: National Institute for Early Education Research.

1107 Puma, M., Bell, S., Cook, R., Heid, C., Shapiro, G., Broene, P., ... & Ciarico, J. (2010). Head Start Impact Study. Final Report. *Administration for Children & Families*.

1108 Magnuson, K. A., Meyers, M. K., Ruhm, C. J., & Waldfogel, J. (2004). Inequality in preschool education and school readiness. *American educational research journal*, *41*(1), 115–157.

1109 Melhuish, E. C. (2011). Preschool matters. *Science*, *333*(6040), 299–300.

1110 Becker, B. (2011). Social disparities in children's vocabulary in early childhood. Does pre-school education help to close the gap? *The British Journal of Sociology*, *62*(1), 69–88.

In the long run, it is clear that bilingual language learning provides children with many advantages.[1111,1112] Even those entering school with little or no knowledge of the language of instruction often gain proficiency equivalent to their peers by the middle of primary school.[1113,1114] Nevertheless, poor educational outcomes among some bilingual children are consistently documented for reasons which remain unclear. Potential reasons include the fact that many bilingual children are raised in socially disadvantaged circumstances, which may independently contribute to language difficulties.[1115] Children introduced to a second language at school must also master a new phonology system when they are learning to read, thus making it difficult for them to achieve early literacy milestones at the same rate as their monolinguistic peers.

It is therefore difficult to make generalisations about bilingual children's language development. Current research suggests, however, that some consistencies in bilingual or multilingual development are evident.

- **Phonology development:** Multilinguistic children appear to reach their early language milestones at a rate similar to those raised in monolingual homes, although bi- or multilingual children may pronounce words with phonological features which 'belong' to the other language they are learning.[1116] This is by no mean universal, however, and appears to be dependent upon the level of exposure to each language and the degree of similarity between the languages.
- **Vocabulary:** It is not uncommon for bilingual children to acquire vocabulary at a slower rate than monolingual children. It is also not uncommon for bi- or multilingual children to have 'non-overlapping sets' of vocabulary, with words mastered in one language but not the other (for example, to know 'dog' in English but not its equivalent ('cane') in Italian). However, studies often find that multilingual children's total *conceptual vocabulary* across all the languages is often equivalent or greater than the vocabulary of monolingual peers.[1117]
- **Syntax and morphological development:** Studies observe that the order of development is essentially the same in bilingual as monolingual children. However, the rate of learning is often associated with the timing and degree of the children's language exposure. In addition, some language 'mixing' or 'code switching' may occur. That is, children may use a word from one language in a sentence mostly consisting of another language (for instance, 'Look at the big elefante mama'). These features should not be conceptualised as 'errors', however, but simply features of bilingual learning. Indeed, many adult bilingual speakers also 'mix' languages in this way. Despite this mixing of words, children tend not to mix the grammatical rules of one language with another.[1118]

1111 Bialystok, E., & Feng, X. (2009). Language proficiency and executive control in proactive interference: Evidence from monolingual and bilingual children and adults. *Brain and language, 109*(2), 93–100.

1112 Wodniecka, Z., Craik, F. I., Luo, L., & Bialystok, E. (2010). Does bilingualism help memory? Competing effects of verbal ability and executive control. *International Journal of Bilingual Education and Bilingualism*, *13*(5), 575–595.

1113 McKean, C., Mensah, F. K., Eadie, P., Bavin, E. L., Bretherton, L., Cini, E., & Reilly, S. (2015). Levers for language growth: Characteristics and predictors of language trajectories between 4 and 7 years. *PLoS ONE, 10*(8).

1114 Gathercole, V. C., & Thomas, E. M. (2007). Language transmission in bilingual families in Wales. Cardiff: Welsh Language Board.

1115 Hoff, E. (2013). Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Developmental psychology*, *49*(1), 4.

1116 Oller, D. K., Eilers, R. E., Urbano, R., & Cobo-Lewis, A. B. (1997). Development of precursors to speech in infants exposed to two languages. *Journal of child language, 24*(2), 407–425.

1117 Oller, D. K., Pearson, B. Z., & Cobo-Lewis, A. B. (2007). Profile effects in early bilingual language and literacy. *Applied Psycholinguistics, 28(2*), 191–230.

1118 DeHouwer, A. (2005). *Early bilingual acquisition. Handbook of bilingualism: Psycholinguistic Approaches*, pp. 30–48.

6.6 How is children's language development assessed during the preschool years?

There are four primary methods for measuring children's language development:

1. observational methods: recording, transcribing and analysing linguistically children's language in interaction
2. parental report of children's language use and understanding
3. direct testing using probes to elicit specific responses
4. instrumental methods measuring physical responses, such as eye-gaze, reaction times and pupil-dilation in response to differing linguistic stimuli.

Examples of these methods are listed in table 6.8. In practice, methods 1–3 are most applicable to use in 'real-world' settings to inform practitioners regarding individual differences between children and to track their progress over time. The validity and reliability of the different approaches vary with the age and stage of children's language development.

Early in development, parental reports of early communication, symbolic understanding, gesture and first words have been shown to be reasonably reliable measures of children's abilities. The most widely used measures involve adaptations of the MacArthur Bates Communicative Development Inventories.[1119] These inventories are at their most reliable up to approximately 14 months of age, with reliability decreasing as children's vocabulary increases.[1120] However, these methods are not without risk of bias, as parents frequently overestimate what their children know.[1121]

Later in development, direct testing becomes more reliable but requires that the practitioner be sufficiently trained to administer the test and interpret the findings. Tests with particularly good reliability and sensitivity include the New Reynell,[1122] the British Picture Vocabulary Scales, Clinical Evaluation of Language Fundamentals,[1123] and the Diagnostic Evaluation of Articulation and Phonology.[1124] Although these tests have been criticised on their potential lack of ecological validity, most find them to provide rich and reliable estimates of children's language ability when offered in tandem with observational assessment.

Observational methods involving recording, transcribing and analysing linguistically children's language in interaction is clearly the most ecologically valid approach. Historically, this method has proved to be very time-consuming, involving high levels of practitioner training. However, software which automatically codes the frequency and complexity of children's language is becoming more widely available, making this form of assessment more accurate and accessible.[1125] As an alternative, language and communication checklists provide a less time-consuming method for using observational data to chart children's progress, although they are considered to be less sensitive. The Ages and Stages questionnaire is an example of a widely used checklist assessment which assesses children's language and communication development.

1119 Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories: User's guide and technical manual (2nd ed.).* Baltimore, MD: Brookes.

1120 Robinson, B. F., & Mervis, C. B. (1999). Comparing productive vocabulary measures from the CDI and a systematic diary study. *Journal of Child Language, 26*, 177–185.

1121 Law, J., & Roy, P. (2008). Parental Report of Infant Language Skills: A Review of the Development and Application of the Communicative Development Inventories. *Child and Adolescent Mental Health, 13*(4), 198–206.

1122 Letts, C., Edwards, S., Schaefer, B., & Sinka, I. (2014). The New Reynell Developmental Language scales: Descriptive account and illustrative case study. [Review]. *Child Language Teaching and Therapy, 30*(1), 103–116.

1123 Wiig, E., H., Secord, W., & Semel, E. (1998). *CELF-Preschool: Clinical Evaluation of Language Fundamentals-Preschool UK*. London: Harcourt Assessment.

1124 Dodd, B., Hua, Z., Crosbie, S., Holm, A., & Ozanne, A. (2002). *Diagnostic Evaluation of Articulation and Phonology*. London: The Psychological Corporation: The Psychological Corporation.

1125 See: https://www.lena.org/

TABLE 6.8

Commonly used measures of children's early language development

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Ages & Stages Questionnaire (ASQ-3)	The Ages & Stages Questionnaires®, Third Edition (ASQ-3™) pinpoints developmental progress in children between the ages of one month to 5.5 years. It is a developmental screening tool designed for use by early educators and healthcare professionals. It relies on parents as experts. It takes 10–15 minutes for parents to complete and 2–3 minutes for professionals to score. It screens the following areas: communication, gross motor, fine motor, problem solving, and personal–social.	1 month to five years	Practitioner or parent	Screening	No	Ages & Stages
Bayley Scales of infant and toddler development, Third edition (The Bayley-III)	The Bayley-III examines all the facets of a young child's development. Children are assessed in the five key developmental domains of cognition, language, social-emotional, motor and adaptive behaviour. It can be used for children between 1 month and 42 months. It takes from 30 minutes to 90 minutes to complete (depending upon the age of child). The Cognitive Scale has internal consistency reliability of .91 to assess counting and early number skills.	1 to 42 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
The Denver Developmental Screening Test (Denver II)	The Denver II is used by healthcare providers to assess child development. It consists of 125 items (the DDST has 105) divided into four general areas of development: personal–social, fine motor-adaptive, language and gross motor. It screens for developmental delay. It is suitable for children aged 0 to 6 years. It takes from 20 to 60 minutes to complete depending on the stress tolerance of the child. Can be used as a screener for children between the ages of five and six.	0 to 6 years	Practitioner	Screening	Yes	Hogrefe
Wellcom	The Wellcom Speech and Language Toolkit for Screening and Intervention in the Early Years was developed to help identify children with potential language difficulties, so that customised intervention activities can be provided to support their language development. The screening tool takes between 10 to 15 minutes to complete by an early years professional.	6 months to 6 years	Practitioner	Screen	No	GL Assessment

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Parental Evaluation of Development Status (PEDS)	PEDS screens development, behaviour, social-emotional/mental health and autism in children aged 0–8 years. It elicits and addresses parents' concerns about children's language, motor, self-help, early academic skills, behaviour and social-emotional/mental health. It consists of 6–18 questions. It takes about two minutes to administer and score if conducted as an interview. Less time is required if parents complete the brief questionnaire in waiting or exam rooms or at home prior to an encounter. Maths skills can be assessed in children aged four and older. The tool has not yet been evaluated in the UK.	0 to 8 years	Practitioner	Screening	No	PEDs
The Parent Report of Children's Abilities (PARCA-R)	The PARCA-R is designed to identify preterm children who are at risk for developmental delay. It is used as a neurodevelopmental outcome measure in observational studies and clinical trials and as a screening tool in child development clinics. It takes no more than 15 minutes to complete.	Pre-term children aged 2 years	Parent	Screening	No	EPICURE
MacArthur Bates Communicative Development Inventories	MacArthur Bates Communicative Development Inventories are parent report measures which assess monolinguistic children's vocabulary comprehension, production, gestures and grammar. Parents or caretakers are asked to observe their child for a period of 15 and 45 minutes and then match their child's use of words against a list of commonly used words within the child's age range. The CDI consists of two scales: the infant scale (covering the period from 8 to 16 months) and the toddler scale (from 16 to 30 months). Measures are available in pen and paper forms and computer software. The CDI has also recently been standardised for use in the UK (UK-CDI) and for bilingual children.	8 to 30 months	Parent	Diagnostic	No	Brooks Publishing
The New Reynell	The *New Reynell Developmental Language Scales (NRDLS)* was developed to identify speech and language delays and impairments in very young children. Practitioners lead children through a variety of play-based activities which permit detailed assessments of the expressive and receptive language capabilities. It takes 35 to 60 minutes to complete, depending upon the child's age and language capabilities.	2-7 years	Speech and language therapists	Diagnostic	Qualified speech and language therapists	GL Assessment
Brigance Early Childhood Screener III	The Brigance Early Childhood Screen III is a comprehensive assessment of cognitive skills associated with children's preschool achievement. It includes a battery of measures which specifically consider children's receptive and expressive language skills.	3 to 5 years	Practitioner	Academic Assessment	Teacher	Curriculum associates international

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
British Picture Vocabulary Scales Third Edition (BPVS3)	The British Picture Vocabulary Scales were designed to assess children's receptive vocabulary capabilities. The BPVS is administered by teachers or speech and language therapists who say a word and ask that the child responds by selecting a picture from four options that best illustrates the word's meaning. Because no spoken response is required, children with autism and other related communication difficulties or those with English as an Additional Language (EAL) can complete the measure. It takes 10 to 15 minutes to complete.	3 to 16 years	Practitioner	Diagnostic	Speech and language therapists and other teaching professionals	GL Assessment
The Clinical Evaluation of Language Fundamentals – Preschool, Second Edition (CELF-Preschool 2)	The CELF-Preschool 2 measures a broad range of expressive and receptive language skills in young children between the ages three and six years. Skills assessed include children's basic concepts, their ability to follow directions, their expressive vocabulary and verbal recall. It takes 30 to 45 minutes to administer, depending on the child's age and capabilities.	3 to 6 years	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Diagnostic Evaluation of Articulation and Phonology (DEAP)	The DEAP was developed to assess articulation problems, delayed phonology and various phonological disorders. It takes five minutes to administer by trained and qualified professionals with a background in speech and language therapy.	3 to 6 years	Practitioner	Screen	Certified professional with graduate qualification	Pearson
Children's Communication Checklist (CCC-2)	CCC-2 is a 70-item questionnaire completed by the child's caregiver to screen for communication problems in children who are likely to have language impairment. It typically takes 5 to 15 minutes for caregivers to complete.	4 to 16 years	Parent	Screen	No	Pearson
British Ability Scales, Third Edition (BAS3)	BAS3 comprises a battery of individually administered tests designed for use by educational and clinical psychologists to assess children or adolescents who have been referred to them for a wide range of reasons, including learning and behavioural difficulties. It enables assessment of different aspects of a child's current intellectual functioning across the age range 3 years to 17 years 11 months. It comprises 20 subtests, each measuring particular types of knowledge, thinking and vocabulary.	3 to 17 years	Practitioner	Diagnostic	Certified professional with graduate qualification	GL Assessment
The Bracken School Readiness Assessment, Third Edition (BSRA)	The BSRA-3 helps to determine if a child is ready for school. It includes subtests assessing children's receptive and expressive vocabulary. It is for children aged 3 years to 6 years 11 months. It takes 10 to 15 minutes to complete.	3 years to 6 years 11 months	Practitioner	Diagnostic	No	Pearson

Name	Description	Child age range	Practitioner or parent administered	Screening or diagnostic	Practitioner qualifications required?	Further information
Wechsler Preschool & Primary Scale of Intelligence – Fourth UK Edition (WPPSI-IV UK)	The WPPSI-IV UK measures cognitive development for children between 2 years 6 months to 7 years 7 months. The Primary Index scales include: verbal comprehension index, visual spatial index, working memory index, fluid reasoning index, processing speed index. The Ancillary Index scales include: vocabulary acquisition index, nonverbal index, general ability index and cognitive proficiency index. It takes 30 to 60 minutes to administer, depending on the age of the child.	2 years 6 months to 7 years 7 months	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
The Wechsler Individual Achievement Test – Third Edition (WIAT-III)	The WIAT-III is a UK-standardised assessment of numerical operations for use with children aged 4 years and above.	Children aged 4 and above	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Kaufman Assessment Battery for Children, Second Edition (KABC-II)	The KABC-II measures cognitive ability and processing skills in children aged 3 years to 18 years. The following scales are included: sequential processing, simultaneous processing, learning ability, planning ability and knowledge. It takes 25 to 70 minutes to administer, depending on the model chosen.	3 years to 18 years	Practitioner	Diagnostic	Certified professional with graduate qualification	Pearson
Early Years Foundation Stage Profile (EYFSP)	A summary of educational attainment taking place at the end of reception. The teacher provides an individual assessment of the child's level of attainment in communication and language, physical development, personal and social emotional development, literacy, mathematics, understanding the world and expressive arts and design. The sections on children's 'listening and attention' (ELG 01), 'understanding' (ELG 02) and 'speaking' (ELG 03) are particularly relevant for understanding children's language and communication skills.	Children who will be 5 on or before the last day of the academic year	Practitioner	Educational assessment	Practitioners at registered early years providers	Government website

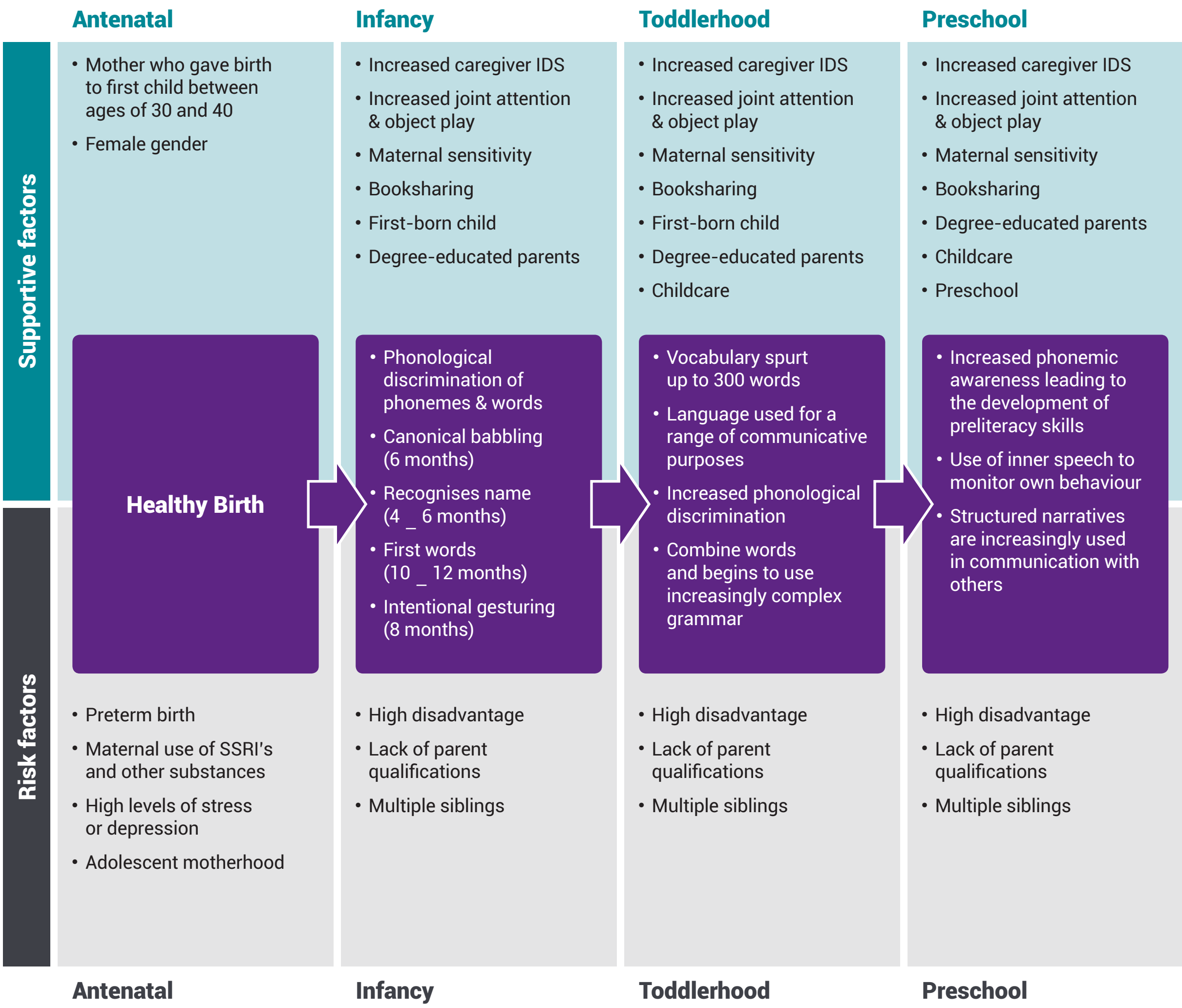
6.7 Implications for practice and commissioning

Summary of key messages

Figure 6.6 provides an overview of the key milestones in children's language acquisition and the processes which support or interfere with this development. More details about this trajectory and age-appropriate methods for assessing progress are summarised further in table 6.9 at the end of this chapter.

FIGURE 6.6

Key milestones in children's language acquisition and processes which support or interfere with typical development



Source: EIF

Key messages: the antenatal period

- Children's language development begins in the womb at approximately 24 weeks gestation, when the unborn child can first hear and discriminate the sounds of their mother's voice.
- Studies show that a premature birth can disrupt brain development in regions affiliated with hearing and phonological awareness. A premature birth is consistently associated with delays in children's language learning during the second year of life.

- Maternal use of toxic substances and various drugs is believed to disrupt brain development associated with children's early language development. The use of SSRIs is particularly associated with language delays during the child's first year. However, maternal depression in the absence of pharmaceutical treatments has also been found to predict language delays, independently of concurrent maternal depression and other sociodemographic risks.
- Maternal age is frequently associated with children's language outcomes. Language outcomes are typically better among children whose mothers gave birth to their first child between the ages of 30 and 40. Adolescent motherhood, by contrast, is more typically associated with an increased likelihood of language difficulties.

Key messages: infancy

- Infants demonstrate a clear preference for their mother's voice within days of birth.
- Studies also find that infants can perceive differences in the phonemes of all languages during the first few months of life. However, this ability is eventually lost during the second half of the first year, as the infant becomes more proficient at distinguishing the phonemes of his or her caregivers' language.
- Studies show that caregiver's use of exaggerated infant-directed speech (IDS) when talking to their infants potentially increases their phonemic awareness. Greater amounts of sensitive IDS occurring during shared attention activities are consistently associated with acceleration in children reaching their language milestones.
- The infant's ability to recognise his or her name is considered a key milestone in the development of children's receptive vocabulary. This typically occurs sometime between four and six months.
- Reduplicative or canonical babbling is a key milestone of children's expressive language development. Reduplicative babbling is the repetition of paired consonant and vowel sounds (for example, 'dadadada'). This typically occurs at around six months.
- By 10 months, reduplicative babbling is replaced by non-reduplicative babbling involving greater variation in consonant and vowel combinations. Studies indicate that the onset and frequency of reduplicative babbling in infancy is predictive of the size of children's vocabulary in the second year of life.
- At around 10 months, most infants start to point to objects or events as a way of indicating to the caregiver that he or she notices something. This is considered to be an important milestone in children's language development, as it suggests that the infant understands that he or she can communicate with others to gain or share information. Protodeclarative pointing frequently occurs during shared attention activities involving objects and has been found to predict the size of children's receptive vocabulary during the second year.
- The amount of time spent in joint attention activities involving object play during infancy is associated with children's vocabulary at 24 months.
- Most children can say one or two words at around the time of their first birthday. These words either refer to family members or familiar objects, such as family pets, toys or household items (cup, juice, etc).

Key messages: toddlerhood

- Language acquisition takes place at a rapid pace throughout the second year. Most children can only say a few words at the time of their first birthday, but will have mastered over 300 at the time of their second.

- Children’s first 50 words are learned at a relatively slow rate during the first half of the second year. Sometime around 18 months, however, many children undergo a word spurt where they may be learning up to ten to 20 new words a day. At this point, it is assumed that children learn new words through a process of fast mapping which allows them to quickly remember labels given for the word. Children also rapidly learn words through contextual cues.
- During the second half of the first year, children begin to speak in sentences which combine two or more words. It is not uncommon for these early sentences to contain errors, however, which represent overgeneralisations of grammatical rules.
- During the second and third year, children use language for an increasing variety of purposes, including asking questions and negating others. As children learn these purposes, they gradually master increasingly complex grammatical structures.
- During the third year of life, children’s use of language becomes increasingly decontextualised from the immediate situation and more contingent on the information provided by others.
- Children’s vocabulary and ability to process words at the beginning of the second year is associated with their language skills at age eight.
- Children’s language capabilities during the second and third years are consistently associated with the quality of their caregiver’s IDS. Caregiver’s responsiveness to child behaviours, their gestures, the diversity of their vocabulary and use of one-word utterances to name objects have all been found to predict the size of children’s vocabularies and the speed with which they process language during the second year.
- The amount and quality of caregiver IDS is highly associated with family income and maternal education. Studies observe that income-related differences in children’s language are, in fact, predicted by income-related differences in the parents’ use of language, not by income itself.
- Income-related differences in children’s language processing are already apparent at 18 months.
- Childcare provided from the child’s second year onwards has been found to improve the language capabilities of toddlers raised in economically disadvantaged homes.
- Delays in children’s language development can be reliably detected during the child’s third year, although up to two-thirds of children may outgrow these delays, whereas some children may grow into them.
- Studies show that girls have a slight advantage in the achievement of language milestones. Boys may also be at greater risk of language delays, although these findings are not consistently observed across studies.
- Firstborn children tend to achieve their language milestones more quickly than younger siblings, although this advantage typically disappears by the third year.

Key messages: ages three to five

- Children’s use of language becomes increasingly more sophisticated between the ages of three and five. During this time, children begin to speak in multi-clause sentences and phonemic awareness steadily increases. Most children will have a vocabulary of over 10,000 words by the time of their fifth birthday.
- Children’s language capabilities by age three years are highly associated with their school readiness at five years and their academic achievement in primary and secondary school. Phonemic awareness is particularly associated with the decoding and recoding skills necessary when learning to read.

- Children's language difficulties identified at age four are thought to be reliable predictors of future language problems. However, developmental change is frequently observed for at least one-third of the population, with children continuing to grow in and out of language difficulties.
- It is not uncommon for children between the ages of three and five to use inner speech as a form of self-monitoring. The use of inner speech is associated with improvements in children's ability to regulate their behaviour and manage their emotions during frustrating situations, as well as monitor and deploy their attention.
- Between the ages of three and five, children demonstrate increasing sophistication in their use of structured narratives. Children's comprehension and use of narrative discourse during preschool is associated with their reading comprehension in primary school.
- Other factors thought to contribute to children's reading and writing capabilities include their knowledge of the alphabet letters, written words, books and other printed materials.
- Children's language capabilities between the ages of three and five are highly associated with family income, parental education and parents' vocabulary. In fact, parental vocabulary is one of the strongest predictors of children's language development from the age of three onwards.
- The extent to which children participate in book sharing acitivites is also highly predictive of their language capabilities throughout childhood and their achievement at school.
- Increases in maternal education during early childhood improve the quality of parent–child interactions and the home learning environment. However, studies suggest that increases in maternal education among disadvantaged families are relatively rare and may not be sufficient to improve the language capabilities of disadvantaged preschoolers such that they are able to catch up to their less disadvantaged peers.
- Enriching preschool education is consistently associated with improved language outcomes among disadvantaged three- and four-year-olds. However, studies also show that these benefits frequently fade and are rarely sufficient to close income-related learning gaps.

What are the implications for early intervention?

A recent update of the Bercow Review[1126] identified support for children's speech, language and communication as essential for improving social mobility, health inequality and employment. The evidence summarised here has specific implications for how this support might be improved to address the needs of socially disadvantaged children, as well as improve the language outcomes of children identified with a specific language impairment.

In the *Foundations for Life* review, we identified five interventions with evidence of improving language outcomes during the early years.[1127] All of these interventions were offered to disadvantaged families at the targeted-selective level and were made available through home visiting support offered to families on a regular basis for a year or longer. The review further observed that there was good evidence to support the use of comprehensive two-generation preschool programmes for supporting children's language development and other cognitive outcomes. We will elaborate on this evidence in the following chapter.

The *Foundations for Life* review and several subsequent EIF reports (*Language as a child wellbeing indicator*; *What works to enhance the effectiveness of the Healthy Child Programme*) also identified a number of activities where evidence is lacking. The first of these is

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1126 See: https://www.bercow10yearson.com

1127 Asmussen, K., Feinstein, L., Martin, J., & Chowdry, H. (2016) *Foundations for Life*: *What works to support parent-child interaction in the early years?* Early Intervention Foundation. https://www.eif.org.uk/report/foundations-for-life-what-works-to-support-parent-child-interaction-in-the-early-years book gifting programmes. Although there is good evidence showing that the number of books in the family home is associated with improved language outcomes, there is little evidence to suggest that book gifting specifically improves these outcomes, particularly in disadvantaged families. For example, a large-scale trial of a book gifting scheme in Australia observed no increases in children's language or preliteracy skills after receiving free books. Although there is some evidence that more intensive dialogical book sharing programmes delivered by teachers, either through preschools or to parents in their homes, may improve children's language outcomes, the evidence underpinning these studies suggests that these programmes may be less effective for highly disadvantaged children.

Another area where gaps have been identified involves the effectiveness of speech and language interventions. While EIF's *Foundations for Life* review and the *Early Language Development* review, published by the Education Endowment Foundation, both identified speech and language interventions which could be potentially effective, none have yet undergone an evaluation which is sufficiently rigorous to attribute causality.[1128] There is also evidence that the impact of many speech and language interventions may fade over time. For example, evidence from the Let's Learn Language trial in Australia, observed that initial benefits from an intervention for 18-month-old toddlers identified as being at risk for language delays faded by the time they were age three, as the language of children not participating in the programme appeared to have 'caught up'.[1129] Thus, a key challenge in this field is to identify the children who stand to gain from these interventions the most.

This current review has not considered the efficacy of any specific intervention, but has summarised the evidence underpinning key risks, as well as the most recent evidence underpinning children's early language development more generally. We now consider how some of this information might be used to enhance the quality of the interventions that are currently available, as well as practices, such as health visiting and the development of new interventions.

First, while children's early language development is predictive of their later language development, there is also consistent evidence showing that children grow into and out of language difficulties. Thus, **there is no perfect point at which language should be assessed. This means that children's language should be monitored on an ongoing basis from the third year onwards, so interventions can be made available as and when needed**. We have already made this point in the *Language as a child wellbeing indicator* report, but feel it is worth re-emphasising here.

Second, it is clear that children's **early language development is strongly associated with family income.** While it is highly unlikely that family income is directly related to early language development, factors associated with income likely contribute to individual differences. So, understanding family income remains useful for the purposes of targeting.

Consistent findings from recent cohort studies provide clear messages about intervention content that will support the development of children at the greatest risk of language delays, including those who are socially disadvantaged. These messages include information about the importance of book sharing, but also the benefits of specific parenting behaviours. As described in section 6.5, studies have observed:

- The quantity and quality of infant direct speech during infancy facilitates the baby's ability to discriminate phonemes and words. Joint attention activities involving object play also support early language learning.

[1128] Law, J., Charlton, J., Dockrell, J., Gascoigne, M., McKean, C., & Theakston, A. (2017). *Early Language Development: Needs, provision, and intervention for preschool children from socio-economically disadvantage backgrounds*. Institute of Education.

[1129] Wake, M., Tobin, S., Girolametto, L., Ukoumunne, O. C., Gold, L., Levickis, P., ... & Reilly, S. (2011). Outcomes of population-based language promotion for slow to talk toddlers at ages 2 and 3 years: Let's Learn Language cluster randomised controlled trial. *BMJ*, *343*, d4741.

- Language quantity, particularly in terms of vocabulary, appears to be most crucial during the second year.
- Children benefit from greater diversity and complexity of input that is responsive to their specific interests and needs during their third year.
- In later preschool, opportunities to participate in conversations that make use of structured narratives are also beneficial, as are activities which support children's preliteracy skills.

Fourth, we have summarised evidence suggesting that **childcare also has the potential to support children's early language development, especially if offered from the age of two onwards, and to children for whom English is an additional language.** Childcare providers should therefore be encouraged to provide learning opportunities which address the language development occurring during the child's third, fourth and fifth years, as described above. Childcare and early education offered during this time might include activities which support children's understanding of narratives and support the development of preliteracy skills, as many programmes already do.

The findings described here also underscore the need for 'two-generation' programmes that address the needs of both parents and children. Childcare and enriching early education provide ideal opportunities for offering support to children which aims to increase their vocabulary and improve their grammar. Support for parents that provides them with strategies for scaffolding their children's language at home could also be made available through childcare and preschool.

Finally, **this chapter highlights the need to start early.** Already by the age of 18 months, income-related gaps are present in children's language capabilities and we know that children are starting to learn language already before they are born. Hence, targeted home visiting support made available to low-income families, as described in previous chapters, should also include information about how best to support children's language development. Already, parents receive messages about the importance of reading, rhymes and singing – which are thought to support children's phonemic awareness. Findings summarised in this review also suggest that information about the use of infant-directed speech, joint attention and triadic object play is also likely to be beneficial.

TABLE 6.9

Developmental competencies – associated risks and methods of assessing children's early language development

Age	Developmental competency	Manifestation/context	Factors which make a difference	Assessment
0–12 months	The ability to discriminate between phonemes and words Canonical babbling (six months) Can recognise own name (six months) Intentional gesturing (8/9 months) First words (10–12 months)	The infant's daily interactions with his/her parents Object play	Infant-directed speech Increases in joint attention and object play activities Parental sensitivity Book sharing Family income Firstborn child Degree-educated parents Family Income Number of siblings in the home.	The Ages and Stages Questionnaire (ASQ-3) The Bayley III The MacArthur Bates CDI
12–24 months	Language is used for an increasing range of purposes Rapid vocabulary spurt Can form sentences involving two or more words	The infant's daily interactions with his/her parents Play Book sharing	Infant-directed speech Increased exposure in joint attention and object play activities Book sharing Family income Firstborn child Degree-educated parents Number of siblings in the home	The Ages and Stages Questionnaire (ASQ-3) The Bayley III The MacArthur Bates CDI
24–36 months	Increasingly sophisticated use of syntax and morphemes Can ask questions and negate others Respond to others in a linguistically contingent way	The infant's daily interactions with his/her parents Play Book sharing Childcare/preschool	Parental scaffolding of speech Book sharing Family income Degree-educated parents Number of siblings in the home Access to childcare and enriching preschool education	The Ages and Stages Questionnaire (ASQ-3) The Bayley III The MacArthur Bates CDI The New Reynell
36–60 months	Uses inner speech to regulate his or her emotions and behaviour Demonstrates increasing mastery of narrative discourse when describing events and stories to others Demonstrates a range of preliteracy skills, including recognising the alphabet and words such as 'stop' or 'exit'	The child's daily interactions with his/her parents Play Book sharing Childcare/preschool	Book sharing Family income Degree-educated parents Access to childcare and enriching preschool education	The Ages and Stages Questionnaire (ASQ-3) British Picture Vocabulary Scales Third Edition (BPVS3) CELF-Preschool 2 DEAP CCC2

Part 4: Conclusions and recommendations

This review was written with the following objectives:

1. to provide a comprehensive summary of the most recent evidence involving early development with respect to four important cognitive competencies: children's understanding of objects, intentions of others (theory of mind), numerical concepts and language
2. to summarise the key risks associated with the development of these four competencies so that effective interventions can be made available to children who most need them
3. to translate the implications of this evidence for improving the quality of early years services, particularly those which aim to reduce income-related differences in children's cognitive performance at school.

In support of these objectives, this review has systematically answered the following seven questions for each of the four competencies:

1. What is the competency?
2. In what ways is the competency supported by other child competencies?
3. How does the competency impact children's development over time?
4. What is typical development during the periods of infancy, toddlerhood and preschool?
5. Which factors support or hinder typical competency development?
6. What methods are most appropriate to assess typical and atypical development?
7. What are the implications for early intervention?

This review is therefore different from previous EIF reviews, as it does not summarise the strength of evidence underpinning individual programmes, but instead provides information that can be used as a reference for commissioning and developing interventions. We believe that this information is useful for everyone involved in supporting children's development, including midwives, health visitors, speech and language therapists, children's centres, childcare providers, preschool educators, intervention developers, commissioners – and of course, parents. We also believe that this information may be useful for developing early years' policies, especially those aimed at closing income-related achievement gaps, as identified in the UK government's Social Mobility Action Plan.[1130]

[1130] https://www.gov.uk/government/publications/social-mobility-action-plan-summary

7. Key findings

In previous chapters, we have highlighted the evidence underpinning the development of specific competencies. Here, we summarise key findings and cross-cutting themes.

7.1 Continuity exists within developmental change

Figure 7.1 provides an overview of many of the early cognitive milestones described in this review, occurring within the domains of children's object knowledge, theory of mind, numerical understanding and language acquisition. These milestones represent a wide variety of cognitive skills acquired during the early years that are supported by rapid changes in the developing brain. These changes begin during the antenatal period when the brain's architecture is first established and then continue in response to children's day-to-day interactions with their caregivers and environments. Early neurological changes occurring in infancy allow children to process a diverse range of information, leading to the mastery of the first words during toddlerhood. Children's understanding of language then transforms knowledge acquired within the other cognitive domains and paves the way for important school readiness skills which are learned in the fourth and fifth years. By the age of five, most children can:

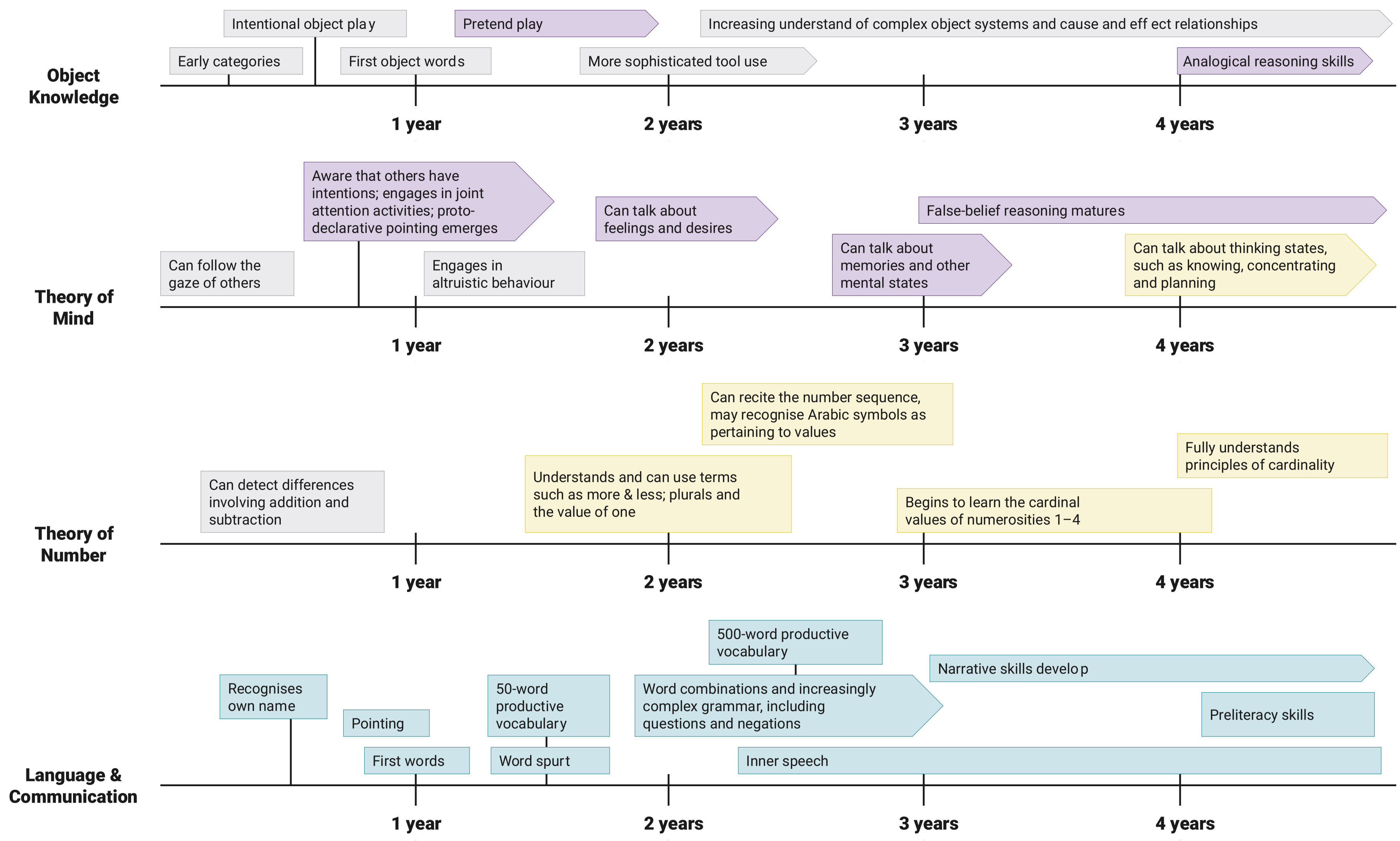
- understand the essential characteristics and functions of a wide variety of familiar and unfamiliar object systems
- accurately predict the thoughts, feelings and intentions of others
- understand the principles of counting and perform simple arithmetic operations
- use language in a way that is grammatically correct and is effective for a variety of communicative purposes.

Despite dramatic changes in early cognitive capabilities, studies observe a fair amount of continuity between processes occurring in infancy and later cognitive skills. For example, children's motor manipulation of objects at four months is associated with their IQ at age four, children's ability to discriminate differences in magnitude at six months is correlated with their numerical knowledge at age three and speech processing capabilities at seven months predict children's vocabulary size at age six. While these associations are often modest in size, and are not always predictive on the individual level, they are found to be independent of each other (as well as other cognitive skills) and tend to increase in magnitude as children develop. **Studies consistently show that children's cognitive capabilities at age four are reliable predictors of their academic success once they enter primary school.**

This review has also summarised evidence showing that a fair amount of continuity exists within children's early learning environments. This continuity includes consistencies in sensitive caregiving behaviours, as well as the quality of children's learning opportunities. **Sensitive caregiving includes high-quality infant-directed speech and behaviours which are responsive to the child's developmental needs.** Supportive learning opportunities include the availability of books, toys and learning materials in the home, as well as enriching experiences outside the home, which may include high-quality childcare and preschool. **Studies show that highly nurturing and stimulating environments in the early years prevent poor cognitive outcomes as children grow older, whereas early experiences of disadvantage pose a developmental risk.**

FIGURE 7.1

Milestones in the development of children's key competencies during the first five years



Source: EIF

While these findings should not be interpreted to mean that children's learning trajectories are cast in stone during the early years, they do provide evidence of cascading processes occurring within the child and his or her environment which begin very early. Such findings therefore have implications about when and how early cognitive capabilities should be assessed, as well as the timing of early interventions. We will return to these points in the final chapter.

7.2 It's not just about words and books

The findings summarised in this review are consistent with those described elsewhere that observe a strong association between children's early exposure to words and their later linguistic capabilities. However, the research described here also shows that **it is not simply about the number of books in the home or the amount of words children hear. Rather, it is about the quality of linguistic interactions – in other words, conversations – taking place between children and their caregivers on a daily basis.** While high-quality linguistic interactions frequently contain more words and can be facilitated by book sharing, the studies reviewed here observe that early language development is best supported through bidirectional, caregiver–child conversations that are responsive to the child's interests and are appropriate for the child's age. In particular:

- infants benefit from infant-directed speech that occurs during joint attention activities involving household items and toys
- toddlers benefit from activities that increase their vocabulary by introducing them to new words
- two-year-olds benefit from more grammatically complex conversations that are responsive to their particular interests and are decontextualised from the present moment
- three and four-year-olds benefit from conversations that encourage them to listen to and produce structured narratives.

Studies also show that the content of children's conversations support children's development within other cognitive domains.

- Conversations about objects and living things are thought to support children's understanding of how the world works and their analogical reasoning capabilities as they grow older.
- 'Mental-state talk' – conversations involving what people think and feel – is associated with increases in children's ability to predict the intentions of others. These skills, in turn, are associated with children's popularity at school.
- Caregiver–child 'number-talk' is associated with children's counting capabilities. Early counting skills are strongly associated with children's mathematical achievement in later primary and secondary school.

These findings have bearing for the contents of programmes and practices. While many parenting interventions and preschool activities already emphasise the importance of book reading, relatively few highlight the importance of daily conversations for supporting children's language development and other cognitive skills. We have described in previous chapters how these messages might be incorporated into existing services and pick them up again in the following chapter.

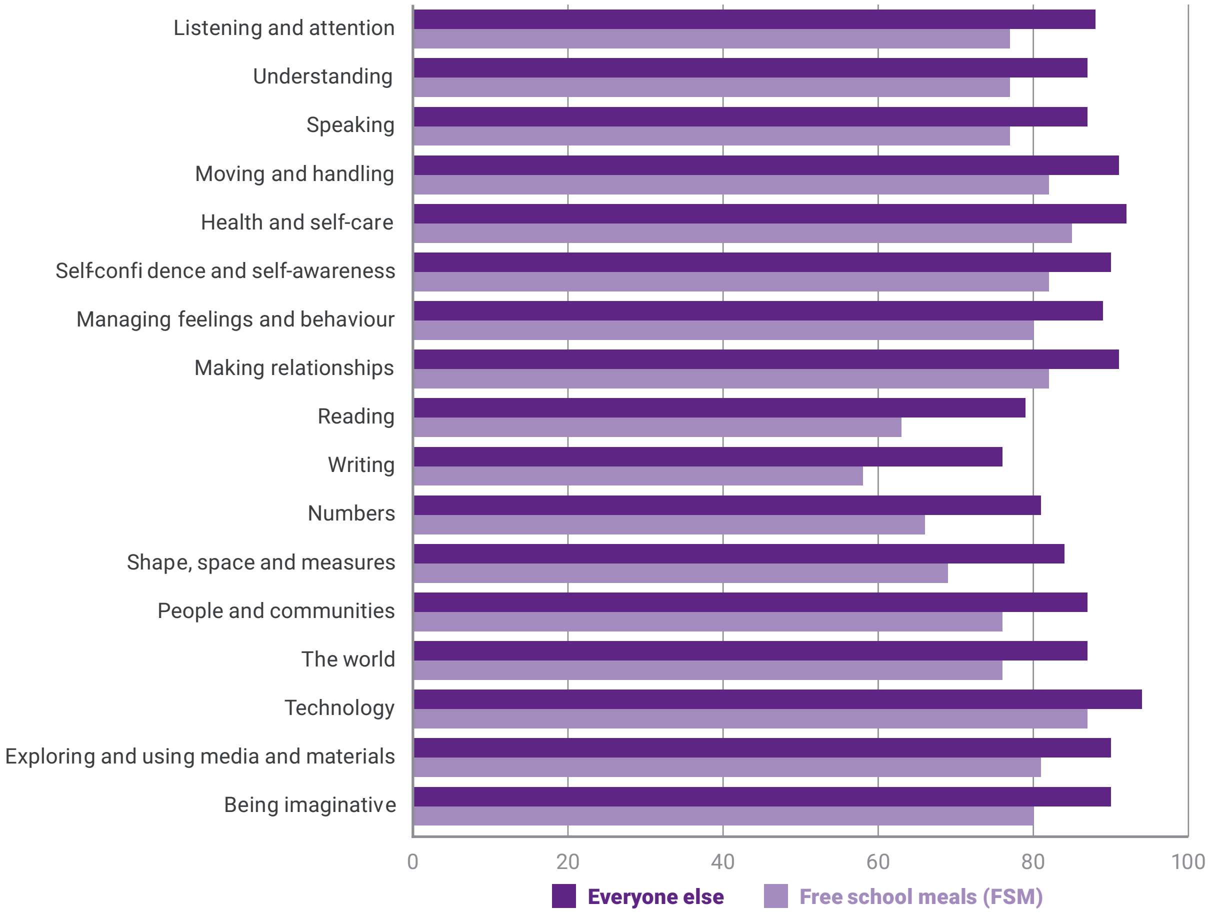
7.3 Income-related learning gaps are both wide and deep

The evidence we have summarised in this review uniformly confirms that wide income-related learning gaps exist across all four cognitive domains. **Income-related learning gaps in children's cognitive understanding are already present before the age of three and steadily increase as children grow older.**

Studies additionally observe that the size of these gaps is already quite wide when children are still very young. For example, the most recent EYFS profile results observe income-related learning gaps (based on children's free school meals eligibility) of 9 to 18 percentage points across all learning areas (see figure 7.2). Findings involving the MCS cohort similarly observe a gap of at least a half a standard deviation on children's language and object problem-solving capabilities at age three.

FIGURE 7.2

Percentage achieving at least the expected level by early learning goal, by free school meal (FSM) eligibility



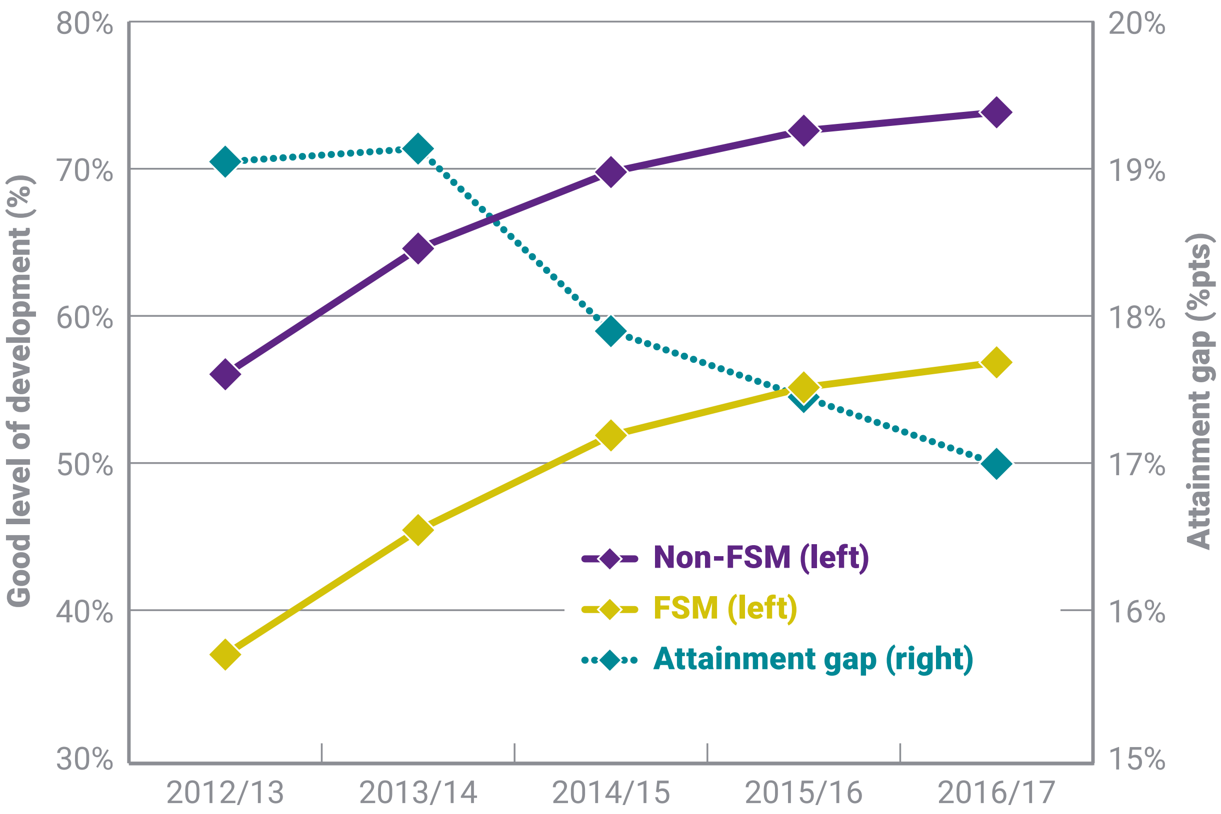
Source: Department for Education (2018)[1131]

[1131] Department for Education (2018) Early years foundation stage profile results: 2016 to 2017. https://www.gov.uk/government/statistics/early-years-foundation-stage-profile-results-2016-to-2017

Evidence also shows that income-related learning gaps are deep, as they are difficult to reverse. Although studies show that enriching preschool programmes often diminish the size of these gaps, such efforts are typically not sufficient for reducing income-related gaps entirely. Although recent trends suggest that income-related gaps have diminished in England by two percentage points since 2012 (figure 7.3), studies more frequently show that advantaged children gain in parallel to their disadvantaged peers.

FIGURE 7.3

FSM attainment gap (pupils achieving a good level of development, 2012/13–2016/17)



Source: Teager & McBride (2018)[1132]

Studies also show that many of the initial gains from enriching preschool quickly fade over time, indicating that one or two years of high-quality education is typically not enough to entirely buffer disadvantaged children from income-related disparities. Indeed, the studies summarised in this review show that income-related learning gaps are best predicted by factors associated with family income that are not specifically addressed through children's educational experiences. These factors include the educational level and vocabulary of the child's parents, high levels of family stress and income-related differences in parenting practices. In this respect, **income-related learning gaps are not determined by one single factor, meaning that there is no single solution.** Strategies for addressing income-related learning disparities must therefore be comprehensive and multifaceted, as we describe in the final chapter.

[1132] Teager, W., & McBride, T. (2018). *An initial assessment of the 2-year-old free childcare entitlement: Drivers of take-up and impact on early years outcomes*. Early Intervention Foundation. https://www.eif.org.uk/report/an-initial-assessment-of-the-2-year-old-free-childcare-entitlement

7.4 It's not just about family income

Factors associated with family income are considered by many to be primary drivers of early learning disparities. The findings summarised in this review do not dispute this conclusion, identifying multiple income-related risks that are directly and indirectly associated with poor cognitive outcomes. It would nevertheless be wrong to conclude that income-related factors are the only risks associated with cognitive differences. In each of the chapters, we have identified an additional set of risks associated with each competency, as well as factors thought to specifically support cognitive development. Many of these supportive factors include parenting behaviours which scaffold specific cognitive skills, including infant-directed speech and book sharing, as previously mentioned, as well as home numeracy activities and toys that increase children's understanding of object categories. Learning opportunities outside of the home are also associated with improved cognitive outcomes. Examples of enriching learning opportunities include visits to parks and museums and opportunities to play with other children.[1133]

Each chapter has also identified a number of competency-specific risks that may be present at various stages of children's development. However, there are several risks – in addition to family income – that cut across all four competencies – so are worth mentioning here. First, there is good evidence to suggest that a preterm birth has the potential to disrupt important neurological processes involved in the development of all of the competencies described in this review. This evidence shows that earlier preterm births create greater risks than do later preterm births, although recent evidence shows an elevated level of risk of difficulties among children born as late as 37 weeks' gestation. These studies also show that cognitive difficulties associated with a preterm birth are frequently not evident until later points in the child's development. For example, language difficulties associated with a preterm birth often do not show up until the child's second year, and numerical difficulties are typically not detected until children enter primary school. This creates challenges in determining how and when to provide interventions to children born prematurely.

Maternal mental health problems are also found to be associated with a variety of cognitive difficulties in children, although not uniformly so. In this respect, studies show that depression during the antenatal period is consistently associated with poor child outcomes during the first few years, independently of whether the mother may be currently depressed. However, SSRIs taken during pregnancy also pose risks to children's cognitive development. Combined, these findings emphasise the need for consideration of effective, nonpharmaceutical interventions as part of a treatment plan for pregnant mothers experiencing mental health problems. Further evidence about the effectiveness of these treatments can be found in our recently published review, *What works to enhance the effectiveness of the Healthy Child Programme*.[1134]

Postnatal maternal mental health problems are also associated with poor cognitive outcomes in children, especially when families are living in economically disadvantaged circumstances. Specifically, studies show that low family income amplifies the relationship between maternal mental health problems and children's cognitive development, whereas greater family income appears to reduce the strength of this association. Nevertheless, maternal mental health problems continue to be associated with child behavioural outcomes across all income levels, meaning that psychological assessments and treatments should also be offered to mothers after the baby is born. Pharmaceutical treatments may also be an effective option during the postnatal period, depending on the drug and whether the mother is breastfeeding.

1133 In a forthcoming resource, EIF will identify a list of appropriate toys, materials and activities grouped by children's age.

1134 Asmussen, K., & Brims, L. (2018). *What works to enhance the effectiveness of the Healthy Child Programme: An evidence update*. Early Intervention Foundation. https://www.eif.org.uk/report/what-works-to-enhance-the-effectiveness-of-the-healthy-child-programme-an-evidence-update/

Finally, this review has identified cognitive difficulties which may have a genetic basis. These include difficulties which are competency-specific, as well as those involving more general cognitive processes, including the executive functions.

- Risks associated with children's understanding of objects may be identified already during the child's first year, in the form of delays in children's large and small motor development.
- The risks associated with autism spectrum conditions may also be detected from the child's first year onwards.
- Language difficulties are typically not evident until the end of the second year, with studies showing that children continue to grow in and out of language problems throughout preschool and primary school.
- Numerical difficulties are typically not reliably present until children enter primary school.
- The executive functions are not thought to fully mature until the fourth and fifth year, making it difficult to assess problems associated with the executive functions before this time.

In sum, these findings suggest that while some problems are evident already during infancy, some difficulties may not be evident until children are aged four or older. We discuss the implications of these findings for assessment and early intervention in the final chapter.

8. Recommendations for early intervention

In this chapter, we synthesise the findings from the previous chapters and other EIF reviews into a set of actionable recommendations for supporting children's early cognitive development.

8.1 The earlier, the better

The evidence described in this review makes clear that individual differences in children's cognitive development are evident from the first year onwards, and that early competencies predict later competencies. Although we do not recommend that formal education begin immediately after birth, we do believe that early years services can be optimised to support children's cognitive development from the antenatal period onwards.

- Activities that support children's cognitive development during the antenatal period include those that target risks associated with a preterm birth and those which increase mothers' access to effective mental health treatments. Evidence-based activities for addressing these two risks are described in greater detail in our *What works to enhance the effectiveness of the Healthy Child Programme* review.[1135]
- Activities that support cognitive development during the first year include intensive home visiting interventions for families with pre-identified risks, including ecnomic disadvantage. As described in our *Foundations for Life* review,[1136] some of these interventions have specific evidence of improving child language outcomes, whereas others have evidence of supporting children's cognitive development more generally.
- Activities found to support children's cognitive development during toddlerhood include targeted home visiting support, as well as high-quality and enriching childcare starting at the age of two.
- There is preliminary evidence to support the use of various speech and language interventions for children identified as having language delays from the age of two onwards. Further details about the assessment of language delays and appropriate treatment can be found in our *Language as a child wellbeing indicator* report[1137] and EEF's recently published *Early Language Development* review.[1138]

[1135] Asmussen, K., & Brims, L. (2018). *What works to enhance the effectiveness of the Healthy Child Programme: An evidence update*. Early Intervention Foundation. https://www.eif.org.uk/report/what-works-to-enhance-the-effectiveness-of-the-healthy-child-programme-an-evidence-update/

[1136] Asmussen, K., Feinstein, L., Martin, J., & Chowdry, H. (2016) *Foundations for Life*: What works to support parent-child interaction in the early years? Early Intervention Foundation. https://www.eif.org.uk/report/foundations-for-life-what-works-to-support-parent-child-interaction-in-the-early-years

[1137] Law, J., Charlton, J., & Asmussen, K. (2017). *Language as a child wellbeing indicator*. Early Intervention Foundation. https://www.eif.org.uk/report/language-as-a-child-wellbeing-indicator

[1138] Law, J., Charlton, J., Dockrell, J., Gascoigne, M., McKean, C., & Theakston, A. (2017). Early Language Development: Needs, provision, and intervention for preschool children from socio-economically disadvantage backgrounds. Education Endowment Foundation. https://educationendowmentfoundation.org.uk/public/files/Law_et_al_Early_Language_Development_final.pdf

- There is good evidence that an enriching, curriculum-based preschool education can substantially improve learning outcomes for disadvantaged children. This evidence includes the provision of curriculum-based activities starting from the age of two onwards.
- There is strong and consistent evidence showing that 'two-generation' support for low-income families may substantially improve disadvantaged children's learning outcomes. By two-generation, we mean support that is provided to both the parent and the child. This support should ideally begin at the time of the child's birth in the form of frequent home visits, as described above, and last until at least the child's second birthday. This support should be intensive enough for parents and other caregivers to learn important scaffolding skills that can in turn be used to support their children's learning. While public health messages about the importance of playing and talking with children often increases parents' awareness of various learning activities, the best evidence tells us these will not be sufficient for disadvantaged parents to effectively put this advice into action.
- From the age of two onwards, intensive two-generation support should continue for the most economically disadvantaged families. The two-year childcare entitlement provides a logical vehicle through which this support can be offered, providing children with enriching educational experiences on a daily basis and support to parents that is sufficiently intense for them to learn new skills.

8.2 A comprehensive approach

We have emphasised throughout this review that many of the learning disparities existing during the first five years are pervasive and not easily reversed. Comprehensive, multifaceted and 'joined-up' strategies are therefore necessary for supporting early cognitive development, especially for disadvantaged children. Table 8.1 provides a list of activities identified in this review and previous EIF publications that have evidence of supporting early cognitive outcomes at the universal, targeted-selective, targeted-indicated, and specialist levels.

As highlighted in this review, a sufficient 'dosage' of intervention is critical for addressing early learning needs in high-risk families. Disappointing findings from the recent evaluations of abbreviated versions of more intensive interventions illustrate this point.[1139] We therefore recommend that interventions and activities be chosen and implemented in a way that can provide significant and lasting results. Such programmes are typically long in duration (a year or longer) and delivered by practitioners who have the qualifications and training to deliver the intervention. While these interventions are frequently more expensive than what is traditionally available, they are nevertheless less wasteful than many lighter-touch activities that have been proven not to provide measurable results. The fact that income-related learning gaps are already present at the age of three suggests that intensive efforts are particularly necessary during disadvantaged children's first three years, starting at birth if not before.

[1139] Jelly, F. & Sylva, K. (2018). Engaging parents effectively. The Sutton Trust. https://www.suttontrust.com/research-paper/engaging-parents-effectively-early-years/

TABLE 8.1

An integrative system of activities and interventions to support children's cognitive development during the early years

Conception to birth	Infancy	Toddlerhood	Ages three to five
Assessment			
Maternal mental health Drug and alcohol misuse Gestational diabetes	Continued maternal mental health screening Assessments for early motor delays throughout infancy Assessments involving infants' use of gesture in late infancy	Speech and language assessment at age 2.5	EYFS
Universal			
	Specialist-led lactation advice to increase breastfeeding Messages about the importance of infant-directed speech and joint attention activities	Messages about the importance of exposing the child to new vocabulary Messages about the importance of mental-state talk and number-talk The provision of enriching learning opportunities outside of the home	Enriching preschool education with curriculum which supports children's understanding of objects, theory of mind, numbers and preliteracy skills Interventions with evidence of supporting skills associated with children's understanding of theory of mind include the Incredible Years Child Training Dinosaur programme and PATHs Preschool.
Targeted-selective			
Home-Visiting for first-time teen mothers (Family Nurse Partnership)	Home visiting support to promote children's learning in low-income families (Family Nurse Partnership; Parents as First Teachers)	Home visiting support beginning in infancy and lasting until age 2 Enriching early years education from age 2 onwards Two-generation programmes targeting parents and children	Two-generation programmes for low-income parents and their children Interventions, such as Parents as First Teachers, REAL and Let's Play in Tandem, which have evidence of increasing parents' ability to scaffold their children's learning School-based interventions, such as the Nuffield Early Language Intervention, which have evidence of improving the language outcomes of disadvantaged children
Targeted-indicated			
Incentive-based smoking interventions Evidence-based psychological treatments for mothers experiencing depression and other mental health problems	Kangaroo mother care for preterm infants Cue recognition training for preterm infants Child First for at-risk families living in socially disadvantaged circumstances, where there are concerns involving child maltreatment, intimate partner violence or maternal mental health issues	Health visiting support for children identified with speech and language delays Support for children identified with special learning needs	Speech and language therapy for children identified with speech and language delays
Specialist			
Specialist support for mothers identified as having chronic substance misuse problems or are otherwise at risk for antenatal complications	Specialist support for children identified with serious learning disabilities	Specialist speech and language support for cleft lip and palate and other identified speech and language difficulties	Specialist speech and language support for cleft lip and palate and other identified speech and language difficulties

8.3 A role for everyone

The comprehensive approach described above identifies a prominent role for everyone involved in the delivery of early years services that support children's early cognitive development.

Parents and other caregivers

During the first five years of life, parents and other close caregivers are chiefly responsible for their children's learning experiences. During infancy, caregivers support their child's learning through sensitive and predictable caregiving behaviours that are responsive to their child's learning needs. These behaviours include the exaggerated, sing-song speech that facilitates children's understanding and production of language, and parent–child play involving toys and objects that reinforce children's early concept development.

As infants grow into toddlers, caregivers continue to support their children's cognitive development through book sharing, pretend play, and opportunities to learn about people and things outside of the home. Conversations about numbers, animals, and shared feelings and experiences also support children's burgeoning understanding of the world.

The vast majority of parents understand how to do these things naturally and are able to support their children's ongoing development through the advice provided through universal services. However, some parents, particularly those living in economically-deprived circumstances, require more intensive support to put this advice into action. Below, we describe ways in which early years services can make evidence-based messages available to all parents, as well as provide extra support to parents who may need more from the antenatal period onwards.

Midwifery

Midwives are in an ideal position to support antenatal brain development by making sure that all expectant mothers are aware of the importance of good nutrition and the risks imposed by drugs, alcohol and tobacco and higher levels of stress. Midwives are also in the best position to coordinate services for mothers where there is a greater risk of a preterm birth, through smoking cessation interventions and services for mothers identified with alcohol and drug misuse problems. Midwives can also play a critical role in identifying maternal mental health problems during pregnancy by referring mothers experiencing difficulties to evidence-based therapies. Further information on the evidence underpinning these activities is provided in our *What works to enhance the effectiveness of the Healthy Child Programme* review.

Health visitors

Health visitors provide a universal service to all family members, including mothers, fathers, partners and other extended family members. Health visitors are therefore in an ideal position to share many of the evidence-based messages identified in this review from the first visit onwards. These messages include information about the value of mind-minded parenting behaviours, infant-directed speech and joint attention activities for supporting children's cognitive development during infancy, as well as the importance of mental-state talk and number-talk during toddlerhood and later preschool.

This advice and support could be made available to all families during the universal contacts, ensuring those closest to the child are in the best position to meet the child's learning needs. However, it is unlikely that the advice that is made available universally will be sufficient for supporting children's development in cases where there are clear risks. As previously described, these risks include low family income, a preterm birth and mothers who are experiencing mental health problems. In these instances, more intensive interventions are most likely required and, in many cases, health visitors are in the best position to deliver them.

Health visitor-led interventions could include intensive home visiting offered at the universal plus or universal partnership plus levels identified in the 2-4-6 model. As described in our *Foundations for Life* and *What works to enhance the effectiveness of the Healthy Child Programme* reviews, many home visiting interventions have good evidence for supporting children's language development, as well as a variety of other important child and parent outcomes. Further details about the evidence and implementation requirements of some of these interventions is listed in the EIF Guidebook.[1140] The evidence summarised in this review further suggests that the frequency of these home visits is important, with visits occurring at least monthly, if not more frequently, until the child's second birthday and potentially beyond.

Health visitors also play an essential role in identifying children with developmental delay as early as possible through universal health reviews, which include assessing children's needs through the use of the Ages and Stages questionnaire (ASQ-3) and other measures of children's early cognitive development. If additional support is required, health visitors can then coordinate and deliver this support in a way that is proportionate to the child's level of need. Further details about how this might be done are provided in our *What works to enhance the effectiveness of the Healthy Child Programme* review.

General practitioners (GPs)

GPs are often the first professional parents turn to when they have concerns about their children's development. GPs therefore play a pivotal role in providing parents with advice about children's early learning needs that is developmentally appropriate and evidence-based, as well as referring parents to other professionals when there are concerns that require further investigation.

Speech and language therapists (SALTs)

Speech and language therapists are in the best position to provide further assessments in cases where specific language delays may be suspected. SALTs are also in a good position to coordinate and deliver interventions to children directly – or to their parents when it is likely to be effective and feasible. Examples of speech and language interventions are provided in EEF's *Early Language Development* report. Speech and language therapists also play an important role in providing valuable training, coaching and support for practitioners working in early years settings.

Educational psychologists

Some of the cognitive difficulties described in this report may require in-depth evaluations that are best conducted by teachers or educational psychologists with specialist training in cognitive assessment. This is particularly true in cases where there may be suspected difficulties with the executive functions and cognitive delays observed in children aged three and older. Educational psychologists should therefore be identified within all local strategies that aim to support children's learning during the first five years.

SENCO (Special Educational Needs Coordinator)/Learning Support Teacher/ psychologists and other specialists

Some of the cognitive difficulties described in this report require in-depth support and monitoring that can only be provided by professionals with specific knowledge about the disorder. This includes circumstances involving poor antenatal outcomes, birth trauma and ASCs. Specialist support teams and individuals should therefore also be identified as part of any local strategy that aims to support children's cognitive development during the early years.

1140 See: https://guidebook.eif.org.uk/

Early childhood education and care (ECEC)

This review has summarised evidence showing that enriching early years settings have the potential to reduce income-related learning gaps when offered to disadvantaged children from the age of two onwards. In particular, this review has identified a set of components and activities that could substantially improve the quality of early years provision. These include:

- play-based opportunities to explore and physically manipulate objects
- play-based opportunities to learn the names of objects and engage in symbolic object play
- conversations with adults that follow the child's lead and are specific to the child's interests
- enriching educational materials which include arts and crafts supplies and educational matching games
- opportunities to learn about objects and the physical world through regular outings to libraries, museums, parks and gardens
- conversations and materials which facilitate children's awareness of others' mental states
- small and large number-talk and activities which facilitate counting
- knowledge of object relationships and complex object systems
- understanding of the perspectives of others through stories and role-play activities
- knowledge of the counting principles and Arabic numerals
- preliteracy skills by increasing their knowledge of printed materials and participation in structured narratives.

Information about specific interventions that can be delivered in early years settings and reception are provided in the individual chapters of this review, covering children's understanding of objects, theory of mind, numbers and language. The EIF Guidebook also contains the details of home visiting interventions targeting families with a child between the ages of three and five that are designed to be delivered alongside early years education. All of these interventions last approximately one year and are intended to be delivered by certified early years teachers.

As described previously, this review has also identified 'two-generation' interventions combining high-quality childcare with individualised support for parents as particularly beneficial for low-income families. The Early Head Start Childcare Partnerships (EHSCCP) in the United States is a recent example of a two-generation model which combines support for parents with enriching childcare for children. The EHSCCP curriculm is based on scientifically proven principles (including many of those described in this review) and children's progress is screened and monitoried on an ongoing basis. The practitioners delivering the programme are also trained and supported to meet the diverse needs of disadvantaged parents, including knowing when and how to refer them on to mental health support. Although the child impacts have not yet been evaluated, the findings from intial feasibility studies are generally positive.[1141] Further details about the evidence underpinning many US Head Start activities can be found in our recent recent evidence review, *Teaching, pedagoy and practice in early years childcare*.[1142]

Children's centres

Children's centres are well positioned to offer or coordinate many of the activities described in this review. These include some of enriching learning opportunities provided through

[1141] Administration for Children, Schools and Families (2018). Early Head Start – Childcare Partnerships. https://www.acf.hhs.gov/ecd/early-learning/ehs-cc-partnerships

[1142] Sim, M., Bélanger, J., Hocking, J., Dimova, S., Iakovidou, E., Janta, B., & Teager, W. (2018). *Teaching, pedagogy and practice in early years childcare: An evidence review*. Early Intervention Foundation. https://www.eif.org.uk/report/teaching-pedagogy-and-practice-in-early-years-childcare-an-evidence-review drop-ins – including visits to museums and parks. Children's centres could also offer more targeted support to children identified as having specific learning needs. However, it is unlikely that children's centres support would be sufficient on its own for improving cognitive outcomes for economically disadvantaged children. Hence, children centre activities should not be provided as a replacement for more intensive support that is best provided by health visitors, teachers or SALTs, but rather be offered as supplementary.

Intervention developers and providers

Much of the evidence summarised in this review is quite recent, meaning that it may not yet be included in interventions which aim to support the cognitive development of children. Examples of recent findings that have implications for children's early learning include:

- messages about the importance of infant-directed speech and joint attention activities
- more specific advice on the importance of mind-minded parenting behaviours and the use of mental-state talk
- the importance of large number-talk and other more formal strategies for improving home numeracy
- the importance of activities outside of the home for supporting children's understanding of the world and object systems.

We view these findings as opportunities for intervention developers to add new content to existing programmes to potentially increase their impact. The above findings also have implications for programmes that are being developed from scratch.

Throughout this review we also emphasise the importance of dosage, especially for programmes targeting specific risks, including family disadvantage. Dosage involves three elements that are thought to contribute to intervention impact:

- The child and parents' exposure to the intervention. Higher intervention exposure is important because provides children and parents with more opportunities to practise new skills. Advice on its own is frequently not sufficient for changing behaviour, especially in situations where families are experiencing greater levels of disadvantage and risk.
- Intervention quality and intensity also support dosage and programme effectiveness. Elements known to increase intervention quality include the quality of the intervention training, systems for ensuring intervention fidelity, delivery by experienced and qualified practitioners and arrangements for ongoing supervision.
- Intervention specificity involves specifying intervention eligibility requirements to ensure that it is reaching the families and children who need it the most. It also involves systems for monitoring children's and parents' progress, to make sure that the interventions are meeting families' needs.

Intervention developers could significantly enhance the quality of interventions by specifying the elements, including the frequency and intensity, which ensure high-quality programme delivery, as well as identifying eligibility requirements. Intervention developers also play an important role in ensuring that dosage is not diluted as their interventions are delivered. This is particularly difficult when there is continued pressure to reduce spending, either by shortening the length of programmes or having them delivered by less-qualified practitioners. Licensing provides one method of ensuring that interventions meet their quality assurance requirements and are delivered as originally intended.

Developers should also be mindful not to overclaim the strength of their evidence. For example, evaluation evidence showing improvements in parenting, practitioner or teacher behaviours does not always mean that children will also benefit. This means that providers should not claim that an intervention is beneficial for children when there is only evidence for parents or teachers. Similarly, positive findings involving low-risk populations do not necessarily apply to higher-risk groups and vice versa. Developers should therefore not assume that their model will benefit children of all ages, when there is only evidence for very young children or older children.

Developers should also not overrepresent the magnitude of a programme's impact. In this respect, it cannot be assumed that long-term benefits will inevitably follow from short-term benefits. Nor can it be assumed that impacts observed in behavioural domains necessarily provide benefits in cognitive domains. For example, improvements in child persistence do not always result in improved cognitive outcomes. Developers should therefore be clear about the programme's primary target population, the strength of its evidence, the outcomes that it has and has not achieved, and the circumstances under which it worked best.

Researchers and evaluators

While this review has summarised a great deal of research, many questions remain unanswered. In particular, we still do not fully understand the role of genetic processes in children's development and the point in development when some genetically-based difficulties first become evident. This is particularly true of difficulties associated with children's numerical understanding, which are typically not evident until children enter primary school. Relatively little is also known about individual differences in ToM capabilities during infancy and their relationship to later ToM outcomes. More research is also required to understand the role of the executive functions in predicting many of the outcomes associated with children's object knowledge, ToM, numerical understanding and language.

Also, relatively little is known about the extent to which many of these cognitive outcomes are best supported by early intervention. Although this review has identified a number of parenting behaviours that are associated with improved cognitive outcomes, there is scant knowledge about how interventions might support parents in learning these behaviours. For example, there is good evidence showing that home numeracy activities and large number-talk are associated with children's early numerical development. However, we know relatively little about how these behaviours are best promoted through parenting support.

Further research is also required to rigorously test the effectiveness of many speech and language therapies. While there is preliminary evidence suggesting that many models show promise with small samples, more rigorous evaluation designs are required to determine the extent to which these relationships are causal and the degree to which programme impacts last over time.

Commissioners of children's services

This review has highlighted the importance of various activities and content for supporting children's early cognitive development. Content identified as important includes messages to parents about infant-directed speech, joint attention activities and object play, mental-state talk, number-talk and learning activities outside of the home. Activities identified as important include:

- intensive home visiting during the first two years
- enriched, 'two-generation' childcare starting from age two onwards
- enriched preschool that includes evidence-based elements which further supports children's understanding of objects, theory of mind, numbers and language.

While all families can potentially benefit from this support, it is most likely to have its greatest impact if delivered to families identified as having specific risks. Specific risks identified in this review include economic disadvantage, a preterm birth, maternal mental health, and learning difficulties which may have a heritable component.

Commissioners should first consider how these risks are currently being addressed within their early years' system, identifying areas of strengths and weaknesses in terms of current outcomes and current provision. Outcomes to consider include the number of children assessed as achieving good development on the EYFS profile, as well as language assessment results from the 2.5-year health check. Commissioners should also consider how many families are eligible for free school meals, the number of preterm births and their current systems for addressing parental mental health problems.

When commissioning new interventions, commissioners should be mindful of the programme's strength of evidence, the circumstances in which it worked best, who it worked for and the magnitude of its impact on improving child outcomes and reducing inequalities. Once the intervention is commissioned, this information can then be used to monitor the programmes' implementation, reach and local impact. Commissioners should also consider whether sufficiently qualified practitioners are available to deliver the intervention, and that resources are available to provide supervision. A key finding from the *Foundations for Life* review was that the interventions with the best evidence for improving early cognitive development were delivered by qualified teachers. This finding is consistent with the broader research literature which shows that early childcare and nursery is more effective when delivered by certified teachers.[1143,1144]

Policymakers

A key aim of this review is to provide recommendations for three priority areas identified in the recent Social Mobility Action Plan:

1. improve the quality of low-income families' home learning environment during the first two years of life
2. improve the quality of the childcare made available through the 15-hour-per-week childcare offer for disadvantaged two-year-olds through more enriching learning opportunities
3. improve the quality of nursery provision made available to disadvantaged children.

Improve the quality of the home learning environment during the child's first two years

Regular home visits that help disadvantaged parents provide an enriching home learning environment have the strongest potential for closing the income-related learning gaps that are already present by the age of three. The evidence reviewed here suggests that these visits should occur at least monthly, if not more frequently, until the child's second birthday. These visits should include advice on:

- strategies for engaging infants in joint attention activities and object play for supporting children's understanding of objects and object relationships
- the use of child-directed speech and conversations to support children's language development in a way that is optimal for the child's age
- the importance of mind-minded parenting behaviours and mental-state talk for supporting the development of children's theory of mind.
- the importance of large number-talk and other mathematical activities for supporting children's early understanding of number.

1143 Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (eds.) (2010). *Early childhood matters: Evidence from the effective pre-school and primary education project*. Routledge.

1144 Sim, M., Bélanger, J., Hocking, J., Dimova, S., Iakovidou, E., Janta, B., & Teager, W. (2018). *Teaching, pedagogy and practice in early years childcare: An evidence review*. Early Intervention Foundation. https://www.eif.org.uk/report/teaching-pedagogy-and-practice-in-early-years-childcare-an-evidence-review

Home visiting support is also likely to have greater impact if supplemented with group-based activities.

While we have not recommended any specific intervention, we have previously identified several models as having evidence of being effective in the *Foundations for Life* review. We therefore believe that there are clear opportunities within the health visiting service to provide effective support, if the support is informed by the evidence-based models described in this review and is sufficiently intensive for parents to learn new skills. However, we also recognised that more intensive health visiting support has clear resource implications. **We therefore recommend that Public Health England and the Institute for Health Visiting explore more fully the potential costs and benefits of offering a sufficiently enhanced health visiting service to provide high-quality home visiting support to improve the quality of the home learning environment in low-income and high-risk families during the child's first two years.**

Improving the quality of early childhood education and care for economically disadvantaged families

This review has highlighted the potential of childcare from the age of two onwards for supporting children's early cognitive development. While we have not weighed the relative benefits of specific models or curriculums, we have identified a number of high-quality activities with evidence of supporting a a range of cognitive competencies. Evidence consistently shows that these activities are most effective when delivered by early years educators who are well qualified, and this often means having a graduate or teacher status. **We therefore recommend that if the Department for Education's primary focus for targeted 2-year-old childcare offer, and the universal 3- and 4-year-old offer, is to reduce the socioeconomic gradient in children's early cognitive development, policy should focus on making quality provision available by increasing the number of graduates and qualified teachers working directly with children in early years settings, as well as ensuring non-graduate routes provide high-quality training which are grounded in the principles outlined in this report.**

8.4 Moving forward

This review has summarised the most recent evidence regarding children's early cognitive development with the aim of improving the effectiveness of early years services and providing recommendations for reducing income-related learning gaps. This evidence suggests that there are no easy solutions, but there are some clear options for moving forward. These options include fortifying the support that is already available to disadvantaged families through increased health visiting, 'two-generation' childcare that supports children and parents, and enriching curriculum-based early education. These options also involve starting as early as possible, already during the antenatal period. We also emphasise the need for a strong commitment, both at the local and central level to make sure that sufficient resources are available so that these options are possible. While these options are clearly costly, they also stand the greatest chance of reducing income-related learning gaps in the short run, and increasing social mobility over time.

Appendix A: Methodology

Literature search strategy

The approach adopted for this review is two-fold. In the first case, we have adopted an exhaustive framework designed to capture every aspect of child development. We then report the literature supporting the measurement and development of these different aspects of development. There is a great deal of potential literature in this area and an exhaustive review would not be feasible in so far as many aspects of child development are covered in greater detail elsewhere. In choosing these studies we have drawn on the expertise of the research team in selecting relevant studies. In the second case, we have also sought to identify predictors of risk associated with different aspects of development at different time points. To do this we have carried out a systematic review of the literature using explicit inclusion and exclusion criteria (Table A) – including studies published since 2000 using representative population studies with samples over 300 and including well developed measures. The procedure for the systematic review is outlined below.

Stage 1: Search strategy

Search the following electronic databases with the following combinations of Medical Subject Headings (MeSH) terms : MEDLINE, CINAHL, EMBASE, PsycInfo, ERIC, British Education Index

TABLE A1

The search strategy (key terms)

1. population/
2. child, preschool/
3. infant/ or infant, newborn/
4. representative
5. birth cohort
6. child development
7. 1 or 2 or 3 or 4 or 5 or 6
8. predictor
9. predictors
10. predicting
11. risk/ or logistic models/ or protective factors/ or risk factors/
12. risks
13. longitudinal
14. 8 or 9 or 10 or 11 or 12 or 13
15. language development/ or child language/
16. self-control/
17. self-regulation
18. executive functioning
19. cognition/
20. social-emotional development
21. socio-emotional development
22. conduct
23. hyperactivity
24. behaviour
25. behavioural
26. cognitive
27. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28. 7 and 14 and 27
29. remove duplicates from 28

Stage 2: Inclusion and exclusion criteria

Studies were included if they were:

- covering two or more time points before 72 months – i.e. not just one time point
- multivariate analysis which include social predictors with an outcome of one or more of the three designated EEF outcomes: cognition/language, self regulation/behaviour, socio-emotional development
- representative population samples with a sample size of at least 300 children. By 'representative' we mean samples which are tied back to a population which allows generalisability
- published in English since January 2000.

Studies were excluded if they were:

- clinical studies – thus included studies will not include studies which only include children with developmental disabilities such as Attention Deficit Hyperactivity disorder, Autism Spectrum Disorder, Language Disorders etc.
- set in developing countries, i.e. not readily generalisable to the UK
- designed to test heritability, i.e. twin studies and adoption studies
- focused on physical growth and nutrition
- in the grey literature.

Exclusions coding

1 focus ie nutrition, obesity, genetics

2 clinical ie autism, low birth weight

3 intervention

4 size less than 300 children

5 developing country

6 Review

7 Dissertation abstract only

Stage 3: Extraction

Relevant data from the papers were then transferred onto the data extraction sheet. Data included Identifiers, population size and country whether it was selected (ie from specific sub population – social disadvantage/cultural groups), age of outcome, age of predictor, results of multivariate analysis in the relevant measurement (B, OR, RR, F etc) and notes on authors conclusions.

Two review authors (JL/JC) independently extracted the data from reports of all eligible studies.

In the report, rather than including the findings from the review as a discrete chapter we have sought to integrate the findings within the sections of the report. The are some areas where this level of data is readily available (for example, language and socioemotional development) but others, such as conditional probability, where we could find no population-level literature. In these cases we have identified lower levels of evidence.

It is also important to acknowledge that in many cases the predictors vary across studies, and for this reason we have employed broad categories such as 'social disadvantage', which could be based on structural aspects of disadvantage, such as income or housing, or more functional aspects, such as maternal education.