WORD LEARNING BIASES AND VOCABULARY ACQUISITION IN TYPICAL AND ATYPICAL DEVELOPMENT

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ABSTRACT

Infants and young children are considered highly skilled word learners, and during the first years of life, they use different word learning biases to facilitate vocabulary learning. In this thesis I investigated the word learning biases used in typical and atypical development, how these learning biases affect word learning and vocabulary development, and how these word learning biases can be used as strategies to boost vocabulary growth. Three different populations with three different developmental paths and language characteristics were investigated: typically developing infants (**Chapter 2**), late talkers (**Chapter 3**) and children born preterm (**Chapter 4**). In **Chapter 2**, I investigated whether typically developing 17-month-olds can learn to use a function bias for object naming and generalisation, and the effect that a function bias intervention can have on general vocabulary growth. I found that infants can learn a function bias but that this does not provide any additional benefit for vocabulary growth than that provided by a shape bias. In **Chapter 3,** I investigated whether late talkers can be taught a shape bias for naming and generalising object labels, and whether this boosts their vocabulary development. The late talkers in my study learned to generalise known labels by shape, but were unable to use this knowledge for novel labels. Thus, I found no evidence that late talkers can learn a strategy that they could use to accelerate general vocabulary learning. Finally, in **Chapter 4**, I investigated the word learning biases children born preterm use and their vocabulary size and composition. Children born preterm in this study showed a shape bias for object generalisation, and showed similar vocabularies to those of full-term children. Overall, the findings across these three studies highlight the important role that word learning biases play in vocabulary learning, how infants will use strategies related to the words they learn in order to make word learning more efficient, and how cognitive processes, such as attention and statistical learning, are involved in the development of the word learning biases.

DEDICATION

In loving memory of Lucha and Mamá Abuelita

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PUBLICATIONS AND PRESENTATIONS

The following articles and research protocols were submitted for publication in peer-reviewed journals, uploaded at a registry of clinical trials, or presented at conferences. All articles and research protocols were based on experimental chapters of the current thesis. I was the primary author, but was advised on study design, data analysis and manuscript revisions by the listed co-authors.

Chapter 1 and Chapter 3

Zuniga-Montanez, C. & Krott, A. (2017) *Vocabulary Intervention for Late Talkers*. Research protocol pre-registered at Clinicaltrials.org. Identifier: NCT03379818 https://clinicaltrials.gov/ct2/show/NCT03379818

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CHAPTER 1

General Introduction and Thesis Outline

Language is an essential tool for communication and social interaction. It allows us to share our thoughts, feelings and needs, but also to understand the world around us. To successfully communicate, we need to be able to understand the meaning of the words that are being used. Thus, word learning and vocabulary development are essential components of language development. In this introduction, I will discuss how infants and young children learn words and how the development of word learning strategies, or lack of them, influences their vocabulary development. First, I will give a general overview of the different theoretical approaches on how infants and young children learn words. Then, I will discuss the three populations this thesis focuses on (typically developing children, late talkers and children born preterm), how they learn words and their vocabulary development. Investigating word learning in these three populations with different developmental characteristics will provide information regarding how word learning typically occurs, but also how deficits in different areas of development can affect how children learn words.

1.1 Word Learning in Typically Developing Children

Infants and young children are considered highly skilled word learners (Behrend, Scofield, & Kleinknecht, 2001; Dollaghan, 1985). To learn what a specific word means, infants need to map what they see to what they hear. However, this is a difficult task: every time infants hear a novel word, they need to identify the correct referent form a wide range of options. This problem is an example of what has been defined as reference uncertainty (Quine, 1960). In one famous example offered by Quine (1960), a native speaker of an unfamiliar language utters the word *gavagai* while pointing to a rabbit. So how does a person that is not familiar with that language know what the word *gavagai* means? In this example, the word *gavagai* could refer to the whole rabbit, the rabbit's ear, the category animals or even the action that the rabbit is doing. In real life, learning words is even more complicated than this example suggests, because words tend to be part of longer phrases or sentences, and are not presented as isolated words like in the *gavagai* problem (Yu & Ballard, 2007). Additionally, direct cues to indicate the referent (i.e. pointing) are not always available (Yu & Ballard, 2007). Therefore, identifying the correct referent of a word can be a difficult task.

Different theoretical accounts have been proposed to explain how infants learn words. Some of these accounts are the associative learning account, the social pragmatic account, the word learning biases and the emergentist coalition model. According to the associative learning account, infants learn words by attending to the statistical regularities of their environment (Kirkham, Slemmer, & Johnson, 2002; Smith & Yu, 2008; Yu, 2008). To pair a word to its referent, infants attend to their surroundings and the events that are salient, then they extract the co-occurring events and associate the words they hear with the objects they see (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). Thus memory and attention are a crucial part of word learning (Samuelson & Smith, 1998). Results from a study by Smith and Yu (2008) supported this account by showing that 12-month-olds can learn the meaning of new words by associating labels and objects presented to them across different trials. In this study, infants were presented with pairs of novel objects and their labels. Interestingly, during each trial, both novel labels were mentioned with no direct indication of which label referred to which object. The results of this study showed that after observing different combinations of the object pairs, infants learned which novel label referred to which novel object. Smith and Yu (2002) suggested that the infants learned the meaning of the novel words by combining information from different trials and associating the co-occurring events (i.e. a specific word that was only mentioned when a specific object was shown) to map the correct word to the correct referent.

In contrast to the associative learning account, the social pragmatic account suggests that infants use the cues that speakers provide (e.g. joint attention, pointing, gestures) to learn what a specific word refers to (Baldwin, 1993a; Baldwin et al., 1996; Baldwin & Moses, 2001; Briganti & Cohen, 2011). According to this account, infants can interpret the speaker's intention and use it to identify the correct referent for a specific word (Baldwin, 1993a, 1993b). For example, if a person says the word *cup* while pointing and looking at a cup, the infant will follow these cues and will use them to identify the object cup and eliminate other potential referents. The results from a word learning study conducted by Briganti and Cohen (2011) supported this account by showing that, at 18 months of age, not only do infants attend more towards objects that are being pointed at, but they also can map novel words to their referents better when an adult points consistently at the objects while mentioning their names. Thus, social cues are important for word learning as they constrain the number of potential referents that a novel word can have.

Besides the associative learning account and the social pragmatic account, research has also shown that during the first years of life, infants and young children can use different word learning biases to assist vocabulary learning. These biases are assumptions about objects that facilitate word learning by limiting the potential referents a novel word can have (Hollich, Hirsh-Pasek, & Golinkoff, 2000). Some examples of these word learning biases are the whole object assumption, the taxonomic assumption, mutual exclusivity and the shape bias. The *whole object assumptio*n is a tendency to assume that a novel word will refer to the whole object and not to a part (or parts) of it (Hollich, Golinkoff, & Hirsh-Pasek, 2007; Markman, 1994; Markman & Wachtel, 1988). In the *taxonomic assumption,* infants assume that a novel word will refer to the object's category and not only to the specific object (Cimpian & Markman, 2005; Markman, 1994; Markman & Hutchinson, 1984; Mayor & Plunkett, 2010). The *mutual exclusivity* assumption suggests that objects can only have one name, so children will not assign a second label to an object that already has a name (Graham, Nilsen, Collins, & Olineck, 2010; Jaswal & Hansen, 2006; Markman & Wachtel, 1988; Markman, Wasow, & Hansen, 2003). Finally, the *shape bias* is the assumption that objects that have the same shape will also have the same name (Borgström, Torkildsen, & Lindgren, 2015; Hupp, 2015; Kucker et al., 2019; Landau, Smith, & Jones, 1988, 1998b; Perry & Samuelson, 2011). Thus, word learning biases can make word learning an easier and quicker process by limiting the amount of information infants need to focus on when mapping a novel word to its referent.

Hollich and colleagues (2000) suggested that neither the associative learning account, the social pragmatic account nor the word learning biases by themselves can fully explain how infants learn words in all possible instances. Instead, they proposed the emergentist coalition model in which word learning occurs through a mixture of social cues, linguistic cues, attention and word learning biases (Golinkoff & Hirsh-Pasek, 2006; Hollich, Hirsh-Pasek, Golinkoff, et al., 2000). Hollich and colleagues (2000) proposed that infants do not use all available cues and information at the same time. Instead, for example, infants may first relay in associations and perceptual cues, and then they may start integrating social cues (Golinkoff & Hirsh-Pasek, 2006). After that, infants may start using word learning biases to reduce potential referents a novel word can have making word learning a quicker and more efficient processes. Similarly, Yu and Ballard (2007) proposed that word learning requires a combination of statistical learning and social cues. Thus, associations, social cues and word learning biases are all useful, but they may be more relevant at different stages during the word learning process.

1.1.1 Vocabulary Development in Typically Developing Children

While infants and young children are considered highly skilled word learners, vocabulary development starts as a slow process. At around 10 to 12 months of age, infants tend to produce their first words (Samuelson & McMurray, 2017). At this age, they also tend to understand only around ten words (Mani & Ackermann, 2018) and require multiple exposures to the same words and objects to map them correctly (Regier, 2005). However, the speed at which infants learn words tends to increase towards the second year of life. By 18 months of age, infants can learn around eight new words per week (Gershkoff-Stowe & Smith, 1997). Therefore, by 24 months children can know between 200 and 400 words (Bates et al., 1994; MacRoy-Higgins, Shafer, Fahey, & Kaden, 2016; Vandormael et al., 2019) and can add to their vocabularies from 22 to 37 words each month (Vuksanovic & Bjekic, 2013). At 24 months of age, children only require minimal exposure to map novel labels to their correct referents (Behrend et al., 2001; Dollaghan, 1985; Gershkoff-Stowe & Hahn, 2007; Holland, Simpson, & Riggs, 2015; Swingley, 2010). Considering the increase observed towards the end of the second year of life, significant changes may be occurring that promote an increase in the speed infants and young children learn words. Therefore, it is important to investigate the word learning biases that infants and young children develop at this age that could account for the acceleration in vocabulary development.

Interestingly, during the first years of life, in the English language object names (i.e. nouns) tend to be the category of words that infants and young children learn the most (Booth & Waxman, 2009; Imai et al., 2008; Sandhofer, Smith, & Luo, 2000). Thus, research has shown that nouns tend to be learned before other categories such as verbs or adjectives (e.g. Gentner, 1982; Imai et al., 2008). Different explanations have been given to why infants and young children tend to learn more nouns during the first years of life. For example, Gentner (1982) suggested that nouns are perceptually and conceptually easier than verbs or adjectives. This because nouns tend to refer to concrete objects that are stable over time (Gentner, 1982; Gentner & Boroditsky, 2010). In contrast, verbs involve a relationship between different components (e.g., agent, object, action, instrument) (Gentner, 1978; Gentner & Boroditsky, 2010) that can change over time (e.g., a spoon is initially empty, and then gets filled with food) (Deák, Ray, & Pick, 2002). Similarly, adjectives are also more difficult to learn as they are abstract and arbitrary properties, and their interpretation may depend on the noun that they modify (Fernald, Thorpe, & Marchman, 2010). For example, while we could use the word *small* to describe a spoon and a table, a *small* spoon and a *small* table are not similar in size. A second explanation of why infants learn more nouns during the first years of life is that the input infants and young children receive guides them to learn more nouns. In a study by Sandhofer and colleagues (2000) it was shown that parents tend to produce more nouns than any other word categories when talking to their children. Additionally, Goldfield, (2000) showed that when teaching a new words, parents tend to ask the children to repeat nouns, but tend to ask them to act verbs or actions. Thus, infants and young children may learn first nouns due to perceptual and conceptual accessibility, but also due to the input they receive during the first years of life.

1.1.2 The Shape Bias and Word Learning in Typical Development

At the end of the second year of life, infants go through a significant acceleration in their vocabulary development commonly defined as the vocabulary spurt (Gershkoff-Stowe & Smith, 2004; Nazzi & Bertoncini, 2003). Therefore, previous research has investigated the word learning biases that children develop around this age that could account for this acceleration in vocabulary. It has been found that around 24 months of age, typically developing children develop a *shape bias*. This bias is a tendency to infer that objects that have the same shape will also have the same name (Borgström et al., 2015; Hupp, 2015; Kucker et al., 2019; Landau et al., 1988, 1998b; Perry & Samuelson, 2011; Smith et al., 2002). With this bias, children tend to generalise known and novel labels to objects that share the same shape, but not to objects that share other properties such as colour or texture (Diesendruck & Bloom, 2003; Hupp, 2015; Perry & Samuelson, 2011). For example, an infant who has learned the word *ball* will be more likely to generalise the word *ball* to other objects with the same shape (i.e. round objects) instead of generalising it to other objects with the same colour, texture or size. While it is not known if the shape bias causes the vocabulary spurt or vice versa, the fact that these two milestones occur around the same time suggests that they may be related (Gershkoff-Stowe & Smith, 2004).

Typically, the presence of a shape bias has been assessed using word extension tasks. In this type of tasks, researchers show to the participant a novel object paired with a novel name in a sentence such as *"Look, this is a kiv"*. Afterwards, infants are shown other objects that share either the same shape, colour or texture as the *kiv,* and are asked: "*Where is the other kiv?"*. In this type of tasks, typically developing infants and young children tend to select the object sharing the same shape significantly more often than objects sharing the same colour or texture, confirming the presence of a shape bias.

Two different accounts in the literature have explained how typically developing children develop a shape bias: the Shape-as-Cue account (SAC) and the Attentional Learning account (ALA). The SAC account suggests that the shape bias develops because infants and young children have learned that shape is a reliable cue of an object's kind (Graham & Diesendruck, 2010; Markson, Diesendruck, & Bloom, 2008). In contrast, the ALA suggests the shape bias develops through the statistical regularities presented in the environment. According to this account, infants identify that shape is relevant for object naming because they are regularly presented with objects which tend to be named and organised by shape (Colunga & Smith, 2008; Smith et al., 2002). While according to the ALA account, a shape bias mainly occurs in naming contexts (Colunga & Smith, 2008; Smith et al., 2002), according to the SAC account the shape bias also occurs in categorisation contexts (Graham & Diesendruck, 2010; Markson et al., 2008). While I will not go into detail regarding the controversy between the ALA and the SAC, we can say that both accounts make the case that a shape bias is developed, but they differ on why it develops.

But how do infants develop the shape bias? According to Smith and colleagues (2002), this is a four-step process. Smith and colleagues (2002) argue that in the first step, infants will associate specific words to specific referents. Following the *ball* example used previously, an infant might hear the word *ball* every time he plays with a specific ball. After hearing the word *ball* multiple times, the infant will associate the word *ball* to the specific object he plays with. In the second step, Smith and colleagues (2002) suggest that after multiple exposures to objects with the same name and same shape (i.e. multiple balls also labelled *ball*), the infant will learn that objects with the same shape will also have the same name (e.g. all balls are round). Therefore, when encountering a novel object with the same shape of a ball, infants will know that that object can be called *ball.* This second step is what Smith and colleagues (2002) define as *first-order generalisation*. In the third step, after repetitive experience with objects organised and labelled by shape, infants learn that in general objects that have the same shape will also have the same name. Thus, Smith and colleagues (2002) suggest that in this third step infants are now able to generalise labels of novel objects to objects that have the same shape, even labels for objects that they have not had experience with before. This third step is what is known as *second-order generalisation*. Finally, in step four, Smith and colleagues (2002) suggest that infants have now a general understanding that objects of the same category have the same shape, therefore the same name. Since most names of objects that children learn during the first year of life are of categories organised by shape (Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg, Russell, & Luna, 2019), the shape bias becomes a useful word learning strategy.

Several studies (e.g. Perry, Samuelson, Malloy, & Schiffer, 2010; Samuelson, 2002; Smith et al., 2002) have supported the development of the shape bias through the four-step process previously described. For example, in a longitudinal study by Samuelson (2002), 18-month-olds were presented with objects organised and named based on shape similarities. After multiple experiences with these objects, infants learned that shape was the relevant property that made two objects share the same name. Thus, through the statistical regularities of the naming experiences (i.e. by being presented with objects that are named according to their shapes) infants developed a shape bias.

1.1.3 The Shape Bias as a Word Learning Intervention

Besides being part of typical development, the shape bias can also be used as a strategy to enhance expressive vocabulary (Samuelson, 2002; Smith et al., 2002). Smith and colleagues (2002) showed that 17-month-olds can learn a precocious shape bias and use it to generalise known and novel labels. During a 7-week intervention program, 17-month-olds were presented with four sets of novel objects organised by shape paired with their novel labels. In two further sessions, participants were tested to see if, after repetitive exposure to objects organised by shape, participants generalised object labels by either shape, colour or texture. Participants in their shape training group based their generalisations of known (first-order generalisation) and novel labels (second-order generalisation) by shape. In contrast, a control group did not show a preference for generalising by any specific property. Additionally, Smith and colleagues (2002) found that after this intervention, the expressive noun vocabulary of their shape training group grew significantly faster throughout the study than the vocabulary of the control group that did not receive any training. Participants in their shape training group produced 256% more nouns at the end of the study compared to the beginning, while participants in their control group produced only 78% more nouns. Thus, Smith and colleagues (2002) suggested that the training provided infants with an advantage in noun learning since it helped them to acquire a useful word learning strategy at an earlier age in life than infants in the control group.

1.1.4 The Role of Function in Typical Word Learning

Despite its importance, shape is not the only important attribute that can define what an object is, and therefore its name. Objects can also be named and classified according to their functions (Diesendruck, Markson, & Bloom, 2003; Namy & Clepper, 2010). Object's function is important as it provides information about an object's purpose, (Diesendruck et al., 2003) and therefore about its category (Booth & Waxman, 2002). While infants and young children tend to rely on shape for word learning and generalisation, older children and adults consider function as the predominant property for naming and extending labels when functional information is available (Graham, Williams, & Huber, 1999). Thus, using the object's function instead of shape may be considered as a more complex and mature way to name objects.

There is an extensive controversy concerning when infants and young children are able to use function for word learning and generalisation. On the one hand, some studies have found that 2- to 5-year-olds cannot generalise labels based on function similarities (Graham et al., 1999; Landau et al., 1998b). In contrast, other studies have found that 2- to 4-year olds can do it when the object's function is demonstrated and explained (Diesendruck et al., 2003) or when they are allowed to manipulate the object and its function during labelling (Kemler Nelson, Russell, Duke, & Jones, 2000). To my knowledge, no one has investigated if infants can use object function as the predominant property for object naming and generalisation.

One reason that has been given for why infants and young children do not seem to use function but use shape for object naming and generalisation, is that functions can be considered perceptually and conceptually more difficult than shapes (Gathercole & Whitfield, 2001; Gentner, 1982; Gentner & Boroditsky, 2010; Landau et al., 1988). Thus, the use of shape, instead of function, is an easy way to eliminate erroneous referents for novel labels making word learning a more straightforward and quicker process. This account would suggest that it might be challenging to teach infants to focus on object functions, instead of shape, for naming and generalisation. Nevertheless, previous research has shown that infants as young as 10 months can use function for object categorisation (Booth, Schuler, & Zajicek, 2010; Booth & Waxman, 2002; Horst, Oakes, & Madole, 2005; Träuble & Pauen, 2007). Thus, if infants can use function for categorisation, there is no obvious cognitive obstacle impeding their use for object naming and generalisation.

To date, no one has assessed if infants can learn to use function instead of shape for word learning and generalisation. Understanding if infants can learn to use function can provide information regarding why infants tend to naturally develop a shape bias instead of a function bias, and if this is due to function being conceptually more challenging than shape for object naming and generalisation in infancy. Thus, **Chapter 2** describes a training programme that had the main aim of teaching 17-month-olds a function bias. This training programme was similar to the one conducted by Smith and colleagues (2002), with the key difference that instead of teaching infants to generalise labels by shape, infants were taught to do so by function. Therefore, while Smith and colleagues (2002) facilitated the development of a bias that infants would have developed soon in life (shape bias), I report a study in which I have investigated whether young infants can learn to use a more complex and mature bias (i.e. function bias) that usually is developed later in life. In **Chapter 2,** I also report data concerning whether a function-training can boost vocabulary learning. While Smith colleagues (2002) assessed only expressive vocabulary, the study I report in **Chapter 2** assessed expressive and receptive vocabulary growth.

1.2 Word Learning and Vocabulary Development in Atypical Development

Even though typically developing children learn words at a rapid rate, and use word learning biases to facilitate vocabulary acquisition, not all children follow the same developmental path. According to Horwitz and colleagues (2003), around 13% of 2-year-olds, and around 17% of 3-year-olds can show significant language delays. Similarly, Rescorla and Alley (2001) suggested that around 10% of children under 2 will have some language delay. Thus, a significant number of infants and young children will show deficits in language development and important vocabulary delays.

Vocabulary delays are a concern as vocabulary size and language skills lay the foundation for later academic success (Bleses, Makransky, Dale, Hojen, & Ari, 2016; Morgan, Farkas, Hillemeier, & Scheffner Hammer, 2015) and can impact social development (Lean, Paul, Smyser, Smyser, & Rogers, 2018; Määttä, Laakso, Tolvanen, Ahonen, & Aro, 2012; Paul, Looney, & Dahm, 1991). Since the shape bias can facilitate word learning and generalisation in typically developing children by tuning infants' attention towards the property by which most objects are organised (Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg et al., 2019), it is important to assess whether populations which are considered to have vocabulary delays also develop this bias. Assessing this in atypical populations can provide information regarding how deficits or delays in different areas of development can affect how children learn words.

Two populations that have shown deficits in language development are late talkers and children born preterm. Late talkers tend to show a delay in vocabulary acquisition in the absence of any other conditions or disorders (Rescorla, 2011; Tsybina & Eriks-Brophy, 2007), while children born preterm can have smaller vocabularies but may also show cognitive, motor and developmental delays (Caravale, Tozzi, Albino, & Vicari, 2005; Ionio et al., 2016). Therefore, while both populations seem to have different developmental characteristics, they both show delays in vocabulary development. On the one hand, late talkers seem to have delays related mainly with language development, while children born preterm can have a general developmental delay. Assessing these two populations will help understanding if a delay in vocabulary development, and potentially a lack of shape bias, is a language specific deficit, or if these delays can be accounted for by a more broad general and cognitive delay. In the following sections, I will describe the vocabulary development of late talkers and children born preterm. I will also describe how the extent of their use of the shape bias, could explain their vocabulary delays.

1.2.1 Late Talkers

Late talkers are children who have a language delay characterised by less than 50 words in their productive vocabulary at 24 months (Ellis Weismer, Venker, Evans, & Jones Moyle, 2013; MacRoy-Higgins & Montemarano, 2016; Rescorla, 2011) and a lack of two-word phrases (MacRoy-Higgins & Kliment, 2017; MacRoy-Higgins & Montemarano, 2016; Pearson, 2013). They show this delay in the absence of any hearing difficulties, or any physiological, cognitive or genetic disorders (Rescorla, 2011; Tsybina & Eriks-Brophy, 2007). Late talkers are often defined as having an expressive vocabulary below the 15^{th} percentile (Colunga & Smith, 2008; Ellis, Borovsky, Elman, & Evans, 2015; MacRoy-Higgins et al., 2016). However, some studies have considered any child below the 30^{th} percentile as a late talker (Colunga & Sims, 2017; Jones & Smith, 2005).

Late talkers are not a homogenous group. While their main characteristic is a delay in expressive vocabulary, they can also have a delay in their receptive abilities (Chilosi et al., 2019; Desmarais, Sylvestre, Meyer, Bairati, & Rouleau, 2008). Additionally, while some late talkers can catch up with their peers at school age, some others will have persistent language difficulties throughout their whole lives (Colunga & Sims, 2017). Children who catch up are known as *late bloomers,* and according to Petruccelli, Bavin and Bretherton (2012), they represent from 50% to 70% of all late talkers. It is important to note that even though late bloomers seem to "catch up" and perform within the expected range for their age, an important percentage of these children may still have lower scores than their typically developing peers in language assessments (Bleses et al., 2016; Dale, McMillan, Hayiou-Thomas, & Plomin, 2014; Rescorla, 2011; Rice, Taylor, & Zubrick, 2008). Previous research has suggested that late talkers that catch up are mainly the ones that only have an expressive vocabulary delay and relatively good verbal comprehension (Chilosi et al., 2019). In contrast, if late talkers have more than just an expressive language delay (i.e. expressive and receptive delays), they may not catch up (Chilosi et al., 2019). If late talkers also have a persistent difficulty in combining words, then they may even be at risk of a future diagnosis of Developmental Language Delay (DLD) (Perry & Kucker, 2019; Rudolph & Leonard, 2016). Therefore, early interventions for late talking children could help late bloomers, as well as late talkers that will have persistent difficulties throughout their lives.

Most research investigating late talkers' development has mainly focused on following them through a few years of their lives to understand their delays and how different areas of development can be affected. It has been found that late talkers are at risk of developmental and academic difficulties (Bleses et al., 2016; Poll & Miller, 2013; Rice et al., 2008). Interestingly, late talkers' social and emotional development, as well as their behaviour, also tend to be impacted (Määttä et al., 2012). For example, in a study conducted by Irwin, Carter, and Briggs-Gowan (2002) parents of children that at the age of 2 were identified as late talkers, reported that during play children were more withdrawn and shy and that they had more difficulties interacting with people. Thus, language inventions could be beneficial also for social development and academic performance in this population.

1.2.1.1 Word Learning and The Shape Bias in Late Talking Children

Currently, the exact reasons why late talkers know and produce fewer words are not well known. However, research has found that, besides having smaller vocabularies, late talkers are also slower than typically developing children at learning (MacRoy-Higgins & Montemarano, 2016) and recognising words (Ellis et al., 2015). Thus, it may be that late talkers have deficits in processes governing the quick and successful learning of words.

One factor that may be contributing to late talkers' difficulties in learning and producing new words is that they are not using the same word learning biases that typically developing children use. While typically developing children develop a shape bias for object naming and generalisation, evidence indicates that late talkers do not (Colunga & Sims, 2012a; Ellis Weismer et al., 2013; Jones, 2003). Instead, late talkers either show a preference for generalising labels based on the object's texture or do not have an evident preference to generalise on the basis of any property (Jones, 2003). As previous research has shown that the shape bias is beneficial for typical word learning, and that it is related to the vocabulary spurt (Gershkoff-Stowe & Smith, 2004), it is a reasonable conjecture that a lack of a shape bias may be contributing to the slow acquisition of words observed in late talkers. To my knowledge, no studies have so far investigated the possibility of teaching late talkers a shape bias as an intervention to promote their vocabulary development.

1.2.2.1 Clinical Approaches and Interventions for Late Talkers

Even though it is clear that late talkers have difficulties in learning words, there are currently no specific interventions designed to target this difficulty in this population. Instead, there are three conventional approaches followed by clinicians: the *wait and see approach*, the *watch and see approach*, and *early intervention*. In the *wait and see approach,* parents are advised to wait until the infant is older to see whether a language delay is indeed present (Girolametto, Weitzman, & Earle, 2013). Many researchers do not accept this approach as it can prevent the child from receiving adequate support by assuming that catching up is the norm for all late talkers. The *watch and see approach* consists of monitoring the infant's language development and evaluating it every 3 to 6 months to determine whether the infant catches up, or if intervention is required (Preston et al., 2010). Finally, *early intervention* means to actively work with the infant to help them develop language and communicating abilities (Warren, 2000). There is a persuasive argument that, ideally, *early intervention* should be the only approach used for late talkers, as even late bloomers can be in the lower range of language assessments (Bleses et al., 2016; Dale et al., 2014; Rescorla, 2011; Rice et al., 2008). Therefore, early intervention will be beneficial for all children, even the ones that will catch up.

When *early intervention* is implemented, clinicians use different techniques to promote language. Some of these techniques, which I describe below, include: *focused stimulation* (Cable & Domsch, 2011), *modelling target words in context* (Cable & Domsch, 2011), *general language stimulation* (Finestack & Fey, 2013), and *milieu teaching* (Finestack & Fey, 2013). *Focused stimulation* consists of establishing a joint focus with the child by producing an object's name (e.g. "*ball*"), a comment (e.g. "*Look!*") or a two-word utterance (e.g. "*big ball*") (Cable & Domsch, 2011). *Modelling target words in context* consists of modelling sentences using certain words and mentioning it to the child in an informal, play-like context (Cable & Domsch, 2011). The *general language stimulation* technique consists of creating a rich environment in which the child can experience different objects and activities (Finestack & Fey, 2013) such as reading books, playing, helping in everyday activities, among others. Finally, the *milieu teaching approach* consists of identifying specific goals and, with the use of naturalistic settings or activities, encourages the child to attempt to use target words or behaviours (Finestack & Fey, 2013).

Studies that have used these techniques have found positive results in late talkers' expressive vocabulary development (e.g. Alt, Meyers, Oglivie, Nicholas, & Arizmendi, 2014; Girolametto, Pearce, & Weitzman, 1997; Robertson & Weismer, 1999; Weismer, Murray-Branch, & Miller, 1993). These positive results have been found when interventions have been conducted in both clinical and research environments (Alt et al., 2014; Robertson & Weismer, 1999), and have also been found in the context of parent-led interventions (Girolametto et al., 1997; Weismer et al., 1993). Most of these studies have examined how to teach either specific words or communication patterns which late talkers do not know, and the effects that this has on general vocabulary growth. However, none of these studies have developed an intervention that targets a specific underlying process for why late talkers may not seem to be learning words as easily and as quickly as their typically developing peers. Considering that the shape bias has been linked to an increase in vocabulary acquisition in typically developing children (Smith et al., 2002), an intervention aiming at teaching late talkers the shape bias has the potential to be a powerful intervention alternative.

In **Chapter 3,** I describe an intervention aimed at teaching the shape bias to late talkers between 24 and 47 months of age. Given the positive evidence found when teaching infants a precocious shape bias (Smith et al., 2002), and the lack of a shape bias in late talkers (Colunga & Sims, 2012a; Ellis Weismer et al., 2013; Jones, 2003), a shape bias training may be a useful way of introducing a word learning strategy that will be beneficial for object naming and generalisation. In **Chapter 3,** I also report data concerning whether a shape bias training can boost vocabulary learning in late talkers.

1.2.2 Children Born Preterm

Another developmental population investigated in this thesis is children born preterm. A birth is identified as being preterm if a child is born before 37 completed weeks of gestation. In 2018, approximately 7.9% of all children born in England were born preterm (Ghosh, 2019). Preterm birth can be divided into four different groups depending on the week in which the child was born: late preterm, moderately preterm, very preterm and extremely preterm (Pérez-Pereira & Cruz, 2018). Late Preterm are children born between 34 to 36 weeks of gestation. Moderately preterm are children born between 32 to 34 weeks of gestation. Very preterm are children born between 28 and 31 weeks of gestation. Extremely preterm are all children born before 28 weeks of gestation. Children born late preterm and moderately preterm (from week 32 to week 36) are the most prevalent type of preterm birth (Ghosh, 2019; Kern & Gayraud, 2007).

Children born preterm are not a homogenous group. On the one hand, some children can be born with severe neurological, cognitive or physical disabilities or impairments that will affect them throughout the rest of their lives (Marlow, 2004; Moster, Lie, & Markestad, 2008; Van Baar, Van Wassenaer, Briët, Dekker, & Kok, 2005; Wood, Marlow, Costeloe, Gibson, & Wilkinson, 2000). However, in other cases, children born preterm may not have any obvious impairments or disabilities and will develop in step with their full-term peers. The risk of having a severe disability or impairment increases with the extent of prematurity (Ghosh, 2019; Kern & Gayraud, 2007; Marlow, Wolke, Bracewell, & Muthanna, 2005). For example, around 20% of children born extremely preterm are born with severe disabilities, approximately 25% are born with moderate disabilities, and around 35% are born with mild disabilities (Marlow et al., 2005).

Therefore, it is important to investigate how children born preterm develop and how different areas of their development are affected.

1.2.2.1 Language Development and Word Learning in Children Born Preterm

Previous research has shown that even though some children born preterm can have a typical development (i.e. they do not have any severe conditions, disorders or impairments) differences in language development can still be observed. Typically, previous research has focused on how language in children born preterm develops from infancy to school age or early adulthood compared to full-term children (Beaulieu-Poulin, Simard, Babakissa, Lefebvre, & Luu, 2016; Brósch-Fohraheim, Fuiko, Marschik, Resch, & Liu, 2019; Caravale et al., 2005; Foster-Cohen, Edgin, Champion, & Woodward, 2007; Kern & Gayraud, 2007; Putnick, Bornstein, Eryigit-Madzwamuse, & Wolke, 2017). Studies have found that when using standardised tests, children born preterm tend to perform below their full-term peers (Sansavini et al., 2010; Stolt et al., 2016; Zambrana, Vollrath, Sengpiel, Jacobsson, & Ystrom, 2016; Zimmerman, 2018). Therefore, it is important to investigate why preterm children with a typical development (i.e. without any severe conditions, disorders or impairments) can still show these differences compared to their full-term peers.

One area of language development that is affected in some children born preterm is vocabulary acquisition. Research has shown that children born preterm, especially very preterm and extremely preterm children, can have smaller vocabularies than full-term children (Brósch-Fohraheim et al., 2019; Kern & Gayraud, 2007; Sansavini et al., 2015). Some researchers suggest that this is because general development in this population tends to be delayed (Holt, 2011). Therefore, they will always show a delay and will achieve most developmental milestones later in life (Cusson, 2003). However, other studies suggest that rather than being delayed, children born preterm have an atypical development (Sansavini, Guarini, & Caselli, 2011; Vandormael et al., 2019), meaning that they will always show differences compared to full-term children.

One way of being able to understand the differences in vocabulary between preterm and full-term children is by assessing how they learn words and what word learning biases they use. As mentioned, one particularly important word learning bias for infants and young children is the shape bias. Research with typically developing children (Gershkoff-Stowe & Smith, 2004; Perry & Samuelson, 2011) and late talkers (Jones, 2003; Jones & Smith, 2005) has shown that vocabulary size is related to the robustness of the shape bias. Thus, if children born preterm have smaller vocabularies compared to their full-term peers, they may also show a less robust shape bias. To my knowledge, no one has investigated the presence of a shape bias in children born preterm. Thus, **Chapter 4** presents a pilot study that had the main aim of probing the shape bias for noun generalisation in children between 24 and 41 months of age that were born preterm, as well as tracing the development of their vocabulary size.

When investigating potential delays in language development, it is important to assess whether these delays could also be the effect of a more general developmental or cognitive delay. As suggested by Deák (2014), language and cognitive development co-develop. Thus, delays in cognitive development may affect language development. Investigating the presence of cognitive delays in language development is even more important in populations such as children born preterm because, even in the absence of severe conditions, disorders or impairments, such children can show cognitive differences compared to their full-term peers (e.g. Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2016; Kern & Gayraud, 2007; Marchman, Feldman, Gresch, Loi, & Fernald, 2018; Yaari et al., 2018). Similarly, research has found that children born preterm can also have significant motor delays, and that these delays can be related to deficits observed in their language and cognitive development (Benassi et al., 2016; Ross, Demaria, & Yap, 2017; Zuccarini et al., 2017). Therefore, given that children born preterm can often show cognitive and motor delays, it is then essential to gather measures of their cognitive and motor development when studying their development of language acquisition. This is to assess if their potential delays are also related to a more broad general delay. Thus, in **Chapter 4**, I also assessed the cognitive and motor abilities of children born preterm, and the relationship of these abilities with their shape bias.

In sum, **Chapter 4** provides insight into one potential underlying reason of why children born preterm have smaller vocabularies than full-term children. Investigating the shape bias in children born preterm and its relationship with vocabulary size and cognitive and motor development brings us a step closer to understanding why children born preterm who otherwise seem to be developing in step with their full-term peers still demonstrate smaller vocabularies.

1.3 Thesis Summary

In summary, the general aims of the work I report in this thesis were: 1) to investigate the word learning biases used in typical and atypical development, 2) to investigate how these learning biases affect word learning and vocabulary development, and 3) to investigate how these word learning biases can be used as strategies to boost vocabulary growth. Three different populations with three different developmental paths and language characteristics were investigated: typically developing infants (**Chapter 2**), late talkers (**Chapter 3**) and children born preterm (**Chapter 4**). In **Chapter 2** and **Chapter 3,** two different word learning interventions were introduced (a function bias in

Chapter 2 and a shape bias in Chapter 3) with the main aim of teaching a word learning bias useful for naming and generalising object labels. In **Chapter 4**, I investigated if children born preterm use a shape bias for noun generalisation, I assessed their vocabulary size and I investigated if there was a relationship between the shape bias and their vocabulary size, cognitive development and motor development. Table 1.1 provides an overview of the three experimental chapters.

Table 1.1 *Summary of The Three Experimental Chapters and Their Main Aims.*

Chapter	Aims	Sample characteristics
2	To investigate whether infants can learn to attend to function as a strategy for word learning and generalisation and to investigate if a function-training programme can accelerate real-world vocabulary growth.	17-months old typically developing infants
3	To investigate if late talkers can learn to use shape as the main property for generalising known and novel labels and the effects that a shape bias training has on real-world vocabulary growth.	Late talkers between 24 and 47 months
4	To explore if children born preterm show a shape bias for noun generalisation, to assess their vocabulary size, and to investigate if there is a relationship between the shape bias and their vocabulary size, their cognitive development and their motor development.	Children born preterm between 24 and 41 months

CHAPTER 2

Teaching a Function Bias Promotes First- and Second-order Generalisation

Abstract

During the first years of life, infants and young children tend to show a shape bias for object naming and generalisation. But shape is not the only important attribute for naming objects. Function also provides information about what an object is, and therefore its name. In contrast to infants and young children, older children and adults tend to use function instead of shape for object naming and generalisation, when functional information is available. The current study investigated whether infants can learn to use the function of objects for noun generalisation at 17 months, an age when infants start to develop a shape bias. In the current study, twenty-four 17-month-olds participated in a 7-week training programme. Participants in a function-training group were taught that objects with the same function have the same label while participants in a control group were exposed to the same objects but without labelling. Infants' generalisation of familiar (first-order generalisation) and novel labels (second-order generalisation) was tested in Weeks 8 and 9. Results showed that the function-training group generalised familiar (first-order generalisation) and novel labels (second-order generalisation) by function, whereas the control group showed a trend to generalise by shape. Parental report indicated similar expressive and receptive vocabulary growth in both groups. Thus, a taught function bias had a similar effect on vocabulary growth as a developing shape bias.

Peer-reviewed publication: A manuscript based on this chapter has been accepted for publication.

2.1 Introduction

Early word learning is critical for children's general development, and large individual differences in early vocabulary development can have long-lasting effects. For instance, children's early vocabulary size and language skills can predict later academic success (Bleses et al., 2016; Morgan et al., 2015). It is therefore important to study the word learning strategies that promote rapid vocabulary growth in infancy.

2.1.1 The Role of Shape and Function in Word Learning and Generalisation

When learning and generalising object labels, infants, children and adults prioritise different object properties depending on the task and information available (e.g. Diesendruck, Markson, & Bloom, 2003; Graham, Williams, & Huber, 1999; Namy & Clepper, 2010). Older children and adults use shape and function, but prefer function when information about the object's function is available (Gathercole & Whitfield, 2001; Graham et al., 1999). For example, Graham and colleagues (1999), showed that adults extend a novel label to objects that share the same function, even if the object with the same function has very different perceptual properties. Function is useful for naming as it provides information about an object's intended use (Diesendruck et al., 2003) and therefore about its category (Booth & Waxman, 2002). While shape typically indicates the category as well, shape can sometimes be misleading. For example, a pen in the shape of a banana is a pen used for writing and not for eating. In this example, the relevant property for the pen to be named *pen* is its intended function (i.e. being used to write), therefore naming and categorising it by its shape will be inaccurate.

In contrast to older children and adults, infants and younger children typically generalise object labels based on shape (Gentner, 1978; Horst & Twomey, 2013; Hupp, 2015; Kucker et al., 2019; Landau et al., 1998b; Perry & Samuelson, 2011). This is because around 24 months (Kucker et al., 2019) children develop a shape bias for noun generalisation, that is, they start to assume that similarly-shaped objects have the same name (Hupp, 2015; Kucker et al., 2019; Landau et al., 1998b; Perry & Samuelson, 2011). Thus, whereas older children and adults prioritise function for generalising object labels, infants and younger children prioritise shape.

Several studies have investigated at what age, and under which circumstances function is used instead of shape for noun learning and generalisation (e.g. Deák, Ray, & Pick, 2002; Diesendruck et al., 2003; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Kemler Nelson, Russell, Duke, & Jones, 2000; Landau et al., 1998; Merriman, Scott, & Marazita, 1993). There are two different perspectives in the literature regarding if young children can use function for object naming and generalisation. One account has suggested that infants and young children rely on perceptual features first and that attention to function occurs later in childhood (Gentner, 1978; Graham & Poulin-Dubois, 1999; Landau et al., 1998b). Gentner (1978) was one of the first researchers to conduct a study investigating this. Gentner (1978) showed that when shape and function are pitted against each other, 2 to 5-year-olds use shape to name novel objects, but 5- to 15-year olds would prefer function over shape. Similar results have been found in studies investigating if the way that function is presented affects its understanding and use. For example, Landau and colleagues (1998) showed that 2-, 3- and 5-year-olds generalise novel names by shape even if function was explained and demonstrated. Graham and colleagues (1999) also found that young children cannot generalise by function even if they are allowed to manipulate the object. In sum, these studies suggest that children will prioritise an object's appearance (shape) over function for naming and generalisation.

Contrary to the studies previously mentioned, further studies with 2- and 3-year-olds have shown that children can extend newly learned object labels based on function when the object's function is demonstrated and explained (Diesendruck et al., 2003) or when they are allowed to manipulate and interact with the objects during labelling (Kemler Nelson et al., 2000). For example, Diesendruck and colleagues (2003) found that three-year-olds can use function instead of shape in a word extension task when the object's function was explained and demonstrated. But, to my knowledge, there are no studies reporting the use of function in naming and generalisation in children below two years of age.

2.1.2 Why do Infants Develop a Shape, but not a Function Bias?

If older children and adults prioritise function when naming and generalising labels (Graham et al., 1999), then why is shape prioritised in infancy and early childhood? There are two possible reasons for this. First, Gentner (1982) suggested that shape is perceptually more accessible than function, and that shape is also more stable over time. In contrast, function becomes apparent only after manipulating an object, and it is usually transient (Landau et al., 1998b). Similarly, Graham and Poulin-Dubois (1999) have argued that shape is a more accessible property than function, as it can be identified immediately upon encountering an object. Therefore, identifying the shape of an object does not require to explore or manipulate the object to know how it looks like. Second, Gentner (1978) also argued that shape is conceptually easier than function. Shape is easier to individuate than function due to clear and stable boundaries (Gentner, 1978). In contrast, function is a complex object property that involves (causal) relations among qualitatively different subcomponents (e.g., agent, object, action, instrument) (Gentner, 1978; Gentner & Boroditsky, 2010). It also requires the integration of information over time (e.g., a spoon is initially empty, and then gets filled with food) (Deák et al., 2002). Note that these reasons for the conceptual simplicity of shape have also been brought forward in the debate on why nouns (object names) are learned before verbs (action names) (e.g. Gentner, 1982; Imai et al., 2008). The problem of mapping a label to an object based on its function resembles the problem of mapping verbs to actions. For example, mapping the verb *write* to the action of writing requires assigning a name to an action that is only visible while it is being performed. The same problem occurs when the word *pen* is named according to its intended function of writing.

Previous research suggests that, since function is perceptually and conceptually more difficult to use than shape, both properties may influence language acquisition at a different stage of development (Träuble & Pauen, 2007). Following this premise, children start using an easily accessible property such as shape, and then they learn to use function to create novel categories. However taking into account previous studies (Diesendruck et al., 2003; Kemler Nelson, Russell, et al., 2000), it appears that under the right circumstances (e.g. when function is explained, demonstrated and manipulated) children can attend to function instead of shape for object naming and generalisation even at an early stage in development. Additionally, research has shown that infants between 10- and 18-month olds can use function for object categorisation (Booth et al., 2010; Horst et al., 2005; Träuble & Pauen, 2007). Therefore, there is no cognitive obstacle impeding the use of function information for object naming and generalisation.

Previous research investigating the role of shape bias in object naming and generalisation has shown that it is possible to accelerate the emergence of a shape bias (Perry et al., 2010; Samuelson, 2002; Smith et al., 2002). For example, Smith and colleagues (2002) showed that 17-month-olds can learn a shape bias for word learning and generalisation before they would naturally develop it. In a seven-week training programme, infants were presented with objects organised by shape and their labels and were able to play and manipulate the objects while listening to their names. After seven weeks, infants in their training group learned to generalise nouns based on the object's shape. They did so for labels that they had been trained on (first-order generalisation) and novel labels that they had never encountered before (second-order generalisation). Similarly, Ware and Booth (2010) showed that 17-month olds could also learn to use shape to extend known (first-order generalisation) and novel (second-order generalisation) words if the shape and function were related in a meaningful way, but this was not the case if function and shape were not clearly related. However, if the preference of using shape over function in noun generalisation is due to conceptual simplicity, then it should be challenging to train infants to develop a function bias instead. If a similar training for function as the ones previously mentioned can enable 17-month-olds to use a function bias, then this would show that conceptual difficulty is not the obstacle that prevents a function bias from being developed.

To investigate if infants do not generalise nouns by function because functions are conceptually too difficult, it is important to investigate if infants can learn to use function for object naming and generalisation. To my knowledge, to date, no one has looked at the possibility of teaching a function bias to infants and the effect this can have in general vocabulary growth.

2.1.1 The Current Study

In this study, I investigated whether infants can learn to attend to function as a strategy for object naming and generalisation and whether a function-training programme has an effect on real-world vocabulary growth. I followed the same procedure as Smith and colleagues (2002), with the key difference that instead of teaching infants a shape bias, I introduced them to a function bias. A group of 17-month olds were randomly assigned to two groups: function-training group and control group. During 7 weekly sessions, participants in a function-training group were taught that objects with the same function can have the same name. A control group was introduced to the same stimuli in a similar 7-week programme but was not taught any labels or shown any functions. After training, participants completed a first-order and a second-order generalisation task. The former tested whether infants extended trained labels based on function, shape, or colour. The latter assessed the same with new labels for new objects that the infants had not encountered during training.

At the start of the study, a sorting task and an eye-tracking task were also introduced to all participants. The sorting task assessed infants' abilities to pick up function similarities and if there were any differences between groups at the start of the study. The attention task assessed participants' joint and sustained attention. Attention was assessed because previous research has suggested that sustained attention (Kannass & Oakes, 2008; MacRoy-Higgins & Montemarano, 2016) and joint attention (Yu & Smith, 2016) can be related to vocabulary learning in early childhood. Thus, since attention can influence word learning, it was important to ensure that both participant groups did not differ in their attention abilities. Finally, parents also reported infants' productive and receptive vocabulary before and after training to assess the effect that a function bias had in general vocabulary growth. Parents were also asked to report infants' productive and receptive vocabulary six months after finishing the study in order to assess any long-term effects the training could have in vocabulary growth.

If infants can learn to attend to function for object naming and generalisation, then the function-training group, and not the control group, should base their word generalisations on function, in both the first- and second-order generalisation tasks. If function-training has an impact beyond the lab-based context where training occurred, then it should boost real-world vocabulary growth. I also predicted that the function-training group would acquire more nouns than the control group because the training focused on teaching object names. Given the similar challenge of mapping nouns to object functions and verbs to actions, teaching infants that objects with the same functions (i.e. actions) have the same name might promote a general understanding that words can refer to actions. Therefore, a function training might boost verb learning outside the laboratory. Consequently, I also predicted that the function-training group would acquire more verbs than the control group.

2.2 Method

2.2.1 Power Analysis

Two power analyses were conducted to determine the study's sample size using G*Power version 3 (Faul, Erdfelder, Lang, & Buchner, 2007). The first power analysis was based on the study conducted by Ware and Booth (2010). First, the effect size of the proportion of correct responses of the first block of their second-order generalisation task was calculated. The means and standard deviations (Group 1: $M = 0.53$, $SD = 0.23$, Group 2: $M = 0.33$, $SD = 0.13$) showed an effect size of 1.07 (Cohen's d). With this effect size, a sample size of 24 infants was estimated with an error probability of 0.05 and a power of 0.80.

The second power analysis was based on the study conducted by Smith and colleagues (2002). First, the estimated effect size of the difference in the number of nouns produced at the end of the study between groups was calculated. It was an estimated calculation as the results provided by Smith and colleagues (2002) did not specify all the information required. The estimated means and standard deviations of both groups produced an estimated effect size of 0.71 (Cohen's *d*). This effect size was then converted to Cohen's *f* following the formula suggested by Cohen (1988). This was done as we were interested in the number of participants required for a repeated measures design and not only in the difference between two means. With the effect size of 0.35, we estimated a sample size of 18 participants with an error probability of 0.05 and a power of 0.80.

2.2.2 Participants

Infants were recruited from Birmingham and surrounding areas through community groups, playgroups, as well as databases of the Infant and Child Lab at the University of Birmingham and the Warwick Research with Kids Group at the University of Warwick. The final sample included 24 typically developing 17-month-old infants, who were randomly assigned to one of two groups: function-training group (4 girls, M = 17 months, 11 days; range: 17 months, 1 day – 17 months, 28 days) and control group (7 girls, M = 17 months, 10 days; range: 17 months, 2 days – 17 months, 27 days). The two groups did not differ in age ($t(22) = 0.25$, $p = .799$, 95% CI = [-.21, .21]), or socioeconomic status ($t(22) = 1.92$, $p = .067$, 95% CI = [-.00, .27]) (for Participant Characteristics, see Table 2.1). All of the participants were born full-term (after 37 weeks of gestation) and were all monolingual English native speakers with no history of hearing difficulties or language delays (as reported by their parents). Six additional infants were excluded from the analysis because they either did not complete the study (n = 5) or were exposed to an additional language at home (n = 1).

The Ethical Committee of the University of Birmingham approved the study. Before the start of the study, all parents provided written consent. The parents were reimbursed for their travel expenses, and the infants received a sticker during each lab visit and a book and a "Junior Scientist" diploma at their final visit.

Table 2.1 *Participant Characteristics*

	Function-training group			Control group		
	n	***M***	***SD***	***n***	***M***	***SD***
Age at start of the study (months)		17.38	0.30		17.35	0.26
Gender						
Male	8			5		
Female	4			7		
Age of first word (months)		11.28[a]	2.42		11.62[a]	3.33
Parent 1 education		3[b]			2.5[b]	
Parent 2 education		3[b]			2.5[b]	
Family income class		4[c]			4[c]	
SES score		0.82[c]	0.12		0.69[c]	0.19

Note. a. Parents did not provide information for 5 participants in the training group and 4 in the control group. b. Parent education was measured on a 4-point scale (1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education). c. Income was measured on a 4-point scale (1= less than £14,000, 2 = £14,001 - £24,000, 3 = £24,001 - £42,000, 4 = more than £42,000). d. For more information on how the SES score was calculated, see section 2.2.2.1 Socioeconomic Status Calculation.

2.2.2.1 Socioeconomic Status Calculation. Participants' socioeconomic status was calculated by computing the mean of parents' education score, parents' occupation score, and household income score. See below for more information on how each score was calculated. Note that in one case socioeconomic status was based only on parents' education and parents' occupation because household income was not reported.

2.2.2.1.1 Parent Education. A 4-point scale was used to determine each parent's education, with 1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education. The average education score of both parents was calculated and then converted to a value between 0 to 1.

2.2.2.1.2 Parent Occupation. Occupation of all parents was classified using the nine levels of the Office for National Statistics - Standard Occupational Classification Hierarchy (Standard Occupational Classification (SOC), 2010) and each parent was assigned a score from 1 to 9, where 9 was the highest value and 1 the lowest. The average score of both parents was calculated, apart from families with a stay at home parent, for which the occupation score was based only on the parent that worked in paid employment. This score was then converted to a value between 0 and 1.

2.2.2.1.3 Household Income. Income was measured on a 4-point scale (1 = less than £14,000, 2 = £14,001 - £24,000, 3 = £24,001 - £42,000, 4 = more than £42,000). This score was then converted to a value between 0 and 1.

2.2.3 Procedure

All of the participants were individually assessed at the Infant and Child Lab at the University of Birmingham. The study took place over nine weekly visits divided into three stages: initial assessments (Week 1), training sessions (Weeks 1 to 7), and final assessments (Weeks 8 and 9). The same initial and final assessments were used for both participant groups, but the training differed.

Table 2.2 *Timeline of Assessments*

Week 1	Week 2 to Week 7	Week 8 and 9
• Initial Assessments - Socioeconomic and general development questionnaire - Vocabulary checklist - Sorting task - Attention task • Training sessions	• Training Sessions	• Final assessments - First-order generalisation task - Second-order generalisation task - Vocabulary checklist

2.2.3.1 Initial Assessments. At Week 1, the parents of all the infants filled in a vocabulary checklist and a socioeconomic and general development questionnaire. During this visit, the participants were also introduced to a sorting task and an attention task to ensure that groups did not differ in their attention or their abilities to pick up function similarities of objects.

2.2.3.1.1 Vocabulary Checklist. The parents filled in the UK Communicative Development Inventory: Words and Gestures (Alcock, Meints, & Rowland, 2017). This vocabulary checklist was used to assess receptive and expressive vocabulary at the start of the study.

2.2.3.1.2 Socioeconomic and General Development Questionnaire. The parents of all participants filled in a socioeconomic and general development questionnaire which was used to gather information about the infant's general development, the infant's family and their socioeconomic status (see Appendix 1). This questionnaire was also informative concerning the eligibility criteria for the study (e.g., it identified whether there was a history of a language delay and also that English was the only language used at home).

2.2.3.1.3 Sorting Task. The participants in both groups were introduced to the same sorting task. This task had the main aims of assessing participant's ability to pick up function similarities and assessing any differences between groups. In this task, infants were presented with two sets of eight objects (16 in total). The objects were either red or green and had one of two novel shapes (see Figure 2.1). One set of objects was made of wax (could be used to draw) and one of clay (could not be used to draw). The objects were mixed and placed on a table in front of the child, along with a paper sheet and two containers. The researcher started the task by saying "*We are going to play a game; we are going to put together the objects that are the same".* Then the researcher took one of the objects made of wax and said: *"Look, this one can be used to draw"* while the researcher drew on the paper with the object demonstrating its function. Then, the researcher placed the object in one container while saying: *"This one goes here"*. The researcher then picked up one of the clay objects (which could not be used to draw) and that had the same shape and colour as the wax object, tried to draw with it and said: "*Oh no, look this one cannot be used to draw"*, and placed it in the other container while saying: *"So this one goes here".* The researcher demonstrated how to sort two more objects and said: *"Now it is your turn, can you help me put the objects that are like these ones (pointing to one container) here, and the objects that are like these ones (pointing to the other container) here?"*. Participants sorted 12 objects themselves, and the task lasted around 5 minutes.

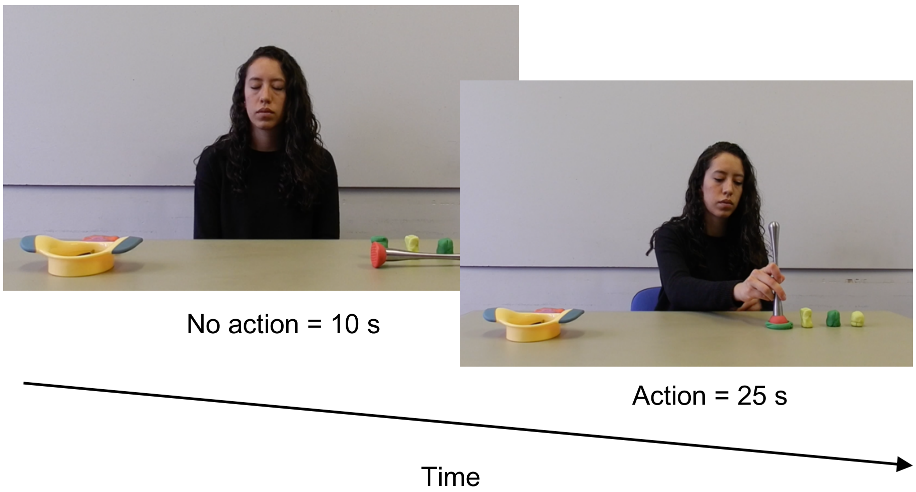
Figure 2.1 *Sorting Task Objects*

Note. All objects were either red or green, and of one of two possible shapes. One set of objects (left) was made of wax and could be used to draw. One set (right) was made of clay and could not be used to draw.

2.2.3.1.4 Attention Task. An attention task was conducted with all participants at the start of the study to assess joint and sustained attention, and to ensure that attention abilities did not differ between groups. In this task, participants sat on their parent's lap at approximately 60 cm away from a monitor. An eye-tracker (EyeLink 1000) located underneath the monitor recorded infants' looking times during this task. Before the start of the task, a 9-point calibration sequence was presented to all participants. During the calibration, a happy face was shown accompanied by a *beep* on nine different sections of the monitor (left-top, centre-top, right-top, left-centre, centre, right-centre, left-bottom, centre-bottom and right-bottom) in random order.

The attention task consisted of 5 video clips. Each video lasted 35 seconds and showed a person performing a simple action with an unusual object on the right or left side of the screen. On the opposite side of the action, a static distracting object was visible (see Figure 2.2). For the first 10 seconds, no object was moved. For the next 25 seconds, the target object was moved and used to perform an action (e.g., a mango splitter was used to cut Play-Doh). On each of the five videos, different objects and actions were used. A 3-s attention grabber was introduced after each video. The presentation order of all videos was randomised for each participant. The side on which the function was performed was counterbalanced across participants.

Figure 2.2 *Still Frames of a Video From the Attention Task.*



Note. For the first 10 seconds, no object was moved. For the next 25 seconds, the target object was used to perform an action.

2.2.3.2 Training.

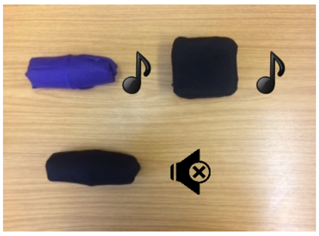
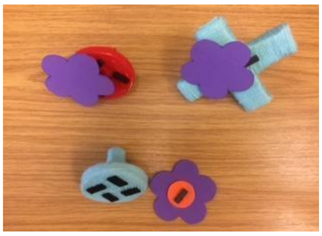
2.2.3.2.1 Function-training Group. Infants in the function-training group were taught four novel words (*kiv, pisk, dax, zav*). Each word was introduced with a set of three novel objects: two referent exemplars that shared the same name, and one contrasting object that did not share the name. The two referent exemplars also shared the same function with each other but differed in both colour and shape. The contrasting object did not share the same function as the referent exemplars but shared the same colour with one of the exemplars and the same shape with the other exemplar (see Figure 2.3). All of the objects were made from materials such as clay, cloth, or plastic and each set of exemplars performed different functions. *Kivs* were used to cut Play-Doh, *daxes* were used to pick up flowers with magnets, *pisks* made noises when shaken, and *zavs* were used to create a pattern on Play-Doh when pressed on it. Note that the objects' functions were not strongly correlated with their shapes.

Infants were presented with each set of objects in a play-like manner for 3 minutes each (total time of each training session was 12 minutes), and the presentation order of all four sets was randomised across participants. The experimenter first presented one exemplar while saying, for example, *"Look it's a kiv and can cut Play-Doh",* and demonstrated the function. Then, the second exemplar was presented with a similar sentence (e.g. *"Look, this is also a kiv and can cut Play-Doh"*). The experimenter also demonstrated each function while explaining it. Halfway through the presentation of each set (after about 1.5 minutes), the contrasting object was presented. The experimenter tried to perform the same function as the two exemplars and said: "*Oh no, this is not a kiv because it cannot cut Play-Doh"*. The contrasting object was then taken away, and the experimenter and participant continued playing with the two exemplars. The same procedure was followed with the other three sets of objects. All object names and functions were mentioned and performed between 10 and 20 times per play session.

The same sets of objects were presented for six further weekly training sessions (Weeks 2 to 7), with presentation order of object sets randomised across participants and sessions. Non-functional play occurred in some training sessions, especially in the last training sessions, to maintain infants' interest (e.g. hiding an object and finding it).

2.2.3.2.2 Control Group. Infants in the control group played freely during seven weekly sessions (weeks 1 to 7) with the same stimuli used in the function-training group, including any additional material (e.g. Play-Doh) required to demonstrate the object's function (see Figure 2.3). Object names and functions were not mentioned or shown for this group. As in the function-training group, each play session lasted 12 minutes.

Figure 2.3 *Sets of Objects Used for the Training Sessions*

Set	Description	Set	Description
	Kiv – cuts Play-Doh Contrasting object - cannot cut Play-Doh		Pisk – makes noises Contrasting object – cannot make noises
	Dax – picks up flowers Contrasting object – cannot pick up flowers		Zav – makes small circles on Play-Doh when pressed onto it Contrasting object – cannot make small circles on Play-Doh when pressed onto it

Note. Each set consisted of two referent exemplars that shared the same name and one contrasting object that did not share the name. Object names and functions were not mentioned or demonstrated to the control group.

2.2.3.3 Final Assessments. During weeks 8 and 9, infants from both groups were assessed with the same final assessments (first-order generalisation task and second-order generalisation task) described below. At the last visit, parents filled in the UK-CDI Words and Gestures questionnaire (Alcock et al., 2017).

2.2.3.3.1 First-Order Generalisation Task. At week 8, all participants were assessed with a first-order generalisation task. This task consisted of two practice trials (practice phase) and eight test trials (test phase). The same objects and materials were presented to both groups. The procedure of this task was also identical for both groups.

2.2.3.3.1.1 Practice Phase. Infants were presented with two practice trials to familiarise them with the procedure of the task. In each practice trial, a standard object (a long blue spoon) of a familiar category (spoons) was presented, accompanied with three objects. These objects shared one property each with the standard object (function: a small orange spoon, colour: a blue box, shape: a long brown block with a similar shape as the standard object). The experimenter said *"Look, this is a spoon and can be used to scoop food. Can you give me the other spoon?"*. In a second practice trial, another set of familiar objects with a different function was introduced (a blue ball as an exemplar, and a round rattle, a blue dinosaur and a green textured ball with oval bumps that made it look different than the exemplar). The same procedure as in the first practice trial was followed. In order to move on to the test phase, infants had to correctly choose both target objects (the small orange spoon and green ball). If necessary, both practice trials were repeated until infants responded correctly to both. Most infants chose the target objects during their first attempt. Infants who did not, were shown the correct choice and were presented again with the same trial. One infant from the control group and two infants from the function-training group required two attempts to respond correctly.

2.2.3.3.1.2 Test Phase. The test phase consisted of eight trials; one trial per exemplar used during the training weeks. In each trial, participants were shown one of the training exemplars and were asked to get an object that was called the same from a set of three possible options (see Figure 2.4). Each of the three objects that participants could choose from shared only one property with the training exemplar (shape, colour or function). For each test trial, the experimenter named the familiar training exemplar, explaining and demonstrating the function as during the function training sessions. For instance, "*This is a kiv and can be used to cut Play-Doh"* while demonstrating the function of the *kiv.* The researcher then said: *"now look at these ones"*. After demonstrating in silence whether the three objects to choose from could perform the function of the familiar exemplar, the researcher asked: *"Can you get the other kiv?"*. The eight trials were presented in one of two orders, counterbalanced across participants.

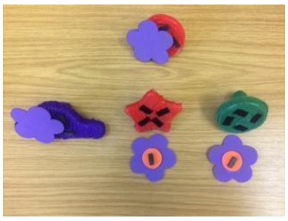
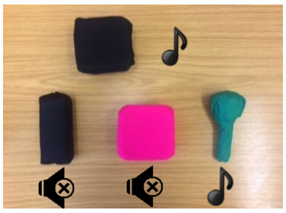
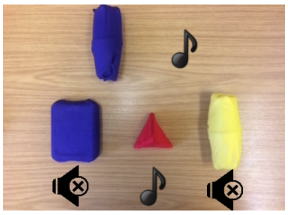
2.2.3.3.2 Second-Order Generalisation Task. At week 9, a second-order generalisation task was introduced, which again consisted of a practice phase and a test phase. Both groups were presented with the same objects and materials, and the procedure was identical for both groups.

2.2.3.3.2.1 Practice Phase. The practice phase was identical to that of the first-order generalisation task in Week 8.

2.2.3.3.2.2 Test Phase. Participants were tested with eight sets of completely new and unfamiliar objects, paired with four novel words and functions that participants had not encountered in the previous weeks (see Figure 2.5). The same procedure as for the first-order generalisation task was followed.

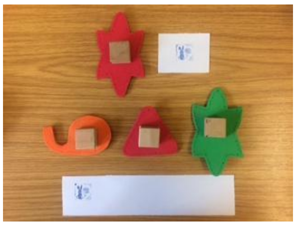
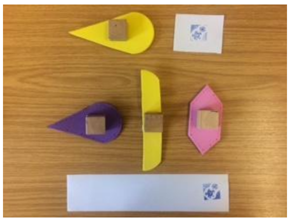
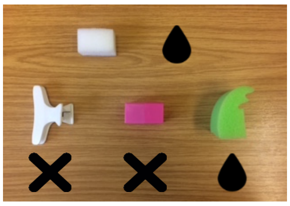
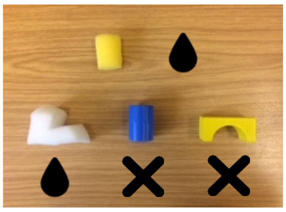
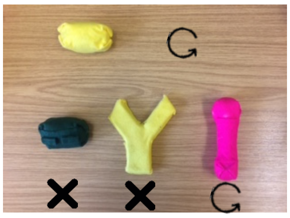
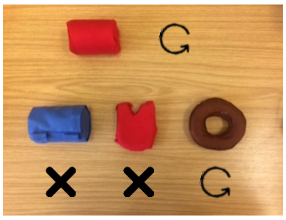
2.2.3.3.3 Vocabulary Checklist. During the last visit (week 9), parents were asked to fill in again the UK-CDI Words and Gestures questionnaire (Alcock et al., 2017) to measure expressive and receptive vocabulary growth over the course of the study.

Figure 2.4 *Sets of Objects Used During the First-Order Generalisation Task (Week 8)*

Trial Set	Description	Trial Set	Description
	Training exemplar – kiv, used to cut Play-Doh Target object: pink triangle		Training exemplar – kiv, used to cut Play-Doh Target object – yellow rectangle
	Training exemplar – dax, used to pick up flowers Target object – purple object		Training exemplar – dax, used to pick up flowers Target object – white object
	Training exemplar – pisk, makes sounds when shaken Target object – green object		Training exemplar – pisk, makes sounds when shaken Target object – red object
	Training exemplar – zav, makes small circles when pressed on Play-Doh Target object – purple object		Training exemplar – zav, makes small circles when pressed on Play-Doh Target object – red object

Note. Each set consisted of one referent object (used during training) and three further objects, with one object matching the standard object by function, one by shape and one by colour. The target object was always the object matching in function.

Figure 2.5 *Sets of Objects Used During the Second-Order Generalisation Task (Week 9)*

Trial set	Description	Trial set	Description
	Exemplar: Gip, used to trace circles on sand. Target object: orange object.		Exemplar: Gip, used to trace circles on sand. Target object: yellow object
	Exemplar: Toma, used to stamp. Target object: orange object		Exemplar: Toma, used to stamp. Target object: pink object.
	Exemplar: Soob, used to absorb water. Target object: green object		Exemplar: Soob, used to absorb water. Target object: white object
	Exemplar: Bosa, used to roll. Target object: pink object		Exemplar: Bosa, used to roll. Target object: brown object

Note. Each set consisted of one referent object and three further objects, with one object matching the standard object by function, one by shape and one by colour. The target object was always the object matching in function. None of the objects, labels, or functions had been used in the study before.

2.2.3.4 Follow up. Six months after finishing the training programme parents were asked to fill in again the UK-CDI (Alcock et al., 2017) to assess long term differences in expressive and receptive vocabulary growth between the function-training group and the control group.

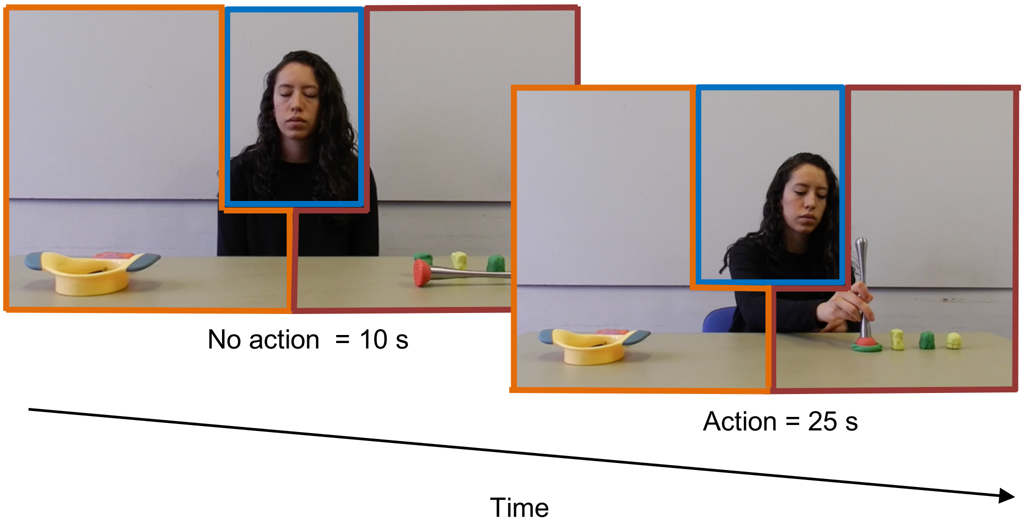
2.2.4 Design and Data Analysis

2.2.4.1 Sorting Task. In order to assess if the participants could pick up function similarities at the start of the study, I calculated the percentage of objects sorted correctly by all participants. Objects were considered as correctly sorted if they were put in the bowl that matched the object's function. A total of 12 objects sorted by function represented 100% of objects sorted correctly. T-tests were used to compare the percentage of objects sorted correctly to chance (chance being 50%) for both groups separately. I then compared the percentage of objects sorted correctly between both groups using a t-test to assess if there was a difference between the performance of the two groups.

2.2.4.2 Attention Task. In order to assess participant's looking behaviour, I conducted two analyses. The first analysis had the main aim of assessing if both groups attend equally to the attention task and if their attention reduced equally over the task. For the first analysis, first, I calculated the total number of seconds each participant looked at each full video. Then, I conducted a 2 (Group: function-training vs control) x 2 (Video: first vs fifth video) analysis of variance (ANOVA) with Group as the between-participants variable and Video as the within-participants variable. In this analysis, the dependent variable was overall looking time to the videos.

The second analysis had the main aim of assessing if both groups looked mainly towards the target object while it was being used to perform a function compared to before any action started. For this, I first divided each video into two different time windows and three regions of interest (ROIs). The two different time windows were the window before the action and the window while the action was performed, with the former lasting the first 10 seconds of the video and the latter 25 seconds. The three ROIs were face ROI, action ROI and distractor ROI (see Figure 2.6).

Figure 2.6 *Example of a How a Video From the Attention Task Was Divided*



Note. Videos were divided into two time windows (before action and during action) and three regions of interest (ROIs) (blue: face ROI, orange: distractor ROI, red: action ROI)

Then, I calculated the proportion of looking times towards the action ROI before action and during action. For example, the proportion of looking times towards the action ROI before the action started was calculated as follows:

$$\frac{\text{mean fixation on action ROI before action}}{(\text{mean fixation on action ROI before action} + \text{mean fixation on distractor ROI before action} + \text{mean fixation on face ROI before action})}$$

An equivalent equation was used to calculate the proportion of looking times towards the action ROI while the novel object was used to perform an action.

To assess if participants in both groups looked more towards the action ROI during the action than before the action, a 2 (Group: function-training vs control) x 2 (Time window: before action vs during action) analysis of variance (ANOVA) was conducted. In this analysis, the dependent variable was proportion of looking times to the action ROI.

2.2.4.3 First- and Second-Order Generalisation Tasks. For the first-order generalisation task, I first calculated the percentage of function, shape, and colour choices. A choice was counted as a function choice if the chosen object shared the same function with the referent object. A choice was counted as a shape choice if the selected object shared the same shape with the referent object. A choice was counted as a colour choice if the object shared the same colour with the referent. The total number of trials was 8. However, the total number of choices differed across participants because some choices were invalid. Three participants had a total number of 7 because on one trial they chose more than one object.

To assess if the participants preferred generalising labels by a specific property, I then analysed the percentage of choices for each property (function, shape, or colour) separately. First, comparisons between the percentage of function choices against chance (change being 33.33% as participants had to choose one of three options) and between the two groups (function-training group vs control group) using t-tests were conducted. The same comparisons were made for the remaining two properties (shape and colour). Separate t-tests were used instead of an analysis of variance (ANOVA) because the percentage of shape, colour and function choices added to 100% for all participants and therefore these three measurements were not independent from each other.

For the second-order generalisation task, I conducted the same analyses as the ones for the first-order generalisation task.

2.2.4.4 Vocabulary Growth. The children's receptive and expressive vocabulary growth over the course of the study were assessed separately. For the expressive vocabulary, three different analyses were conducted. The first analysis had the main aim of assessing the increase in expressive vocabulary size over the course of the study between both participant groups. For this, I first calculated the total number of words parents reported at the start of the study and at the end of the study. Afterwards, a 2 (Group: function-training vs control) x 2 (Testing time: total expressive vocabulary before and total expressive vocabulary after) analysis of variance (ANOVA) was conducted. For this analysis, the between-participants factor was Group, and the within-participants factor was Testing time. The dependent variable was the total expressive vocabulary at each testing time.

For the second analysis, I ran a regression analysis. The main aim of this analysis was to assess if the group participants were in (function-training or control) had an effect on vocabulary size at the end of the study, but also to assess if the number of words participants produced at the start of the study also had a significant effect on expressive vocabulary size at the end of the study. In this regression analysis the outcome variable was Expressive vocabulary at the end of the study, and the predictors were Group and Expressive vocabulary at the beginning of the study.

The third analysis had as main aim to assess if there were any differences in the increase of specific types of words between groups. For this analysis, first, I divided the total number of words into three categories: nouns, verbs, and other words. For the word type *nouns*, words in the following categories of the UK-CDI (Alcock et al., 2017) were included: animal words, vehicle words, words for toys, food and drink words, words for body parts, words for clothes, words for small household items, words for people, 17 items from furniture words, and 19 items from outside words. For the word type *verbs*, all words from the category action words were included. For the *other words* category, words that were not in the noun or verb category were included. The word type *nouns* was selected as participants in the function-training groups were taught names of objects. The word type *verbs* was selected because highlighting the importance of functions (i.e. actions) for object naming, might promote a general understanding that words can refer to actions (i.e. verbs). To investigate if there was a difference in the growth of a particular word type between participants, I conducted a 2 (Group: function-training group vs control group) x 2 (Testing time: before vs after training) x 3 (Word type: nouns, verbs or other words) ANOVA. Group was the between-participants variable, and Testing time and Word type were within-participants variables. The dependent variable was the number of words produced. The same two analyses were conducted for the receptive vocabulary.

2.2.4.5 Follow up. To assess the long-term differences in vocabulary growth of the training programme, expressive and receptive vocabulary after six months as reported by participants' parents was gathered. For the follow up, only ten participants of the function-training group and five of the control group were included. The parents of the other nine participants did not respond to the follow-up invitation. Due to this high attrition rate, vocabulary size after six months was analysed separately from vocabulary at the beginning and end of the 9-week intervention programme.

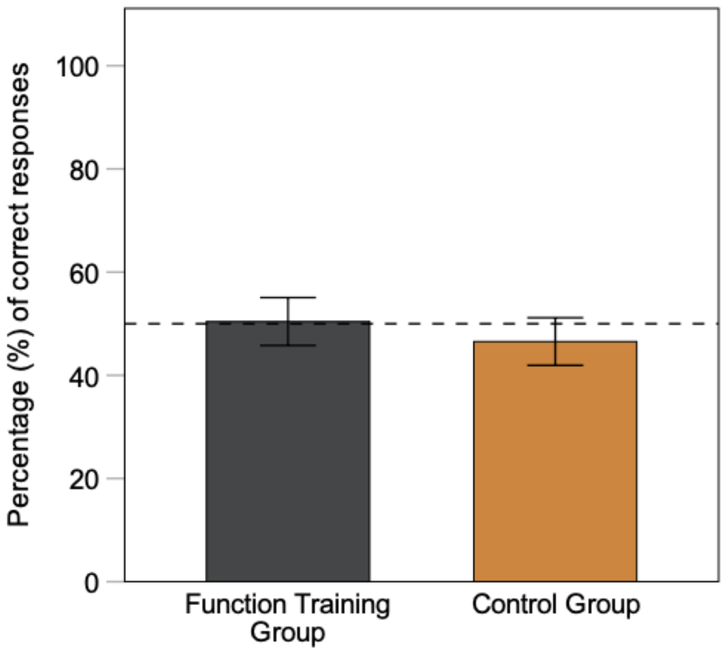
For expressive vocabulary, first, the total number of words produced by participants was calculated and compared between groups using a t-test to assess if there were any group differences in the size of their expressive vocabulary. Afterwards, all of the words were divided into three categories (nouns, verbs and other words) as in Section 2.2.4.4. To investigate if there was any difference in the number of words of a particular word type between groups, I conducted a 2 (Group: function-training group vs control group) x 3 (Word type: nouns, verbs or other words) ANOVA. Group was the between-participants variable, and Word type was the within-participants variables. The dependent variable in this analysis was the number of words produced six months after the intervention. The same two analyses were conducted for receptive vocabulary after six months as reported by the participants' parents.

2.3 Results

2.3.1 Sorting Task

The participants' sorting choices were analysed to assess if participants could pick up function similarities and sort objects by this property at the start of the study. The function-training group sorted objects by function in 50.41% of the trials (SD = 7.30), which did not differ significantly from chance (chance being 50%), $t(11) = 0.19$, $p = .847$, 95% CI = [-4.22, 5.05]. The control group sorted objects by function in 46.53% of the trials (SD = 7.25), which also did not differ significantly from chance, $t(11) = -1.65$, $p = .127$, 95% CI = [-8.07, 1.15]. A comparison between groups revealed no significant difference between groups, $t(22)= 1.30$, $p = .206$, 95% CI = [-2.28, 10.04]. The results showed no evidence to indicate that sorting choices in both groups differed reliably from chance or between groups (see Figure 2.7). Thus, the participants in both groups did not pick up function similarities and did not sorted objects by function similarities in this task.

Figure 2.7 *Percentage of Correct Responses in the Sorting Task for Both Participant Groups*



Note. The dotted line represents chance level (50%). Error bars represent 95% CIs of the means.

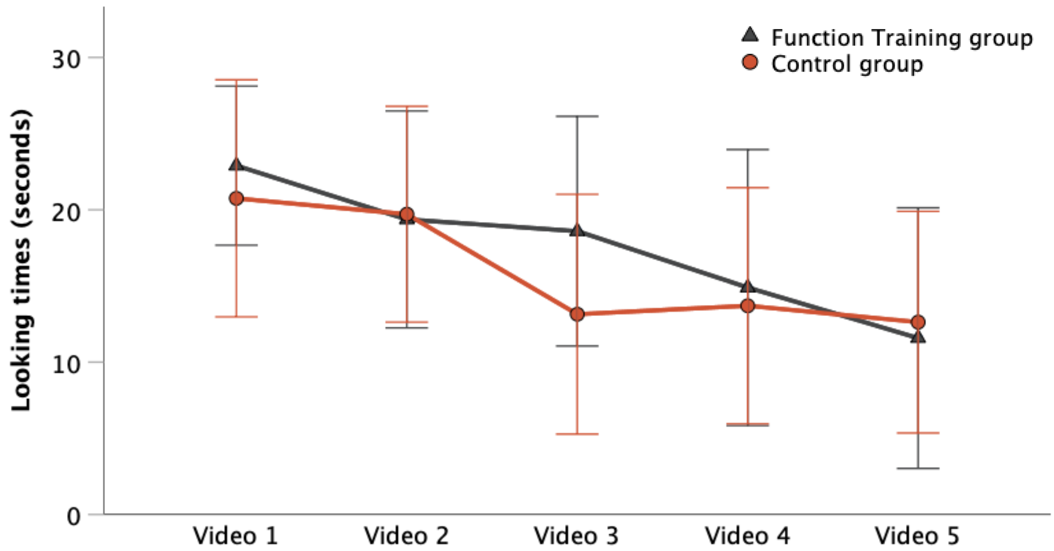
2.3.2 Attention Task

Two participants (one from the control group and one from the function-training group) were removed from the analyses of the attention task as they did not look to any of the five videos.

To assess whether both groups attended equally to the attention task and whether their attention declined equally over the task, the total looking times at the beginning and end of the task were calculated (see Figure 2.8). Participants in the function-training group looked to the first video on average for 22.89 seconds (*SD* = 7.77) and to the fifth video for 11.57 seconds (*SD* = 12.72). Participants in the control group looked on average for 20.74

seconds (*SD* =11.57) to the first video and 12.62 seconds (*SD* = 10.82) to the last video. A 2 (Group: function-training vs control) x 2 (Video: first vs fifth video) ANOVA revealed that there was no significant main effect of Group, $F(1, 20) = 0.01$, $p = .893$, $\eta_p^2 = .00$, neither was the interaction between Group and Video, $F(1, 20) = 0.48$, $p = .495$, $\eta_p^2 = .02$, but the main effect of Video was significant, $F(1, 20) = 17.94$, $p < .001$, $\eta_p^2 = .47$. Thus, both participant groups looked significantly less towards the last video compared to the first video, and this reduction in looking times was similar for both groups.

Figure 2.8 *Looking Times Towards all Videos Across the Two Groups*



Note. Error bars represent 95% CIs. Both participant groups looked less towards the end of the task compared to the first video.

The proportion of looking times to the action ROI before and during action was compared to assess at which time window participants looked more to the action ROI, and to assess if there was any difference between groups. Participants in the function-training group looked more towards the action ROI during movement than before movement started (M_{before} = 0.16, SD_{before} = 0.07; M_{during} = 0.72, SD_{during} = 0.11). Participants in the control group also looked more towards the action ROI during movement than before movement started (M_{before} = 0.17, SD_{before} = 0.09; M_{during} = 0.66, SD_{during} = 0.25). This was confirmed by a 2 (Group: function-training vs control) x 2 (Time window: before vs during action) ANOVA, which showed a main effect of Time window, $F(1, 20) = 157.06$, $p < .001$, $\eta_p^2 = .88$, but no main effect of Group, $F(1, 20) = 0.24$, $p = .625$, $\eta_p^2 = .01$, nor an interaction between Group and Time window, $F(1, 20) = 0.74$, $p = .399$, $\eta_p^2 = .03$[1]. These results suggest that participants looked significantly more to the target object when it was used to perform an action and this was similar for both groups. Thus, participants' attention patterns were similar in both groups.

2.3.3 First-Order Generalisation

In order to assess participants' preference for generalising known objects by a specific property, the percentage of function, shape and colour choices in the first-order generalisation task were analysed. The left panel of Figure 2.9 shows the results of the first-order generalisation task. With a Bonferroni adjusted alpha level of .016 per comparison (.05/3), results showed that the function-training group generalised the trained labels on the basis of function significantly more often than chance (M = 57.44%, SD =

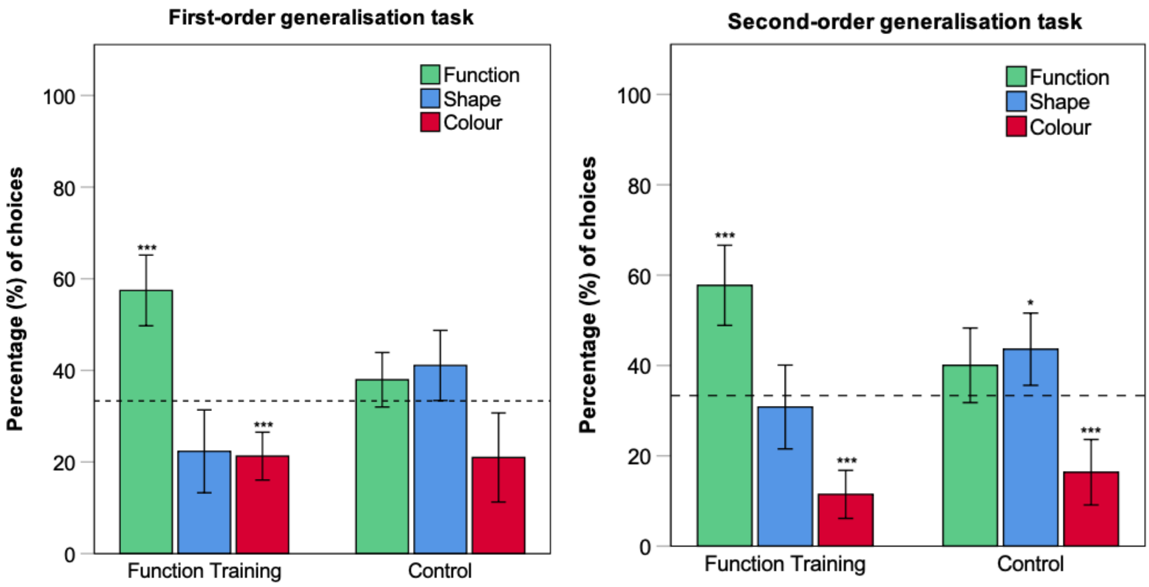
[1] Additional analyses were conducted to compare if participants looked longer towards the action ROI than the other two ROIs before and while the action was being performed. Results showed participants in both groups looked significantly more towards the face ROI before action started, and looked significantly more towards the action ROI while the action was being performed compared to the rest of the ROIs. See Appendix 2.

12.15, $t(11) = 6.87$, $p < .001$, 95% CI = [16.38, 31.83]), while their generalisations based on shape similarities were at chance level, ($M = 22.32\%$, $SD = 14.23$, $t(11) = -2.67$, $p = .021$, 95% CI = [-20.05, -1.96]). In contrast, the control group generalised object labels on the basis of function at chance level ($M = 37.94\%$, SD = 9.36, $t(11) = 1.70$, $p = .116$, 95% CI = [-1.33, 10.56]), and showed a trend towards significance in their generalisations by shape ($M = 41.07\%$, $SD = 12.03$, $t(11) = 2.22$, $p = .048$, 95% CI = [.09, 15.39]). Generalisations on the basis of colour were significantly below chance in the function-training group ($M = 20.23\%$, $SD = 8.49$, $t(11) = -5.34$, $p < .001$, 95% CI = [-18.48, -7.69]), and at chance level in the control group ($M = 20.98\%$, $SD = 15.30$, $t(11) = -2.79$, $p = .017$, 95% CI = [-22.07, -2.62]). Importantly, with a Bonferroni adjusted alpha level of .025 (0.05/2), infants in the function-training group generalised object names based on function significantly more often than the control group, $t(22) = 4.40$, $p < .001$, 95% CI = [10.30, 28.67], while they generalised object names on shape significantly less often than the control group, $t(22) = -3.48$, $p = .002$, 95% CI = [-29.91, -7.58]. Thus, participants in the function-training group generalised labels in the first-order generalisation task mainly by function, while the control group showed a trend towards generalising by shape.

2.3.4 Second-Order Generalisation

In order to assess if participants showed a preference for generalising novel objects by a specific property, the percentage of function, shape and colour choices in the second-order generalisation task were analysed. The right panel of Figure 2.9 shows the results of the second-order generalisation task. With a Bonferroni adjusted alpha level of .016 per comparison (.05/3), results showed that the function-training group generalised labels based on function significantly more often than chance ($M = 57.73\%$, $SD = 13.96$, $t(11) = 6.05$, $p < .001$, 95% CI = [15.53, 33.28]), while their generalisations based on shape were not significantly different from chance (*M* = 30.80% , *SD* = 14.60, *t*(11) = -0.59, *p* = .561, 95% CI = [-11.80, 6.75]). In contrast, the control group generalised labels on the basis of function at chance level (*M* = 40.03%, *SD* = 12.99, *t*(11) = 1.78, *p* = .102, 95% CI = [-1.55, 14.95]), while their generalisations based on shape were significantly above chance (*M* = 43.60%, *SD* = 12.59, *t*(11) = 2.82, *p* = .016, 95% CI = [2.27, 18.27]). As in the first-order generalisation task, choices on the basis of colour were significantly below chance for both groups (function-training group: *M* = 11.45%, *SD* = 8.35, *t*(11) = -9.06, *p* < .001, 95% CI = [-27.18, -16.56]; control group: *M* = 16.36%, *SD* = 11.41 *t*(11) = -5.14, *p* < .001, 95% CI = [-24.21, 9.70]). Results also showed that, with a Bonferroni adjusted alpha level of .025 (0.05/2), infants in the function-training group generalised novel labels on the basis of function significantly more often than the control group, *t*(22) = 3.21, *p* = .004, 95% CI = [6.28, 29.13], while they generalised based on shape similarly to the control group, *t*(22) = -2.29, *p* = .031, 95% CI = [-24.34, -1.25]. Thus, participants in the function-training group generalised novel labels mainly by function. In contrast, participants in the control group showed a preference for generalising labels by shape, but this was not significantly different to the percentage of shape choices in the function-training group.

Figure 2.9 *Percentage of Function, Shape, and Colour Responses in the First and Second-Order Generalisation Tasks*



Note. *Dotted lines represent chance level (33.3%). Asterisks indicate significant differences from chance (* $p \leq .05$, ** $p \leq .01$, ***$p \leq .001$). Error bars represent 95% CIs of the means.*

2.3.5 Vocabulary Growth

2.3.5.1 Expressive Vocabulary. Expressive vocabulary size at the start and end of the study were analysed to assess the effects that the intervention had in vocabulary capacity at the end of the study. At the start of the study, participants in the function-training group produced on average a total of 56.08 words (*SD* = 59.72), while participants in the control group produced on average a total of 44.50 words (*SD* = 49.72). At the end of the study participants in the function-training group produced on average a total of 136.41 words (*SD* = 103.61), while participants in the control group produced on average a total of 103.58 words (*SD* = 71.43). A 2 (Group: function training vs control) x 2 (Testing time: before and after) analysis of variance showed that there was a significant main effect of

Testing time $F(1, 22) = 58.211$, $p < .001$, $\eta_p^2 = .72$, but no significant main effect of Group $F(1, 22) = 0.59$, $p = .448$, $\eta_p^2 = .02$, or interaction between Testing time and Group $F(1, 22) = 1.35$, $p = .257$, $\eta_p^2 = .05$. Thus, both groups had a similar increase in their expressive vocabularies.

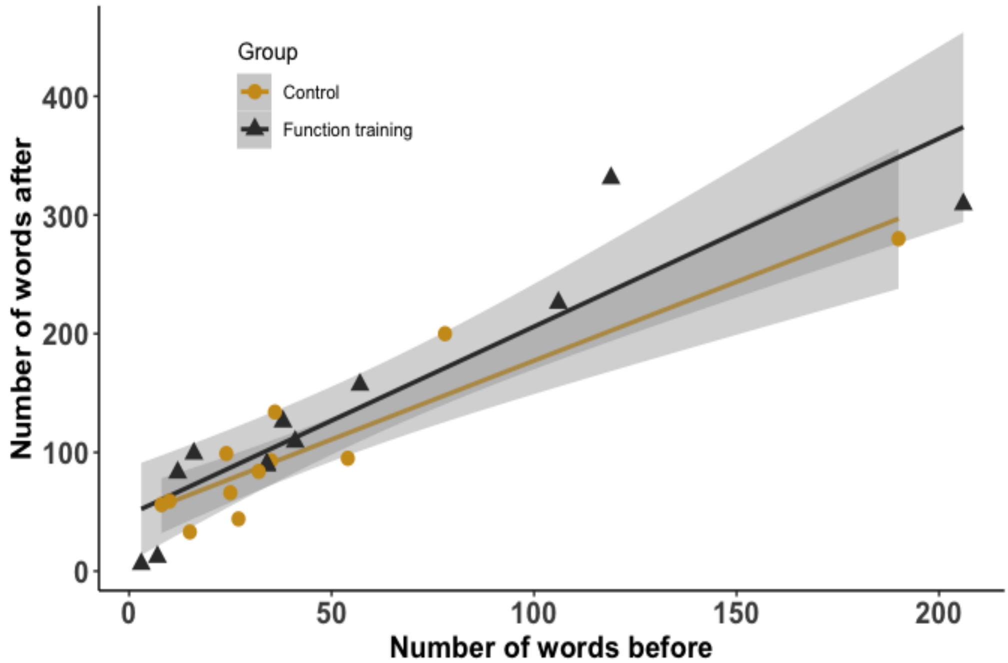
A further regression analysis was conducted to assess if the group participants were in (function-training or control) and the expressive vocabulary size at the start of the study could predict overall expressive vocabulary capacity at the end of the study. Results showed a significant effect of expressive vocabulary at the start of the study ($p < .001$). No significant effect of Group or interaction between the Expressive vocabulary before the start of the study with Group was found (see Table 2.2 and Figure 2.10). Thus, the final number of words the participants produced was only predicted by the initial number of words produced, and no other variables played a significant role in this.

Table 2.3. *Summary of Regression Model Predicting Expressive Vocabulary at the End of the Study*

	Estimate	**SE**	**t value**	***p***
Intercept	27.60	8.97	3.074	.005
Group	12.82	12.60	1.018	.321
Expressive Vocabulary Before	1.46	0.23	6.26	< .001***
Group * Expressive Vocabulary Before	-0.24	0.27	-0.86	.395

Note. $^*p \leq .05$, $^{**}p \leq .01$, $^{***}p \leq .001$

Figure 2.10 *Regression Analysis Predicting Expressive Vocabulary at the End of the Study*



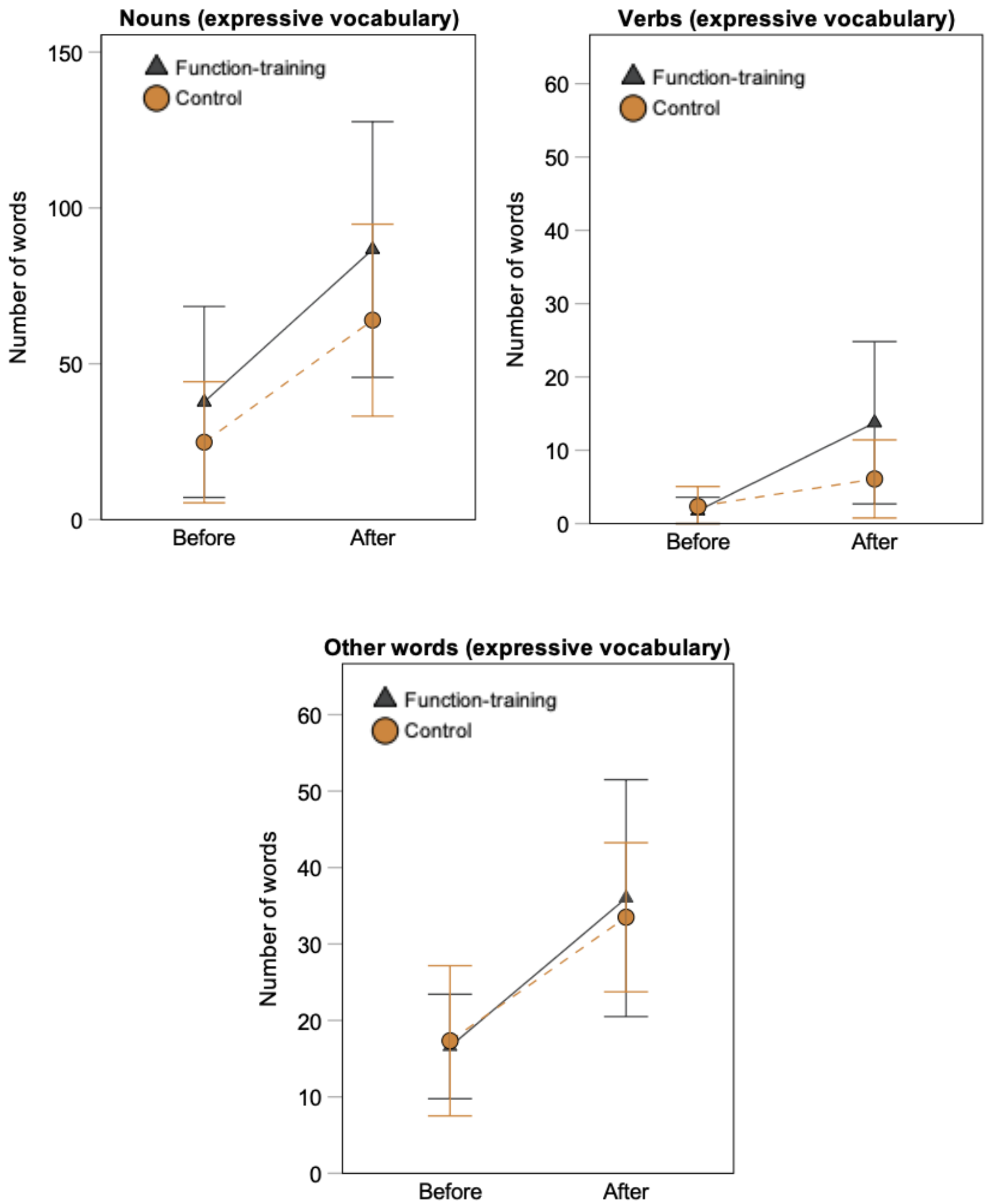
Note. Number of words in participants' expressive vocabulary at the end of the intervention, predicted by the number of words at the beginning of the intervention and the participant group (function-training vs control).

Finally, I examined whether there was any difference between groups in the increase of a particular word type (nouns, verbs, and other words) at the end of the study. Figure 2.11 shows the nouns, verbs and other words produced before and after the training programme, according to parents' responses on the UK-CDI (Alcock et al., 2017). Results of a 2 (Group: function-training and control group) x 2 (Testing time: before and after) x 3 (Word type: nouns, verbs and other words) ANOVA showed a significant main effect of Testing time $F(1, 22) = 58.21$, $p < .000$, $\eta_p^2 = .72$, and Word type $F(2, 44) = 28.67$ $p < .000$, $\eta_p^2 = .56$, on infants' productive vocabulary. No significant main effect of Group $F(1, 22)$

= 0.59 , $p = .448$, $\eta_p^2 = .02$, interaction between Testing time and Group $F(1, 22) = 1.35$, $p = .257$, $\eta_p^2 = .05$, or interaction between Word type and Group, $F(2, 44) = 1.05$, $p = .358$, $\eta_p^2 = .04$ were found. However, results showed a significant interaction between Word type and Testing time, $F(2, 44) = 57.93$, $p < .000$, $\eta_p^2 = .72$. Finally, there was no significant three-way interaction between Group, Testing time, and Word type, $F(2, 44) = 0.48$, $p = .622$, $\eta_p^2 =.02$.[2] A post-hoc comparison of the three word types revealed that participants learned significantly more nouns ($M = 44.04$, $SD = 25.82$) than verbs ($M = 7.88$, $SD = 12.04$) $t(23) = 8.74$, $p < .001$, 95% CI = [27.61, 44.73], and more nouns than other words ($M = 17.79$, $SD = 12.20$) $t(23) = 6.57$, $p < .001$, 95% CI = [17.98, 34.51]. Results also showed that participants learned more other words than verbs $t(23) = -6.54$ $p < .001$, 95% CI = [-13.04, -6.78]. Thus participants, in both groups had a similar increase in their expressive vocabulary, with nouns being the category where they acquired more words, followed by other words and then verbs. However, a higher increase of nouns is not surprising, as this is the category of words infants learn the most at this age.

[2] One additional analysis was conducted to assess the difference in expressive vocabulary growth between the two participant groups for nouns in the UK-CDI that refer to objects for which function plays an important role compared to nouns that are not function-based in the same way. Results showed that both participant groups had a similar vocabulary increase at the end of the study in the function-based noun category and other nouns category. See Appendix 2.

Figure 2.11 *Nouns, Verbs and Other Words Produced Before and After the Training Programme*



Note. *Error bars represent 95% CIs of the means.*

2.3.5.2 Receptive Vocabulary. Receptive vocabulary size at the start and end of the study were analysed to assess the effects that the intervention had in receptive vocabulary capacity at the end of the study. Participants in the function-training group understood on average 190.50 words (*SD* = 79.84) at the start of the study, while participants in the control group understood 171 words (*SD* = 91.94). At the end of the study, participants in the function-training group understood on average 300.16 words (*SD* = 72.21) at the start of the study. Participants in the control group understood 271.16 words (*SD* = 82.24) at the end of the study. The results of a 2 (Group: function training vs control) x 2 (Testing time: before and after) analysis of variance showed a significant main effect of Testing time $F(1, 22) = 89.07$, $p < .001$, $\eta_p^2 = 0.80$, but no significant main effect of Group $F(1, 22) = 0.59$, $p = .45$, $\eta_p^2 = .02$, or interaction between Testing time and Group $F(1, 22) =0.18$, $p = .67$, $\eta_p^2 = .00$**.** Thus, participants in both groups had a similar increase in their receptive vocabulary throughout the intervention programme.

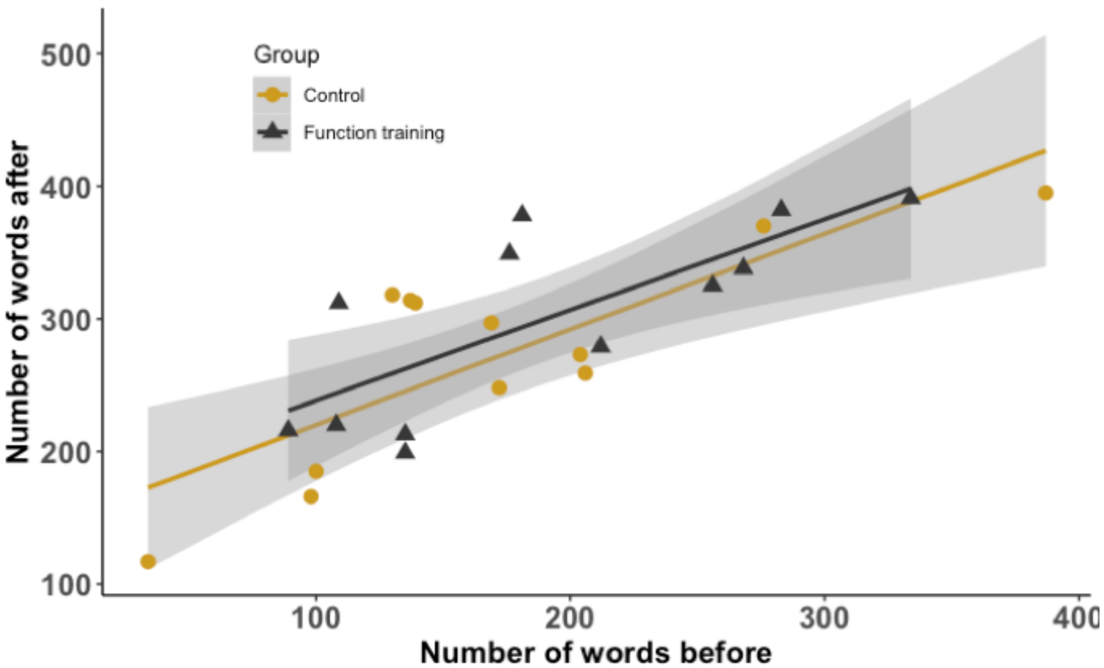
Similarly to expressive vocabulary, a regression analysis was conducted to assess if group (function-training or control) and receptive vocabulary at the start of the study played a significant role on receptive vocabulary at the end of the study. Results showed only a significant effect of the number of words in receptive vocabulary at the beginning of the study ($p < .001$), but no significant effect of Group or interaction between Receptive vocabulary at the start of the study with Group (see Table 2.4 and Figure 2.12). Thus, similar to expressive vocabulary, the final number of words in participants' receptive vocabulary was only predicted by the initial number of words participants had in their receptive vocabulary.

Table 2.4 *Summary of Regression Model Predicting Receptive Vocabulary at the End of the Study*

	Estimate	SE	t value	*p*
Intercept	148.12	31.81	4.65	< .001***
Group	21.89	50.41	0.43	.668
Receptive vocabulary before	0.71	0.16	4.35	<.001***
Group * Receptive vocabulary before	-0.03	0.25	-0.14	.886

Note. * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Figure 2.12 *Regression Analysis Predicting Receptive Vocabulary at the End of the Study*

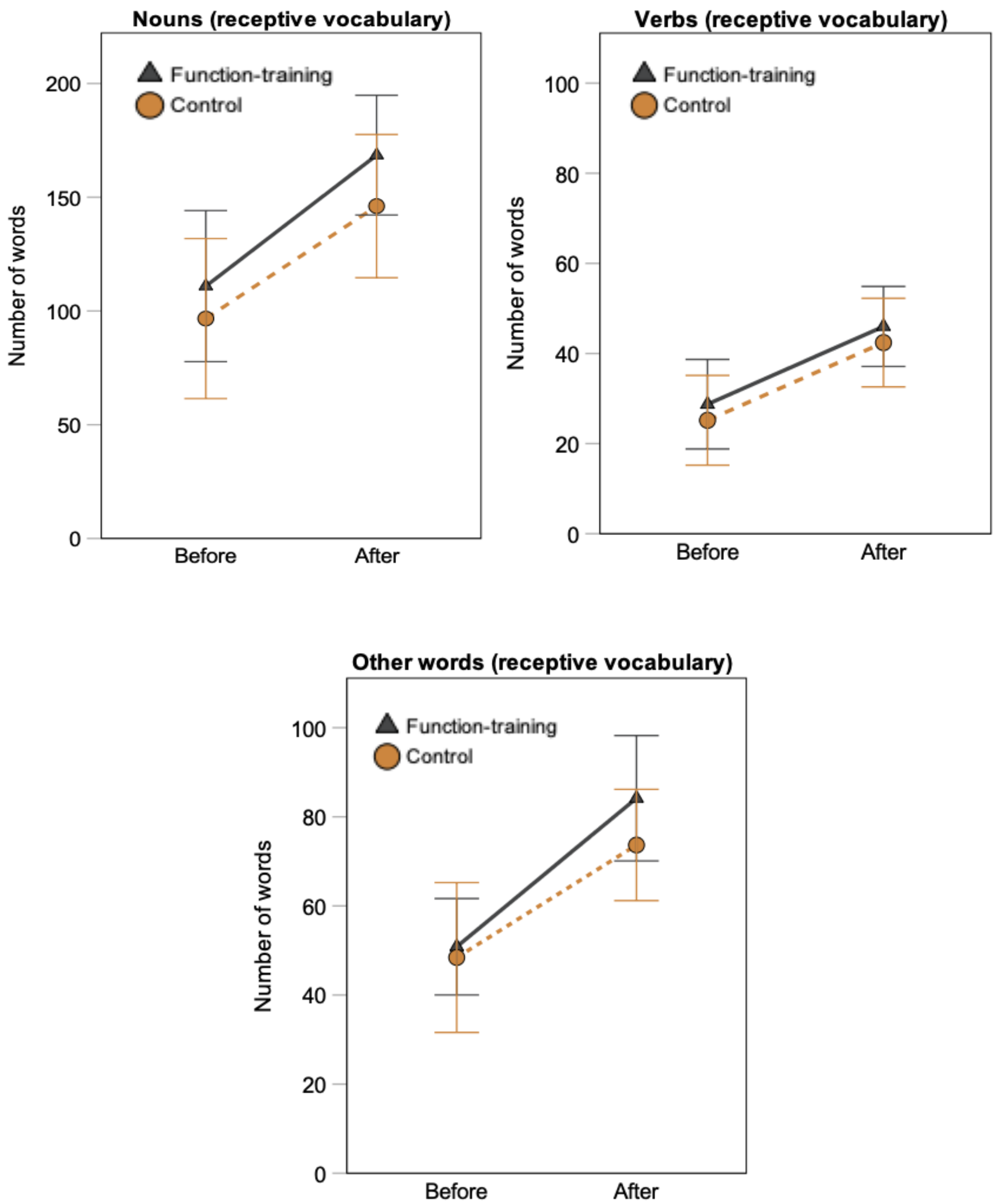


Note. Number of words in participants' receptive vocabulary at the end of the intervention, predicted by the number of words at the beginning of the intervention and the participant group (function-training versus control).

Similarly to expressive vocabulary, a 2 (Group: function-training vs control) x 2 (Testing time: before vs after) x 3 (Word type: nouns, verbs and other words) analysis of variance was conducted to assess if there was any difference in receptive vocabulary at the end of the study on a specific word type across the training study. Figure 2.13 shows the number of nouns, verbs and other words in participants' receptive vocabulary before and after the training programme. Results showed that there was a significant main effect of Testing time $F(1, 22) = 61.52$, $p < .000$, $\eta_p^2 = .73$, and Word type $F(2, 44) = 149.31$, $p < .000$, $\eta_p^2 = .87$, as well as a significant interaction between Word type and Testing time, $F(2, 44) = 17.55$, $p < .000$, $\eta_p^2 = .44$. No significant main effect of Group $F(1, 22) = 0.86$, $p = .363$, $\eta_p^2 = .03$, interaction between Testing time and Group $F (1, 22) = 0.40$, $p = .531$, $\eta_p^2 = .01$, or interaction between Word type and Group $F(2, 44) = 0.96$, $p = .390$, $\eta_p^2 = .04$ were found. Finally, there was no significant three-way interaction between Group, Testing time, and Word type, $F(2, 44) = 0.28$, $p = .676$, $\eta_p^2 = .01$.[3] A post-hoc comparison of the three word types revealed that participants learned significantly more nouns ($M = 53.50$, $SD = 39.88$) than verbs ($M = 17.25$, $SD = 13.61$), $t(23) = 5.13$, $p < .001$, 95% CI = [21.65, 50.85], and that they learned more nouns than other words ($M =29.29$, $SD = 19.85$) $t(23) = 3.33$, $p = .003$, 95% CI = [9.19, 39.21]. Results also showed that participants learned more other words than verbs $t(23) = -3.72$, $p = .001$, 95% CI = [-18.72, -5.35]. Thus participants, in both groups had a similar increase in their receptive vocabulary, with nouns being the category where they acquired more words, followed by other words and then verbs. However, a higher increase of nouns is not surprising, as this is the category of words infants learn the most at this age.

[3] One additional analysis was conducted to assess the difference in receptive vocabulary size at the end of the study between the two groups for nouns in the UK-CDI that refer to objects for which function plays an important role compared to nouns that are not function-based. Results showed that both participant groups had a similar vocabulary increase in the function-based noun category and the other nouns. See Appendix 2.

Figure 2.13 *Nouns, Verbs and Other Words Understood Before and After the Training Programme*



Note. *Error bars represent 95% CIs of the means.*

2.3.6 Follow up

Six months after finishing the study, the participants' parents were asked again to fill in the UK-CDI Words and Gestures questionnaire (Alcock et al., 2017) to assess any long term differences the intervention had in vocabulary learning. Note that out of the initial 24 participants, only the parents of 10 participants (out of 12) from the function-training group and five (out of 12) from the control group filled in the vocabulary checklist. Therefore, results of the follow up should be taken with caution.

2.3.6.1 Expressive Vocabulary. After 6 months of finishing the study, participants in the function-training group produced on average 294.20 words (*SD* = 133.36), while infants in the control group produced on average 344 words (*SD* = 37.63*)*. The difference between the number of words produced was not significant between groups $t(13) = -0.80$, $p = .435$, 95% CI = [-183.40, 83.80].

A comparison between the three word types (nouns, verbs and other words) was also conducted to investigate if there was any difference in any the number of words on each word types between groups six months after the intervention programme. The number of nouns, verbs and other words is reported in Table 2.5. A 2 (Group: function-training group vs control group) x 3 (Word type: nouns, verbs or other words) analysis of variance revealed a significant main effect of Word type $F(2,26) = 162.39$, $p < .000$, $\eta_p^2 = 0.92$, but no main effect of Group $F(1,13) = 0.64$, $p =.435$, $\eta_p^2 = 0.04$, or interaction between Word type and Group $F(2.26) = 0.68$, $p = .513$, $\eta_p^2 = 0.05$. Thus, expressive vocabulary size after six months was similar for both groups.

2.3.6.2 Receptive Vocabulary. After six months of finishing the study, participants in the function-training group understood on average 353.50 words (*SD* = 60.67) while participants in the control group understood on average 383.80 words (*SD* = 10.61). Similarly to expressive vocabulary, a comparison between the three word types (nouns, verbs and other words) was also conducted. The number of nouns, verbs and other words in receptive vocabulary is reported in Table 2.5. A 2 (Group: function-training group vs control group) x 3 (Word type: nouns, verbs or other words) analysis of variance revealed a significant main effect of Word type $F(2,26) = 556.20$, $p < .000$, $\eta_p^2 = 0.97$, but no main effect of Group $F(1,13) = 1.32$, $p = .271$, $\eta_p^2 = 0.09$, or interaction between Word type and Group $F(2,26) = 0.57$, $p = .570$, $\eta_p^2 = 0.04$. Thus, receptive vocabulary size after six months was similar for both groups.

Table 2.5 *Number of Words After Six Months of Finishing the Training*

		Function-training group	**Control group**
Receptive vocabulary	Nouns	195.90 (31.16)	211.40 (10.78)
	Verbs	53.10 (14.58)	59.00 (0.00)
	Other words	104.50 (19.93)	115.20 (3.76)
Expressive vocabulary	Nouns	168.20 (69.22)	194.60 (15.24)
	Verbs	41.70 (24.40)	50.60 (11.19)
	Other words	84.30 (40.46)	98.80 (13.27)

2.4 Discussion

In the current study, 17-month-olds took part in a 7-week function-training that had the main aim of teaching them a function bias. I predicted that participants in the function-training group would generalise familiar (first-order generalisation) and novel labels (second-order generalisations) by function. I also predicted that similarly to Smith and colleagues (2002), the function training would boost expressive and receptive vocabulary growth at the end of the study, and six months after.

This study has two key findings. First, as predicted, infants in the function-training group predominantly generalised familiar (first-order generalisation) and novel (second-order generalisation) object labels based on function. They did so more often than infants in the control group. Thus, 17-month-old infants can be taught a function bias as a successful word learning strategy. Second, a function-training did not boost vocabulary growth outside the laboratory, either after the training or six months later. Note that the results for six months after training was finished are tentative as the number of participants taking part in the follow up was very small, especially in the control group.

2.4.1 Function-training Promotes First- and Second-order Noun Generalisation

The current study extends the word learning literature in three important ways. First, this study is the first to show that infants can learn to attend to function for extending familiar words to novel referents (i.e. first-order generalisation). Successful first-order noun generalisation based on function had previously only been shown in 2- to- 3-year-old children (Diesendruck et al., 2003; Kemler Nelson, Russell, et al., 2000), and had not been reported in all studies with 2- to 5-year-old children (Graham et al., 1999; Landau et al., 1998b). Thus, this study is the first to show this effect in infants. Second, this study shows that infants can use this function-training to learn and generalise novel words never encountered before (i.e. second-order generalisation). Thus, it expands the existing literature by adding function-training for nouns as one of the limited number of strategies that children can use for second-order generalisation: shape-training for nouns (Perry et al., 2010; Samuelson, 2002; Smith et al., 2002), seeing iconic gestures for verbs (Aussems &

Kita, 2020), and experience with the object's function to highlight object's shape (Ware & Booth, 2010). Third and most importantly, results show that at 19 months infants are cognitively ready to use function for word learning. The function training was equivalent in design to the shape training of Smith and colleagues (2002), but while Smith and colleagues (2002) accelerated a bias that infants would have developed around the time of their training or soon after that, we introduced a bias that infants would not have developed until a few years later. This underlines that conceptual difficulty is not the obstacle that prevents young children from developing a function bias.

The finding that infants in the function-training group could use function for word learning and generalisation suggests that infants do not prefer shape over function in word learning (e.g. Hupp, 2015; Kucker et al., 2019; Landau et al., 1998; Perry & Samuelson, 2011) because function is more difficult to perceive or use than shape. Infants seem to develop a shape bias because shape is a more easily accessible property than function. Infants can identify the shape of an object as soon as they see the object (Graham & Poulin-Dubois, 1999) and is stable over time (Gentner, 1982). In contrast, function requires manipulating an object and is mostly transient (Landau et al., 1998b). Furthermore, many of the nouns children acquire early refer to objects with correlated shapes and functions (e.g., spoon). Children can use the highly accessible cue (i.e. object shape) to eliminate erroneous referents for novel labels. Thus, this type of input might naturally lead infants to prefer shape over function for word learning and generalisation.

It is likely that participants in the function-training group were able to learn a function bias because of two main reasons. First, infants were presented consistently with objects organised by function, which tuned infants' attention to the property of the referent objects that older children and adults use for word learning and generalisation. By observing these statistical regularities in the language input, infants learned that function is an important property for object naming and generalisation. Second, it is likely that the function training was successful because function is a relevant property for naming and categorisation of the objects that infants encounter. Note that Samuelson (2002) was not able to teach 15- to 24-month-olds a material bias using a training programme very similar in structure to the current study and that by Smith and colleagues (2002). Only a small number of objects that infants typically encounter are non-solid objects that are from categories organised and named by material (Samuelson, 2002). Therefore, while statistical regularities are important, infants appear only to pick up a bias that is strongly supported by the type of words they are learning.

One limitation of the current study is that it is not possible to know if seven weeks of training were necessary to teach infants a function bias. The first- and second-order generalisation tasks were only administered until weeks 8 and 9. Future studies should test generalisation each week to assess how many training sessions infants require to learn a function bias.

2.4.2 Why Did Function-training Not Promote Vocabulary Growth?

Contrary to findings from Smith and colleagues (2002) for shape-training, the function-training did not boost expressive vocabulary growth outside the laboratory at the end of the study or after six months of the intervention programme. This may be the case because the function bias of the function-training group may not have provided an added benefit for vocabulary growth, above and beyond a potential developing shape bias observed in the control group. Note that children in the control group of Smith and colleagues (2002) did not show a shape bias, but participants in the current study showed a trend towards generalising labels based on shape similarities. Thus, it could be suggested that participants in the control group were already developing a strategy that was boosting their vocabulary growth. This is also shown by the fact that participants in the training group of Smith and colleague's (2002) study showed an increase of 41.4 nouns, which was very similar to the increase observed in our control group (39.17 more nouns). As the shape and function of objects that infants interact with tend to be highly correlated, either shape or function is often sufficient for knowing what an object is and what it is called. For example, spoons consist of a handle and a concave part that is used to eat liquids. Its shape provides information about what the object is and its function. Thus, the taught function bias in the function-training group and the shape bias in the control group may both have been beneficial for vocabulary growth, which may have reduced the difference between the two groups.

In the current study, I also assessed receptive vocabulary growth. However, previous interventions have only assessed expressive vocabulary (Perry et al., 2010; Samuelson, 2002; Smith et al., 2002). Therefore, results cannot be compared to any previous research. However, it seems that the two word learning strategies in the two participant groups (function bias and shape bias) led to the same receptive vocabulary development.

In contrast to the study by Smith and colleagues (2002), children in the current study showed a large variability in the initial number of words in both receptive and expressive vocabulary. Children in the function-training group started with an average 190 words in their receptive vocabulary and on average 56 in their expressive vocabulary. However, their receptive vocabulary ranged from 89 to 334 words and their expressive vocabulary from 3 to 206 words. Similarly, children in the control group started with on average 171 words in their receptive vocabulary with a range of 34 to 387, and with on average 44.50 words in their expressive vocabulary, with a range of 8 to 190 words. Our results suggest that vocabulary size after the intervention was affected by initial vocabulary size. It could be that a function bias training, or even a shape bias training, are only beneficial for children with a specific initial number of words. Future studies should look at how an intervention aimed at teaching a shape bias or function bias benefit infants with various vocabulary sizes. In other words, future research should assess if children with small and large vocabularies benefit equally or not from a shape and a function bias training.

2.4.3 Conclusions

Infants can be taught a function-bias as a successful strategy for noun learning and generalisation (first-order generalisation), which they can use even for novel words never encountered before (i.e. second-order generalisation). Nevertheless, learning a function bias by the end of the second year of life does not seem to provide an additional benefit to a developing shape bias. To conclude, this study shows that infants can learn to focus on objects' functional properties as a general word learning strategy. It also shows that the preference for shape in early word learning and generalisation may not be because function is conceptually more difficult than shape. Instead, since most objects infants learn tend to be organised by shape, and since shape and function tend to be correlated, using the more accessible cue (i.e. shape) can be enough to know what an object is and therefore its name.

CHAPTER 3

Can Late Talkers be Taught a Shape Bias for Noun Extensions?

Abstract

Late talkers show a vocabulary delay in the absence of any additional conditions or disorders that may account for this delay (Tsybina & Eriks-Brophy, 2007). One reason that may be contributing to this delay is that, contrary to typically developing children, late talkers do not show a shape bias for noun generalisation (Jones, 2003). Instead, they generalise labels based on texture or do not have a preference at all (Jones, 2003). The main aims of the current study were to assess whether late talkers can be taught to extend object labels by shape and to assess the effect this has in vocabulary learning. Fourteen late talkers between 24 and 47 months were randomly allocated to either a shape training group or a specific word training group. Across seven weekly sessions, participants in the shape training group were taught that objects similar in shape had the same name. The participants in the specific word training group were introduced to seven sets of target words that referred to real objects. In two further sessions, their noun generalisation strategies were assessed. The results showed that the participants in the specific word training group had no preference for any property (shape, colour, or texture) in the generalisation tasks. The results also showed that the participants in the shape training group extended labels by shape for known object labels, but showed no preference when extending unfamiliar object labels. Expressive and receptive vocabulary assessments showed no group differences in vocabulary increase over the course of the study. Thus, I found no evidence that explicit shape bias training helps late talkers to pick up on a helpful word learning strategy or boosts vocabulary growth.

Pre-registration: Prior to recruitment and data collection, a protocol for the current study was registered on ClinicalTrials.gov (https://clinicaltrials.gov/ct2/show/NCT03379818)

3.1 Introduction

Previous research has shown that between 10 to 18% of children below 3 years of age can have a language delay (Horwitz et al., 2003; Rescorla & Alley, 2001). One group of children that has shown significant language delays in the absence of any hearing difficulties, or any additional physiological or cognitive disorders are late talking children (Rescorla, 2011; Tsybina & Eriks-Brophy, 2007). As discussed in Chapter 1, late talkers are generally defined as children who by the age of 2 produce fewer than 50 words (Ellis Weismer et al., 2013; MacRoy-Higgins & Montemarano, 2016; Rescorla, 2011) and do not combine two-word phrases (MacRoy-Higgins & Kliment, 2017; MacRoy-Higgins & Montemarano, 2016; Pearson, 2013). Late talkers also tend to be below the 15th percentile of expressive vocabulary (Colunga & Smith, 2008). However, some previous studies have classified any child below the 30th percentile of expressive vocabulary as a late talker (Colunga & Sims, 2017; Jones & Smith, 2005). Although one of the main characteristics of a late talker is a delay in expressive vocabulary, some late talkers can have both expressive and receptive delays (Chilosi et al., 2019; Desmarais et al., 2008). While some late talkers will catch up and become late bloomers, others will have significant delays throughout their lives (Colunga & Sims, 2017). Therefore, since late talkers seem to have significant delays in vocabulary acquisition, it is important to investigate how word learning can be improved in this population.

3.1.1 Language and Vocabulary Delays in Late Talking Children

Currently, the underlying reasons why late talkers show a delay in their vocabulary development are not well known. But, differences in the language development of typically developing children and late talkers have been observed since the first few months of life. For example, during the first 12 months of life, late talkers show a different pattern in phonetic development characterized by a delay in the onset of canonical babbling, and the use of fewer and less complex combinations of sounds than the ones produced by typically developing infants (MacRoy-Higgins & Schwartz, 2013; Mirak & Rescorla, 1998; Thal, Oroz, & McCaw, 1995). Additionally, late talkers also tend to produce their first words later than typically developing children (Ellis Weismer & Evans, 2002). Previous research has suggested that the differences observed are because late talkers acquire language at a slower rate compared to their peers (Hawa & Spanoudis, 2014), and in consequence, their language development is delayed (MacRoy-Higgins et al., 2016) for around 12 months (Rescorla, Alley, & Christine, 2001; Rescorla, Mirak, & Singh, 2000). Nevertheless, these differences could also suggest an atypical language development instead of a simple delay.

The main characteristic of late-talking children is that they do not know or learn as many words as other children their age. A difficulty for learning new words has also been observed in experimental settings, even when late talkers receive the same input and see the same stimuli as typically developing children (Desmarais et al., 2008; Ellis Weismer et al., 2013; MacRoy-Higgins et al., 2016). For example, Ellis Weismer and colleagues (2013) showed that late talkers perform below their typically developing peers in fast-mapping tasks and that their performance was correlated with their productive vocabulary size, with children with smaller vocabularies having more difficulties in the fast-mapping task. Similar differences have been observed even when extensive experience with the objects and their labels was provided. For example, MacRoy-Higgins and Montemarano (2016) taught a group of late talkers the names of 12 novel objects in an intervention that lasted ten sessions. Researchers found that late talkers were unable to learn as many object names as their typically developing group, and were also unable to produce any of the object names. Interestingly, in this study, late talkers also showed reduced attention to the objects being shown to them compared to their typically developing peers. Learning new words requires being able to attend to the correct stimuli (Samuelson & Smith, 1998). However, if late talkers are attending to what is happening around them for shorter periods of time, they may miss important learning information. Thus, if late talkers have difficulties in learning words, even when they are explicitly taught to them, and show reduced attention, late talkers may have significant deficits in general abilities required to map words to their referents successfully.

While learning novel words seems to be a difficult task for late-talking children, differences have also been found in how late talkers recognize and process known words. Results from an eye-tracking study conducted by Ellis, Borovsky, Elman and Evans (2015) showed that when listening to object names, late talkers between 18 and 24 months of age are slower than typically developing children at recognizing the correct referent. Additionally, in this study, late talkers frequently switched their attention between looking at the object that represents a specific label and a distractor. Thus, late talkers may also be attending to their surroundings differently than typically developing children.

While findings from previous research suggest that late talkers might have reduced or atypical attention, this is unlikely the only reason why late talkers have difficulties in learning words. One additional contributor might be that late talkers do not use the same word learning biases as typically developing children (Horvath, Rescorla, & Arunachalam, 2018). Towards the end of the second year of life, typically developing children learn that objects can be named based on their shapes, thus, they develop a shape bias (Borgström, Torkildsen, & Lindgren, 2015; Landau, Smith, & Jones, 1998; Perry & Samuelson, 2011). The shape bias is a useful word learning strategy for noun generalisation because most words infants learn during the first years of life refer to categories of objects organised by shape (Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg et al., 2019). Previous research has shown that the robustness of the shape bias can be related to vocabulary size (e.g. Gershkoff-Stowe & Smith, 2004; Perry & Samuelson, 2011), with children with smaller vocabularies also having a less robust shape bias. Despite being a predominant word learning bias in typical development, it has been reported that late talkers, do not exhibit this bias (e.g. Colunga & Sims, 2012; Jones, 2003). Instead, late talkers prefer to generalise labels to objects sharing the same texture, or do not have a preference at all (Jones, 2003). Therefore, late talkers lack a useful word learning bias for object naming and generalisation.

Interestingly, research has shown that instead of a shape bias, some late talkers develop a texture bias (Jones, 2003), which can put them at a disadvantage for word learning. For a word learning bias to be useful, it has to be related to the type of words children learn (see Chapter 2). Most of the words children learn during the first years of life are names of concrete objects organized by shape (Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg et al., 2019). Thus, a texture bias is not useful for the type of words children are learning and can even hinder their vocabulary development by tuning them to irrelevant properties for naming and generalising. It is important then to investigate whether late talkers can be taught a useful bias for the type of words they encounter, namely a shape bias.

3.1.2 Vocabulary Interventions for Late Talkers

Research has shown that all late talkers, even the ones that eventually catch up, are at risk of persistent developmental and academic difficulties related to their initial language difficulties (Bleses et al., 2016; Dale et al., 2014; Di Giacomo, Ranieri, Donatucci, Caputi, & Passafiume, 2016; Gilkerson, Richards, & Topping, 2017; Moyle, Weismer, Evans, & Lindstrom, 2007; Poll & Miller, 2013; Rice et al., 2008), with children even being at risk of a future diagnosis of Developmental Language Delay (DLD) (Perry & Kucker, 2019; Rudolph & Leonard, 2016). Because of this, all late talkers may require additional support at some point during their lives. In a study by Moyle and colleagues (2007), 37.5% of children identified as late talkers at the age of 2 still required the support of a Speech and Language Therapist (SLT) at the age of 5. Therefore, it is important to look at interventions aimed at promoting early vocabulary development.

As mentioned in Chapter 1, previous research has looked at different interventions for late-talking children, and the effect that these interventions have on general expressive vocabulary growth (e.g. Alt, Meyers, Oglivie, Nicholas, & Arizmendi, 2014; Buschmann, Multhauf, Hasselhorn, & Pietz, 2015; Girolametto, Pearce, & Weitzman, 1997; Robertson & Weismer, 1999). For example, Robertson and Weismer (1999) taught late talkers different sets of target words in context. Results showed that after 12 weeks, late talkers produced 37 more words outside the experimental setting, while participants in a control group produced an average of 10.3 new words. Alt, Meyers, Oglivie, Nicholas, and Arizmendi (2014) taught four late talkers different target words during 7 to 10 weeks in a cross-situational based intervention. Results showed that late talkers were able to learn and produce most taught words (participants learned 90.75% of the target words), and that they acquired 21.6 words per week outside the research environment. However, it is important to take these results with caution as no control group was included in this study. Consequently, it is difficult to assess whether this increase occurred as a consequence of the intervention, or if it could have occurred even with no intervention. As seen in these studies, previous research has reported positive effects in late talkers' general word learning when only specific target words have been taught.

When looking at intervention studies with late talkers, two gaps in the literature can be identified. First, most research has investigated the effect interventions have in expressive vocabulary. To my knowledge, no one has, so far, examined the effects interventions can have on receptive vocabulary. Since, some late talkers have difficulties in both expressive and receptive vocabulary (Chilosi et al., 2019; Desmarais et al., 2008), it is important also to investigate how receptive vocabulary growth can be accelerated. Second, none of the interventions previously mentioned targeted potential underlying reasons why late talkers may have difficulties in learning words. Instead, their main objective has been to teach specific words or communication patterns that late talkers do not know.

As mentioned before, one important deficit in late talkers is that they do not show a shape bias for object naming or generalisation. Since the shape bias has been linked to vocabulary size (Gershkoff-Stowe & Smith, 2004; Perry & Samuelson, 2011), it may be that promoting the development of a shape bias may help late talkers also to learn more words. The results of a study conducted by Singleton and Anderson (2020) suggest that highlighting shape information is beneficial for late talkers' vocabulary development. Singleton and Anderson (2020) found that accompanying the teaching of object labels with gestures that highlight objects' shape promotes word learning in late talkers between 21 and 30 months of age. It also led late talkers to generalise labels more often to instances of the same category, compared to when no gestures were used. While this study showed that highlighting an object's shape aids noun learning and first-order generalisation of nouns, it is important to investigate how children learn about categories and object labels at a level of general word learning strategies, therefore how children learn about second-order generalisation by shape. In typical development, second-order generalisation by shape has been related to the acquisition of novel object names at a rapid rate (Smith et al., 2002). To my knowledge, no studies have looked at teaching late talkers a shape bias for naming and generalising of known object labels (first-order generalisation) or novel object labels (second-order generalisation).

Besides being a characteristic of typical language development, the shape bias can be used as a strategy to boost vocabulary learning. Smith et al. (2002) showed that 17-month-olds can be taught to generalise names to objects that share the same shape before they would naturally learn it. During seven weekly sessions, infants were presented with sets of novel objects organized by shape paired with novel labels. Through play, the researchers showed the infants how objects that shared the same shape also shared the same name. After this intervention programme, infants were able to generalise labels of known and completely novel objects based on shape. Importantly, using a vocabulary checklist filled in by the infants' parents, the study also found that production of nouns increased significantly more throughout the intervention than that of a control group of infants who did not receive the intervention. Thus, teaching typically developed infants a shape bias before the end of the second year of life boosted their vocabulary acquisition.

Despite the possibility of using the shape bias as a way of boosting language acquisition, teaching late talkers this principle and its effect on their vocabulary development has not been explored. Investigating if late talkers can learn a shape bias by explicitly teaching them the names of objects organised by shape is a step forward to understand the underlying difficulties this group of children have and how they can be improved. An intervention programme targeting a word learning principle that late talkers might not have yet acquired (i.e. the shape bias) could help them develop a useful attentional bias for word learning and generalisation.

3.1.3 The Current Study

The present study investigated if late talkers can be taught to use shape as the main property for generalising known and novel labels. Additionally, given the evidence of the benefits of teaching infants a shape bias for their language development (Smith et al., 2002), and considering that highlighting shape via gestures seems to aid noun learning and first-order generalisation in late talkers (Singleton & Anderson, 2020), the current study examined the effects that a shape training bias has on vocabulary growth. Similar to Smith and colleagues (2002), in the current study a group of late talkers (shape training group) completed a seven-week training programme in which they were taught through play that objects with the same shape also shared the same name. A second group of late talkers (specific word training group) also followed a seven-week training programme, but they were introduced with sets of real objects and their labels. This group functioned as a control group. After the seven-week training programme, participants in both groups took part in a first- and a second-order generalisation task which assessed if they extended labels of known or novel objects based on shape, colour or texture. Finally, parents reported their children's receptive and expressive vocabulary before and after the training programme.

Furthermore, at the beginning of the study participants were assessed with two cognitive tasks, a sorting task, and an attention task. The main aims of the cognitive tasks were to assess any potential cognitive delays and if there were any cognitive differences between groups. The main aims of the sorting task were to investigate if participants could pick up shape similarities, if they would show a preference for organizing objects by shape before the start of the intervention and if there were any differences between groups. The main aim of the attention task was to assess participants' joint and sustained attention. This was done because research has shown that sustained attention (Kannass & Oakes, 2008; MacRoy-Higgins & Montemarano, 2016) and joint attention (Yu & Smith, 2016) can be related to vocabulary learning in early childhood. Additionally, deficits in attention have also been linked to language delays (Ebert & Kohnert, 2011; Finneran, Francis, & Leonard, 2009). Therefore, assessing participants' attention allowed us to see whether their attention might explain their vocabulary learning skills and if there were any differences in attention between groups.

I predicted that if late talkers can be taught a shape bias, participants in the shape training group should be able to generalise known (first-order generalisation) and novel labels (second-order generalisation) based on shape similarities. If a shape training boosts vocabulary learning, the parents of participants in the shape training group should report a higher vocabulary increase at the end of the study compared to parents of participants in the specific word training group. Following the results of Smith and colleagues (2002), it was expected that late talkers in the shape training group would, in particular, learn more nouns than other words. If the shape training boosted word learning, such an intervention could function as a powerful alternative to teaching children specific words.

3.2 Method

3.2.1 Power analysis

Two power analyses were conducted to determine the sample size need for this study. The first power analysis was based on a longitudinal study conducted by Ware and Booth (2010) that had the main aim of assessing if infants can learn to categorise objects by shape if they are exposed to an object's function that is correlated to its shape. For this power analysis, first, the effect size of the proportion of correct responses to the first block of their second-order generalisation task was calculated. The means and standard deviations (Group 1: $M = 0.53$, $SD = 0.23$, Group 2: $M = 0.33$, $SD = 0.13$) showed an effect size of 1.07 (Cohen's *d*). With this effect size, a sample size of 24 infants was estimated with an error probability of 0.05 and a power of 0.80.

The second power analysis was based on the shape bias training study conducted by Smith and colleagues (2002). First, the estimated effect size of the difference in the number of nouns produced at the end of the study between groups was calculated. It was an estimated calculation as the results provided by Smith and colleagues (2002) did not specify all the information required. The estimated means and standard deviations of both groups produced an estimated effect size of 0.71 (Cohen's *d*). This effect size was then converted to Cohen's *f* following the formula suggested by Cohen (1988). This was done as we were interested in the number of participants required for a repeated measures design and not only in the difference between two means. With the effect size of 0.35, I estimated a sample size of 18 participants with an error probability of 0.05 and a power of 0.80.

The two power analyses were based on studies investigating typically developing children because, to my knowledge, there are no studies that have investigated a training program to teach late talkers a shape bias, or any other word learning strategies, with late talkers. Thus, considering both power analyses the target sample size was 24 participants. Due to a high attrition rate and university closure forced by the Covid-19 pandemic, the target sample size was not achieved, and only 14 participants who finished the intervention were included in the current study.

3.2.2 Participants

Fourteen late talkers between 24 and 47 months were recruited through Speech, and Language therapists working for the Birmingham Community Healthcare NHS Foundation Trust, through Language Through Playgroups, or through community, social and playgroups (see section 3.2.1.2 for a description of the recruitment process). Participants were randomly assigned to one of two groups: shape training group (M = 33 months; range: 25 months – 39 months) or specific word training group (M = 31 months; range: 25 months – 35 months). At the starting point, the groups did not differ in age $t(12) = .55$, $p = .587$, 95% CI = [-.41, .70], or socioeconomic status $t(12) = .10$, $p = .918$, 95% CI = [-.14, .15]. For more information on how the SES score was calculated, see Section 3.2.2.2 Socioeconomic Status Calculation.

All participants were full-term (born after 37 weeks of gestation) monolingual English native speakers from Birmingham and its surrounding areas. Besides a language delay, none of them, as reported by their parents, were diagnosed with any additional conditions or disorders. No family history of speech or language disorders was reported by any of the participants' parents. None of the participants had attended any formal language interventions prior to the study, and none commenced one during the study. Five participants were on waiting lists to receive additional support from Speech and Language Therapists. See Table 3.1 for a listing of participant characteristics. Five additional infants were recruited but dropped out of the study. Four more participants did not finish the study due to university closure, and a further three finished the study but were excluded from the analysis due to a confirmed (n = 1) or suspected (n = 2) diagnosis of ASD.

All participants were individually assessed at the Infant and Child Lab (University of Birmingham). The study was approved by the West Midlands – Solihull Research

Ethics Committee and by the Ethics Committee of the University of Birmingham. Parents signed a consent form before the start of the study, and children were asked if they wanted to play before starting the study. The children's parents were reimbursed for travel expenses, and the children received a sticker after each visit as well as a book and a "Junior Scientist" diploma at the last visit.

3.2.2.1 Participant Identification and Recruitment. The participants were recruited through three different sources: 1) via the Speech and Language Therapy Services at the Birmingham Community Healthcare NHS Foundation Trust, 2) through community, social and playgroups, or 3) via Language Through Playgroups (playgroups where parents are given general guidance on how to promote language development and are shown different activities and games they can do at home with their children).

3.2.2.1.1 Recruitment Through Birmingham Community Healthcare NHS Foundation Trust. Parents of children referred to these services attended an individual screening session with Speech and Language Therapists from Birmingham Community Healthcare NHS Foundation Trust. This screening session was not done specifically for the present study, it was done to assess if a child should receive an intervention provided by Speech and Language Therapists. In this session, children were evaluated and divided into three categories: i) children with a mild language delay, ii) children with a moderate delay, and iii) children with a severe delay. In general, the assessments consisted of observing the child and assessing the number of words/sounds they made and whether the child was able to communicate and interact with others. Only children with a severe language delay are invited to take part in a subsequent intervention programme run by the NHS services. However, at the time of the study, it was taking up to a year between the initial assessment and the start of the NHS intervention, meaning that the intervention described in this study occurred before any NHS intervention.

Parents of children with a moderate to severe language delay, and with no conditions or disorders that could explain their delay, were provided by the Speech and Language Therapist with a leaflet about the current study at the end of their assessment. The therapist informed them that they could contact us to see whether their child might be able to participate in our study. The Speech and Language Therapist also informed families that their participation would not affect the services provided to them by the Birmingham Community Healthcare NHS Foundation Trust and that they were still going to receive an evaluation/intervention appointment with them in the future as planned. Interested families contacted the researcher directly to sign up for the study.

3.2.2.1.2 Recruitment Through Playgroups and Community Groups. Flyers were shared in different social and community groups, as well as in different playgroups. Parents that were interested in the study contacted the researcher directly. Parents were explained the study and were asked to fill in a consent form and a couple of questionnaires to assess if the child was eligible for the study. The first questionnaire was the Oxford CDI (O-CDI) (Hamilton, Plunkett, & Schafer, 2000), a vocabulary checklist of words that a child knows and produces. To be able to take part in the study, children had to be below the 25^{th} percentile for their chronological age on the O-CDI. The second questionnaire was a socioeconomic and general development questionnaire that was used to determine if the child had any conditions or disorders that could explain his/her delay, their general health, if they were full term, etc. Only children with no hearing problems or any other conditions or disorders that could explain their language delay were able to take part. After assessing this information, researchers contacted families that fulfilled the inclusion criteria and invited them to take part in the study.

3.2.2.1.3 Recruitment via Language Through Play Groups. The Language Through Play groups are sessions run by Language Champions in the Birmingham area where families play different games aimed at boosting language, and the Language Champion (the person running these groups) gives general guidance on how to promote language development. The researcher provided families attending these playgroups with a leaflet of the study and were told to contact the researcher if interested. When parents contacted the researcher, they were asked to fill in the same two questionnaires than the families recruited via playgroups and community groups: the O-CDI (Hamilton et al., 2000) and a socioeconomic and general development questionnaire. These questionnaires were again used to assess if the child was eligible for the study. Similarly to the recruitment through playgroups and community groups, to be able to take part, children had to be below the 25th percentile on the O-CDI (Hamilton et al., 2000), and only participants with no hearing problems or any other conditions or disorders that could explain their delay were eligible for the study. After assessing this information, the researcher contacted families that fulfilled the inclusion criteria, and they were invited to take part in the study.

3.2.2.2 Socioeconomic Status Calculation. The same procedure as in Chapter 2 was used to calculate socioeconomic status in this study, namely by calculating the average of the three following scores: parents' education score, parents' occupation score, and household income score. See below for more information on how each score was calculated. Note that for one participant in this study, socioeconomic status was based only on the parents' occupations as household income and parents' education was not reported.

3.2.2.2.1 Parent Education. A 4-point scale was used to determine each parent's education, with 1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education. The average education score of both parents was calculated and then converted to a value between 0 to 1.

3.2.2.2.2 Parent Occupation. Occupation of all parents was classified using the nine levels of the Office for National Statistics - Standard Occupational Classification Hierarchy (Standard Occupational Classification (SOC), 2010) and each parent was assigned a score from 1 to 9, where 9 was the highest value and 1 the lowest. The average score of both parents was calculated, apart from families with a stay at home parent, for which the occupation score was based only on the parent that worked in paid employment. This score was then converted to a value between 0 and 1.

3.2.2.2.3 Household Income. Income was measured on a 4-point scale (1 = less than £14,000, 2 = £14,001 - £24,000, 3 = £24,001 - £42,000, 4 = more than £42,000). This score was then converted to a value between 0 and 1.

Table 3.1 *Participant Characteristics*

	Shape training group			Specific word training group		
	n	***M***	***SD***	***n***	***M***	***SD***
Age at start of the study (years)		2.76	0.52		2.61	0.43
Gender						
Male	6			4		
Female	1			3		
Number of siblings						
0	1			3		
1	4			3		
2	2			1		
Birth order						
First born	3			4		
Second born	2			2		
Third born	2			1		
Age of first word (months)		21.25[a]	9.91		22.17[a]	3.25
Parent 1 education		2.5[b]			2.5[b]	
Parent 2 education		2[b]			2[b]	
SES score		0.75[c]	0.12		0.74[c]	0.12

Note. a. Two children of the shape training group and two children of the specific word training group were not yet using words to communicate at the beginning of the study as reported by parents. b. Parent education was measured on a 4-point scale (1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education). c. For more information on how the SES score was calculated, see section 3.2.2.2 Socioeconomic Status Calculation.

3.2.3 Procedure

All infants were randomly assigned to one of two groups: shape training group or specific word training group. The study took place over nine weekly visits and was divided as follows: initial assessments (Week 1), cognitive assessments (Week 2), training sessions (Weeks 1 to 7), and final assessments (Weeks 8 & 9) (see Table 3.2). The same initial assessments, cognitive assessments and final assessments were used for both groups, but the training sessions differed across groups.

Table 3.2 *Timeline of Assessments*

Week 1	Week 2	Week 3 to Week 7	Week 8 and 9
• Initial Assessments - Socioeconomic and general development questionnaire - Vocabulary checklist - Sorting task - Attention task • Training sessions	• Cognitive assessments - Block design subtest - Zoo locations subtest • Training sessions	• Training Sessions	• Final assessments - First-order generalisation task - Second-order generalisation task - Vocabulary checklist

3.2.3.1 Initial assessments. In Week 1, parents completed the socioeconomic and general development questionnaire as well as the Oxford CDI (O-CDI) (Hamilton et al., 2000). All participants then took part in a sorting task and attention task.

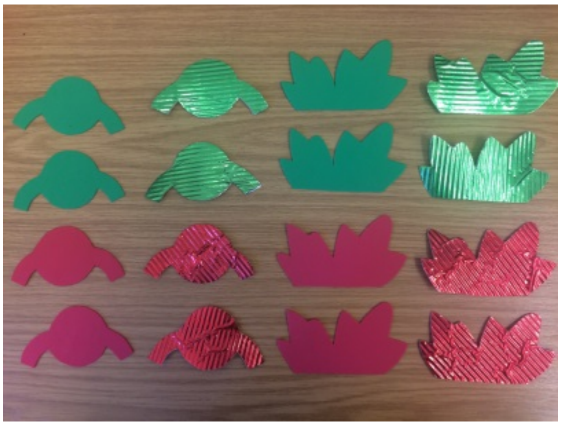
3.2.3.1.1 Socioeconomic and General Development Questionnaire. In this questionnaire, parents were asked about different areas of the children's development. Information provided in this questionnaire was used to double-check the inclusion and exclusion criteria. It also provided information regarding the child's development, their family and their socioeconomic status (see Appendix 3). Parents of children that were recruited through playgroups, community groups or Language Through Playgroups did not answer this questionnaire during the first session, as it was the same one used to assess if their child was eligible for our study and therefore the information was already obtained.

3.2.3.1.2 Vocabulary Checklist. During the first visit, parents filled in the O-CDI (Hamilton et al., 2000) which is a vocabulary checklist of words and phrases that children may know or understand during the first years of life. Parents of children that were recruited through playgroups, community groups or Language Through Playgroups did not answer this questionnaire during the first session, as it was the same one used to assess if their child was eligible for our study and therefore the information was already obtained

3.2.3.1.3 Sorting Task. To assess if participants could pick up shape similarities and if they showed a preference to organize objects by shape before the start of the study, a sorting task was administered. This task also had the main objective of assessing if there were any differences between groups in their sorting preferences. Each child was presented with 16 novel objects. All objects were either red or green, were made of either foam or corrugated paper, and were of one of two possible shapes (see Figure 3.1). How to sort by shape was shown to them with examples. Objects were mixed and placed on a table. Two containers were also placed on the table, one of the left and the other on the right side. The researcher started the task by saying *"We are going to play a game. We are going to put together objects that are the same".* The researcher took one of the objects (e.g., a red round object made of corrugated paper), placed it in a container and said: *"This one goes here"*. Then, the researcher took another object with a different shape, but with the same colour and texture as the first one (e.g. a red spikey object made of corrugated paper), placed the object in a second container and said: "*And this one goes here"*. The researcher then demonstrated what the participant had to do with two more objects that also differed in shape and had the same colour and texture (e.g. a green round object made of foam and a green spikey object made of foam). Afterwards, the researcher said: *"Now it is your turn, can you help me putting the objects that are like these* (pointing to the container on the left) *here, and the objects that are like these* (pointing to the container on the right) *here?".* Participants then sorted 12 remaining objects. The sorting task lasted approximately 5 minutes. Note that the procedure of this task was the same procedure as the Sorting Task of

Chapter 2, but the objective of the task and the stimuli used were different. In Chapter 2, the main objective of the sorting task was to assess if participants could pick up function similarities and if they showed a preference for organising objects by function, however the main aim of this sorting task was to assess if late talkers could pick up shape similarities and if they showed a preference to organize objects by shape before the start of the study

Figure 3.1 *Stimuli Used in the Sorting Task*

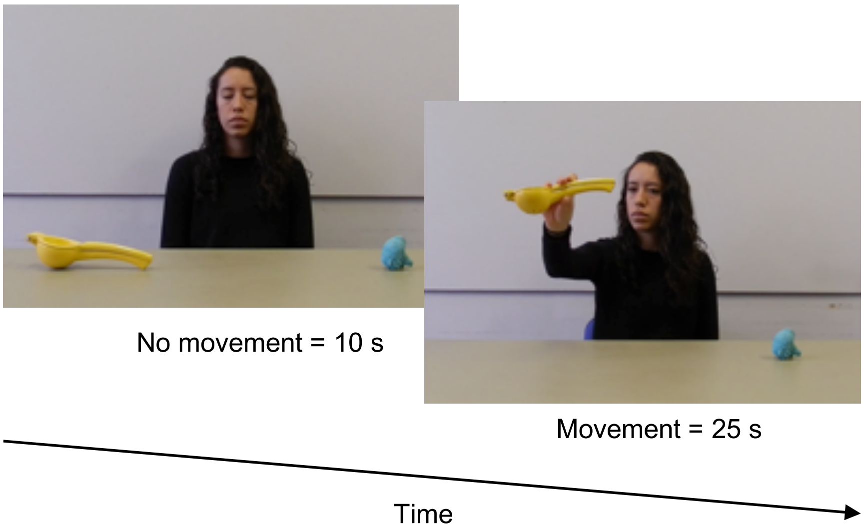


Note. All objects were either green or red, and either made of foam or corrugated paper. They were also of one of two possible shapes.

3.2.3.1.4 Attention Task. All of the participants took part in an attention task to assess infants' joint and sustained attention, and to assess any differences in attention between groups. In this task, each child sat on their parent's lap in front of a computer screen located at a distance of approximately 60 cm from the participants. The computer screen was connected to an eye-tracking camera (EyeLink 1000) which was located underneath the screen and recorded the participant's looking times. Before the start of the task, a 9-point calibration sequence was presented. During this calibration, a small happy face was shown accompanied by a *beep* on nine different sections of the monitor in a random order (left-top, centre-top, right-top, left-centre, centre, right-centre, left-bottom, centre-bottom and right-bottom).

For the attention task, participants watched five short video clips (35 seconds each) that consisted of a person with two objects placed on the right and left side of the screen. In all videos, for the first 10 seconds no object was moved. For the following 25 seconds, the person in the video started moving only one of the novel objects. On the other side of the screen, the other object (distracting object) was not moved (see Figure 3.2 for an example). All five videos followed the same procedure, but different objects were used for each video. The object that was moved, as well as the side in which the object was being moved, was counterbalanced and randomized between participants. The order of presentation of each clip was randomized between participants. A 3-second attention grabber was introduced after each video. Note that the procedure of this task was the same as the Attention Task of Chapter 2, but the videos used in both tasks were different.

Figure 3.2 *Still Frames of an Example of a Video From the Attention Task*



Note. Each video lasted 30 seconds. During the first 10 seconds no object was moved. During the following 25 seconds, the target object was moved.

3.2.3.2 Cognitive Assessments. During the second visit (Week 2), two cognitive assessments were presented to all participants to examine if any cognitive delays were present and to make sure that both groups did not differ in their visual-spatial and working memory abilities. These two assessments were the Zoo Locations and the Block Design subscales from the Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK). The presentation of both subtests lasted around 20 minutes.

3.2.3.2.1 Block Design Subtest. This subtest assessed visual-spatial abilities. In this task, the researcher created different designs using red and white blocks, and participants were asked to recreate them with other blocks.

3.2.3.2.2 Zoo Locations Subtest. This subtest assessed working memory. In this task, the researcher placed different animal cards on a zoo layout. Participants observed them for a few seconds, and then the cards were removed. Afterwards, participants were asked to remember where the cards were and to place them in the zoo layout.

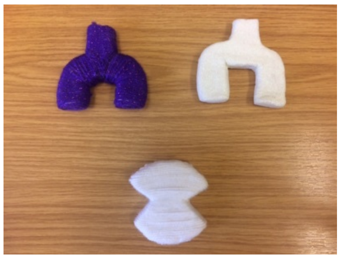
3.2.3.3 Training Sessions. During seven weekly sessions (from Week 1 to Week 7), the participants were introduced to several toys or toy-like novel objects. The stimuli and procedure for each group (shape training group or specific word training group) differed and are described below.

3.2.3.3.1 Shape Training Group. From Week 1 to Week 7, children in the shape training group were presented with four novel words paired with four novel sets of objects in a play-like session. Each set of objects consisted of two exemplars and a contrasting object. The two exemplars shared the same shape but had different colours and textures. The contrasting object had a different shape than the exemplars but had the same colour as one of the exemplars and the same texture of the other exemplar (see Figure 3.3). Each set was presented for 3 minutes, and each session lasted approximately 12 minutes.

During each session, the experimenter first presented one of the exemplars of one set by saying, for example: "*Look! It is a kiv. Do you want to play with the kiv?".* The researcher presented the second exemplar with a similar sentence (e.g. "*Look! This is also a kiv. Let's play with the kiv".* The participants were allowed to play with the objects and listened to the researcher mentioning their names with sentences such as *"You are playing with the kiv".* Halfway through the presentation of the exemplars (after approximately 1.5 minutes), the researcher brought out a third contrasting object and said: "*Oh no, look, this is not a kiv".* The contrasting object was taken away immediately, and the experimenter and the participant continued playing with the two exemplars. All of the names were mentioned between 10 and 20 times per session. The same procedure was used to present the three remaining sets of objects. The presentation order between participants was randomized.

During Sessions 2 to 7, the same four sets of objects and the same procedure was followed. The order of presentation of each set was randomized between sessions and between participants.

Figure 3.3 *Sets of Objects Used in the Shape Training Group for the Training Sessions*

Set	Description	Set	Description
	Exemplars name: Kiv Contrasting object		Exemplars name: Dax Contrasting object
	Exemplars name: Psik Contrasting object		Exemplars name: Zav Contrasting object

Note. Each set consisted of two exemplars that shared the same shape and one contrasting object.

3.2.3.3.2 Specific Word Training Group. From Week 1 to Week 7, children in the specific word training group were introduced to 28 real objects and their names. These words were divided into seven sets of four words (see Table 3.3). All words were selected from the Wordbank: An open database of children's vocabulary development (Frank, Braginsky, Yurovsky, & Marchman, 2016), which is an open repository of data from the MacArthur-Bates CDI. Twenty-eight words were randomly selected as target words from a list of words that 80% of children in the UK at 25 months know.

During each session, only one set of objects and their names were presented by saying, for example: "*Look! This is a giraffe, and look, this is a bear. Do you want to play with the giraffe and the bear?".* The participants were allowed to play freely with all objects, and the names of the target objects were mentioned between 10 and 20 times per session. Similarly to the shape training group, each session lasted 12 minutes. Techniques such as focused stimulation and modelling target words, which have proved to be useful for word learning in late talkers were used. As mentioned in Section 1.2.2.1, focused stimulation consists on repeating labels while establishing a joint focus with the child (Cable & Domsch, 2011). Modelling target words consists of modelling sentences and words to the child in context (Cable & Domsch, 2011). The order of presentation of the sets was randomized across participants.

Table 3.3 *Sets of Objects Used in the Specific Word Training Group for the Training Sessions*

Set number	Objects used
Set 1	Bunny, frog, block, stairs
Set 2	Bike, blanket, fire engine, toy
Set 3	Bear, giraffe, cheese, mouse
Set 4	Peas, chicken. stove, plate
Set 5	Sheep, elephant, carrot, biscuit
Set 6	Flower, tree, butterfly, bee
Set 7	Cup, fork, bread, ice cream

3.2.3.4 Final Assessments. To assess if after the training sessions participants generalised object labels by shape, colour or texture, both participant groups were assessed with a first-order (week 8) and a second-order generalisation task (week 9). At Week 9, parents were also asked again to fill in the O-CDI (Hamilton et al., 2000) to assess vocabulary growth over the nine weeks.

3.2.3.4.1 First-Order Generalisation Task. At Week 8, the participants in both groups were assessed with a first-order generalisation task which consisted of two practice trials (practice phase) and eight test trials (test phase). Both participant groups were presented with exactly the same objects, and the procedure of this test was also identical for both groups.

3.2.3.4.1.1 Practice Phase. The participants were presented with two practice trials to familiarize them with the procedure of the task. In each practice trial, a standard object (e.g. a yellow plastic ball) was presented, accompanied with three objects sharing only one property each with the exemplar (e.g., shape: a blue ball, colour: a yellow block, and texture: a plastic chair). The experimenter said *"Look, this is a ball. Can you give me the* *other ball?".* A second trial was introduced with another set of familiar objects (a green plastic spoon, a metal spoon, a plastic chair and a green block) and the same procedure was followed. All the participants chose the correct (shape matching objects) during the first trial.

3.2.3.4.1.2 Test Phase. This phase consisted of eight trials. In each trial, the participants were presented with one of the exemplars used during the training sessions of the shape training group accompanied by three objects that matched the exemplar on shape, colour or texture only (see Figure 3.4). For each testing trial, the experimenter presented one of the exemplars and said, for instance, "*Look, this is a kiv".* Then the researcher said *"Now look at these ones"* while placing on the table three objects sharing only one visual property with the exemplar (shape only, colour only or texture only), and asked, "*Can you get the other kiv?"*. The same procedure was used to present the other seven trials. Trials were presented in one of two possible orders which was counterbalanced between participants.

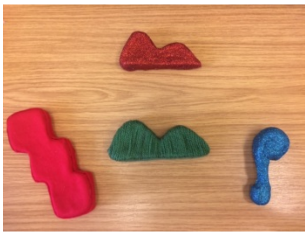
3.2.3.4.2 Second-Order Generalisation. At Week 9, all the participants were assessed with a second-order generalisation task which consisted of two practice trials (practice phase) and eight test trials (test phase). Both groups were presented with exactly the same objects, and the procedure of this test was also identical for both groups.

3.2.2.4.2.1 Practice Trials. The same two trials as the practice trials of the first-order generalisation task were introduced and the same procedure was followed.

3.2.2.4.2.1 Test Trials. The participants were tested with eight unfamiliar objects paired with four novel words, neither of which had been used during the training sessions. The same procedure as the one for the first-order generalisation was followed, and trials were presented in one of two possible ways which was counterbalanced between participants (see Figure 3.5).

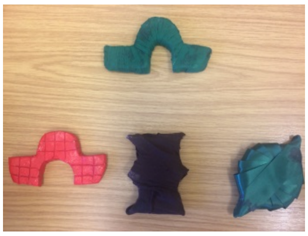
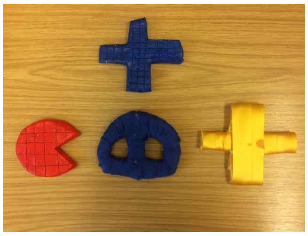
3.2.3.4.3 Vocabulary Checklist. In Week 9, parents were asked again to fill in the O-CDI (Hamilton et al., 2000). This was used to compare the number of words children understood and produced before and after the training sessions.

Figure 3.4 *Sets of Objects Used During the First-Order Generalisation Task (Week 8)*

Trial Set	Description	Trial Set	Description
	Training exemplar – kiv Target object - black one		Training exemplar - kiv Target object - white one
	Training exemplar – pisk Target object – green one		Training exemplar - pisk Target object - purple one
	Training exemplar – dax Target object – yellow one		Training exemplar - dax Target object - black one
	Training exemplar – zav Target object - red one		Training exemplar -zav Target object - purple one

Note. Each set consisted of one exemplar (top) and three possible matching objects (bottom), with each one matching the exemplar on shape, texture or colour only. The target object was always the object that shared the same shape with the exemplar.

Figure 3.5 *Sets of Objects Used During the Second-Order Generalisation Task (Week 9)*

Trial Set	Description	Trial Set	Description
	Training exemplar - gip Target object - red one		Training exemplar - gip Target object - orange one
	Training exemplar - toma Target object - red one		Training exemplar - toma Target object - yellow one
	Training exemplar - soob Target object - yellow one		Training exemplar - soob Target object - green one
	Training exemplar - bosa Target object - pink one		Training exemplar - bosa Target object - pink one

Note. Each set consisted of one novel exemplar (top) and three possible matching objects (bottom), with one object matching by shape, one by texture and one by colour. The target object was always the object that shared the same shape with the exemplar.

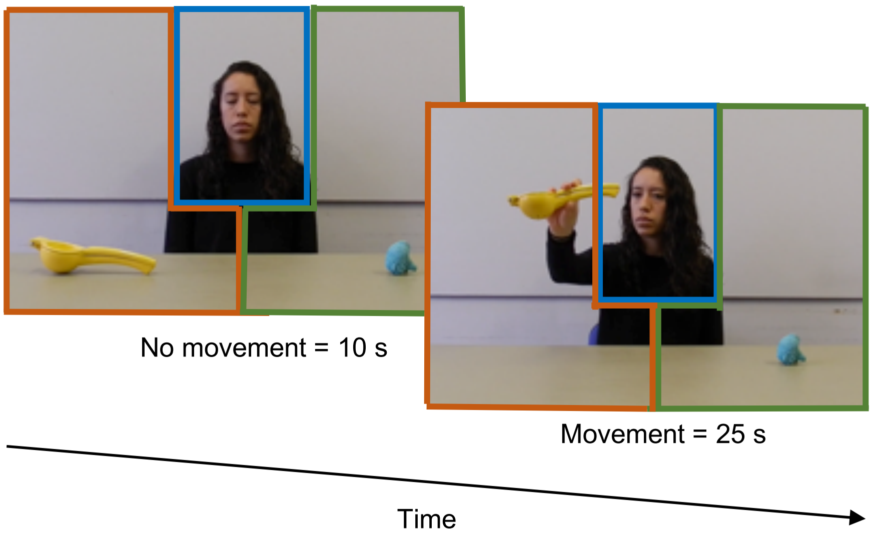
3.2.4 Design and Data Analysis

3.2.4.1 Sorting Task. In order to assess if participants could pick up shape similarities and to assess if they showed a preference for organizing objects by shape before the start of the study, I analysed the percentage of correct choices in this task. Objects were considered as sorted correctly if they matched on shape to the first two objects that were put by the researcher in the bowl. A total of 12 objects sorted by shape represented 100% of objects sorted correctly. I then compared the percentage of objects sorted correctly by shape to chance for both groups separately using a t-test. Chance was 50% as this was a forced-choice task. Next, I compared the percentage of objects sorted correctly between groups using a t-test to assess if there was any difference between groups.

3.2.4.2 Attention Task. For the attention task, two analyses were conducted. The first analysis assessed if both participant groups attended equally to the videos presented in the attention task and if their attention reduced equally at the end of the task. For this analysis, I first calculated the total number of seconds participants looked at each full video. Then, I conducted a 2 x 2 analysis of variance (ANOVA) with the between-participants factor of Group (shape training group vs specific word training group) and the within-participants factor of Video (first video vs fifth video). In this analysis, the dependent variable was total looking times to each video.

The second analysis assessed if participants looked more to the target object while this object was being moved compared to before any movement was made. Therefore, it assessed participants' joint and sustained attention to the object that was being moved. For this analysis, I first divided each video into two time windows (before and during movement) and three regions of interest (ROIs). The *before* time window contained the first 10 seconds and the *during* time window contained the following 25 seconds of each video clip. The three ROIs were: face ROI, target ROI and distractor ROI (see Figure 3.6 for an example of how each video was divided into three ROIs).

Figure 3.6 *Example of a How a Video from the Attention Task Was Divided Into Two Time Windows*



Note. Videos were divided into two time windows (before and during movement) and three regions of interest (ROIs) (blue: face ROI, orange: distractor ROI, red: action ROI)

Then, I calculated the proportion of looking times towards the target ROI before movement and the proportion of looking times towards the target ROI during movement. The following equation was used to calculate the proportion of looking times towards the target ROI before movement:

$$\frac{\text{mean fixation on target ROI before movement}}{(\text{mean fixation on target ROI before movement} + \text{mean fixation on face ROI before movement} + \text{mean fixation on distractor ROI before movement})}$$

A similar equation was used to calculate the proportion of looking times to the target ROI during movement.

To assess if participants looked more towards the target ROI during movement than before movement, a 2 x 2 analysis of variance (ANOVA) with one between-participants factor of Group (shape training groups vs specific word training group) and one within-participants factor of Time window (before movement vs during movement) was conducted. In this analysis, the dependent variable was the proportion of looking time towards the target ROI.

3.2.4.3 Cognitive Assessments. To assess if participants showed any significant delays in cognitive development, the results of the two cognitive tasks were analysed. First, I calculated the raw score obtained by participants on each cognitive assessment (block design subtest and zoo locations subtest) and transformed it into their equivalent age using the guidelines of the WPSSI-IV Administration and Scoring Manual. For each assessment, the equivalent age obtained in the task was compared to their chronological age using a t-test to assess if there was a significant difference between their performance and their expected performance.

Then, the difference in months between their chronological age and the equivalent age obtained according to their scores on each subtest was calculated using the following equation:

$$(\text{Equivalent age of score obtained} - \text{Chronological age in months})$$

A result of zero represented no delay and a performance as expected for their chronological age. A negative score represented a delay in months. A positive score represented a result above their chronological age in months. Two additional t-tests were used to compare the two groups on each cognitive assessment to ensure groups did not differ on the cognitive assessments.

3.2.4.4 First- and Second-Order Generalisation Tasks. To assess participants' preference to generalise object labels by shape, colour or function, I first calculated the percentage of texture, shape, or colour choices, for both first- and second-order generalisation. A choice was counted as a shape choice if the object chosen shared the same shape with the referent object. A choice was counted as texture choice if the object chosen shared the same texture with the referent object. A choice was counted as a colour choice if the object chosen shared the same colour with the referent. The total number of trials for both the first- and second-order generalisation was eight. However, for one child in the first-order generalisation task, the total was seven, and for one child in second-order generalisation task the total was also seven because they did not choose any objects for one trial (for these two participants their percentage of choices was based on seven trials instead of eight). I then compared separately the percentage of choices for each property between groups using a t-test. I also compared the percentage of choices of shape, texture and colour against chance for each group separately using t-tests. As participants had to choose one of three options (either shape match, colour match or texture match), chance was 33.33%. Separate t-tests were used instead of an analysis of variance (ANOVA) because the percentage of shape, colour and function choices added to 100% for all participants and therefore these three measurements were not independent of each other.

I then conducted two regression analyses, one for the percentage of shape choices in the first-order generalisation task and one for the percentage of shape choices in the second-order generalisation tasks. The main aim of these analyses was to investigate if the type of intervention participants were in had an effect on the percentage of shape choices, but also if other factors (e.g. attention, sorting score, vocabulary at the start of the study) also played a significant role on the percentage of shape choices of each task. For each regression analysis, the outcome variable was the percentage of shape choices. The predictor variables were Group (shape training group or specific word training group), Expressive vocabulary at the start of the study, Sorting score and Proportion of looking times towards the target during movement in the attention task.

3.2.4.5 Vocabulary Growth. Receptive and expressive vocabulary were analysed separately. For expressive vocabulary, I conducted three different analyses. The first analysis assessed expressive vocabulary growth across the study between groups. For this analysis, I conducted a 2 (Group: shape training group vs specific control group) x 2 (Testing time: expressive vocabulary before vs expressive vocabulary after) analysis of variance. The between-participants factor was Group, and the within-participants factor was Testing time. The dependent variable was the number of words infants produced.

The second analysis investigated if the type of intervention participants were in had an effect on vocabulary size at the end of the study, but also if other factors such as sorting score, attention skills and vocabulary at the start of the study, had a significant effect on expressive vocabulary growth. For this analysis, I conducted a regression analysis with the outcome variable Expressive vocabulary at the end of the study, and four predictors which were Group, Expressive vocabulary at the start of the study, Sorting score and Proportion of looking times towards the target during movement in the attention task.

Finally, the main aim of the third analysis was to investigate if there were any differences in the increase of specific word types between groups. Since the intervention conducted by Smith and colleagues (2002) showed that a shape bias training can boost mainly expressive noun learning, I divided expressive vocabulary into two word categories: *nouns* and *other words*. The word type *nouns* included all object names from the O-CDI (Hamilton et al., 2000), and the word type *other words* included the rest of the words from the O-CDI (Hamilton et al., 2000). I then conducted a 2 (Group: shape training group vs specific word training group) x 2 (Testing time: expressive vocabulary before vs expressive vocabulary after) x 2 (Word type: nouns vs other words) analysis of variance. This analysis had one between-participants factor of Group and two within-participants factors (Word type and Testing time). The dependent variable for this analysis was the number of words produced. The same three analyses were conducted for receptive vocabulary.

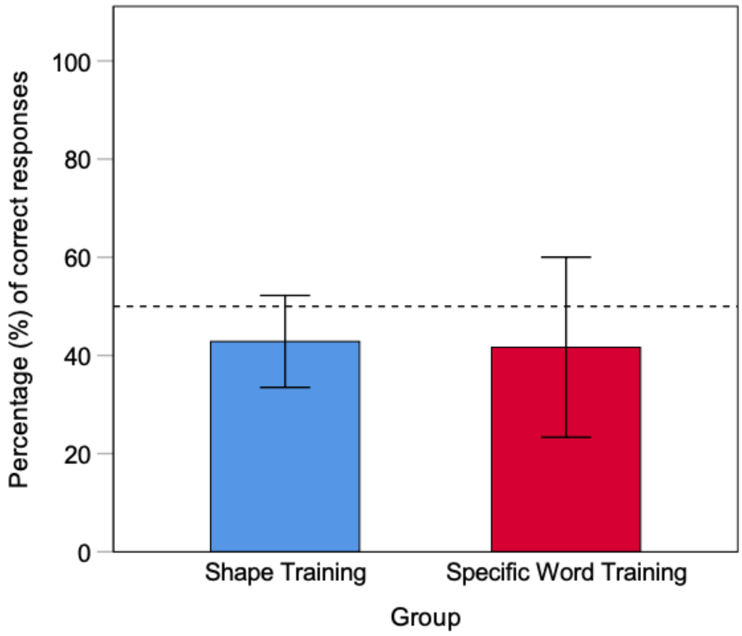
3.3 Results

3.3.1 Sorting Task

To assess if the participants could pick up shape similarities and if they had a preference for sorting objects by shape before the start of the intervention, both groups were presented with a sorting task. The participants in the shape training group sorted 42.85% (SD = 10.12) of the objects correctly by shape and participants in the specific word training group sorted 41.66% (SD = 19.83) of the objects correctly by shape. In both groups, the participants' sorting choices did not differ significantly from chance (chance being 50%) (shape training group $t(6) = -1.86$, $p = .111$, 95% CI = [-16.50, 2.22]; specific word training group $t(6) = -1.11$, $p = .308$, 95% CI = [-26.67, 10.10]) (see Figure 3.7).

Sorting choices did not differ significantly between groups, $t(12) = 0.14$, $p = .890$, 95% CI = [-17.15, 19.52]. Therefore, I did not find evidence that sorting choices were made in a consistent way.

Figure 3.7 *Percentage of Correct Responses for Both Groups in the Sorting Task*

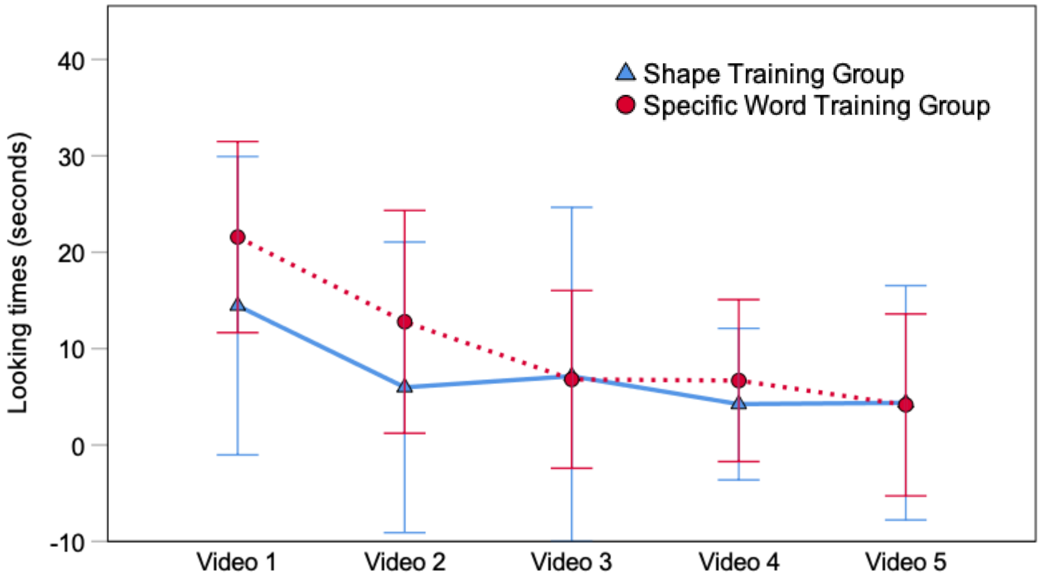


Note. The dotted line represents chance level (50%). Error bars represent 95% CIs of the means.

3.3.2 Attention Task

Two participants from the shape training group were removed from all analyses of the attention task as they did not look to any of the videos. For the rest of the participants, the total looking times (in seconds) to all five videos of the attention task were calculated (see Figure 3.8). To assess if both participant groups attended equally to the videos in the attention task, and to assess if their attention reduced equally in both groups, I analysed the total looking times (in seconds) to the videos. A 2 (Group: shape training group vs specific word training group) x 2 (Video: first video vs fifth video) ANOVA was conducted. The participants in the shape training group looked on average to the first video for 14.45 seconds (SD = 12.46) and to the fifth video for 4.37 seconds (SD = 9.79). The participants in the specific word training group looked on average for 21.57 seconds (SD =10.71) to the first video and 4.16 seconds (SD = 10.20) to the last video. The results of the 2 x 2 ANOVA showed a significant main effect of Video, $F(1, 10) = 16.27$, $p = .002$, $\eta_p^2 = .61$, but no significant main effect of Group, $F(1, 10) = 0.42$, $p = .530$, $\eta_p^2 = .04$. Results also showed no significant interaction between Group and Video, $F(1, 10) = 1.16$, $p = .307$, $\eta_p^2 = .10$. Thus, the participants in both groups looked for a significantly shorter duration to the last video than to the first video. The looking times were similar across the two groups.

Figure 3.8 *Looking Times Across the Two Groups for all Videos*



Note. Error bars represent 95% CIs.

The proportion of looking times towards the target ROI before and during movement were calculated and compared to assess if participants looked more towards the target object while it was being moved than before. The participants in the shape training group looked more towards the target ROI during movement than before movement started (M_{before} = 0.15, SD_{before} = 0.12; M_{during} = 0.68, SD_{during} = 0.11). The participants in the specific word training also looked more towards the target ROI during movement than before movement started (M_{before} = 0.23, SD_{before} = 0.19; M_{during} = 0.67, SD_{during} = 0.21). This was confirmed by results of a 2 (Group: shape training group vs specific word training group) x 2 (Time window: before vs during movement) ANOVA. Results showed a main effect of Time window, $F(1,10) = 94.51$, $p < .001$, $\eta_p^2 = .90$, but no main effect of

Group, $F(1, 10) = 0.17$, $p = .689$, $\eta_p^2 = .01$ or an interaction between Group and Time window, $F(1, 10) = 0.97$, $p = .348$, $\eta_p^2 = .08$. [4] Thus, the infants in both groups looked significantly more towards the target ROI while the object was being moved than before.[5]

3.3.3 Cognitive Assessments. To assess participants' cognitive abilities and rule out any significant delay, results from the two cognitive assessments were analysed.

3.3.3.1 Block Design Subtest. To assess participants' visual-spatial abilities, scores from the block design subtest were analysed. One participant of the specific word training group did not want to participate in the block design task, therefore is not included in this analysis.

The participants in the shape training group had a mean chronological age of 33.42 months and obtained scores equivalent to 33 months ($SD = 2.44$) in this task. There was a difference of -0.42 months ($SD = 4.54$) between their chronological age and their equivalent age, however this difference was not statistically significant $t(6) = 0.25$, $p = .811$, 95% CI = [-3.77, 4.6]. In the specific word training group, participants had a mean chronological age of 31.83 months and obtained scores equivalent to 33 months ($SD = 2.00$). There was a difference of +1.17 ($SD = 5.03$) between their chronological age and their equivalent age however this difference was not statistically significant $t(5) = -0.56$, $p = .595$, 95% CI = [-6.45, 4.11]. An independent samples t-test revealed that the difference between chronological age and the equivalent age was not statistically different between

[4] Additional analyses were conducted to assess if participants looked more towards the target ROI than to the face ROI and the distractor ROI. Results showed that before movement, participants did not show a preference for any ROIs, but looked more towards the target ROI during movement. See Appendix 4.

[5] An exploratory comparison was conducted between the total looking times in the attention tasks between typically developing children in Chapter 2 and late talkers in this chapter (Chapter 3). This analysis had the main aim of assessing whether late talkers attend to objects that are being shown to them for less time than typically developing children. Results showed that on average, late talkers looked similarly than typically developing children towards the first video, but looked less towards the remaining four videos. Note that results of this comparison should be taken with caution because the videos used in both chapters were different, and the age of both participant groups was also different. See Appendix 4.

groups $t(11) = -0.60$, $p = .560$, 95% CI = [-7.43, 4.24]. Therefore, the participants in both groups showed similar visual-spatial abilities in this task, and these abilities did not differ from what was expected on the basis of their chronological age.

3.3.3.2 Zoo Locations Subtest. To assess working memory, scores from the zoo locations subtest were analysed. The participants in the shape training group had a mean chronological age of 33.42 months and had scores in this subtest equivalent to 32.28 months (*SD* = 3.25). While there was a difference of -1.14 months (*SD* = 5.04) between their chronological age and their equivalent age, this was not statistically significant $t(6) = .59$, $p = .571$, 95% CI = [-3.52, 5.81]. The participants in the specific word training group had a mean chronological age of 31.57 months and obtained scores in this subtest equivalent to 32.14 months (*SD*= 3.48). There was a difference of +0.57 months (*SD* = 5.19) between their chronological age and their equivalent age, but this was not statistically significant $t(6) = -.29$, $p = .781$, 95% CI = [-5.37, 4.22]. An independent samples t-test revealed that the difference between chronological age and equivalent age was also not statistically significant between groups $t(12) = -0.62$, $p = .543$, 95% CI = [-7.67, 4.24]. Thus, participants in both groups had similar scores, and these scores did not differ from what it is expected for their chronological age.

3.3.4 First-Order Generalisation

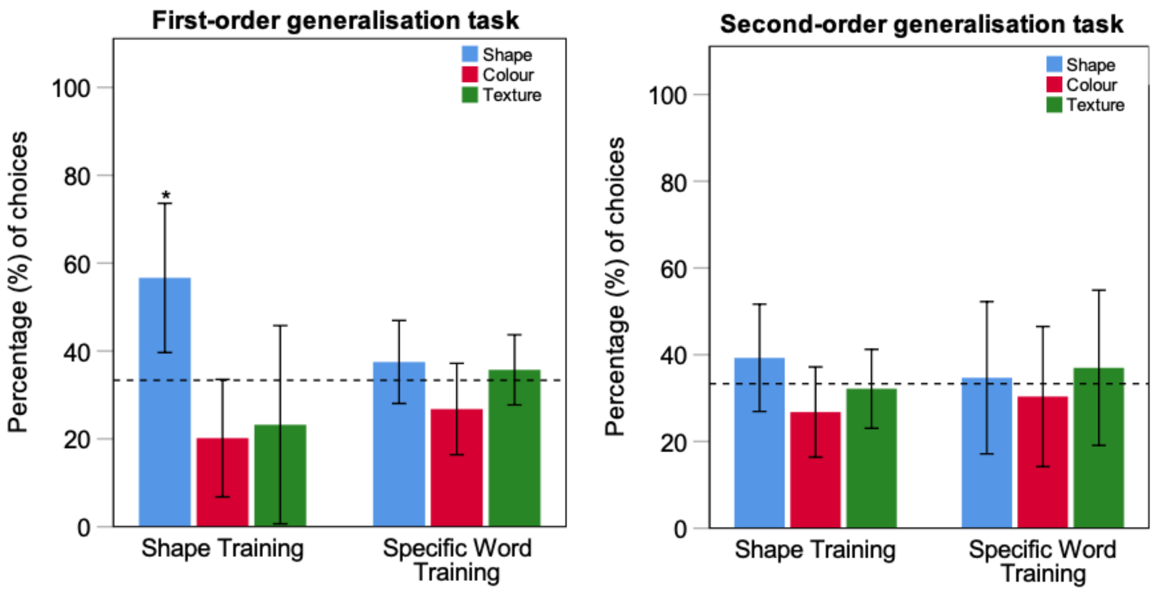
To assess the property by which participants preferred to generalise labels in the first-order generalisation task, the percentage of shape, colour and texture choices were analysed. The participants in the shape training group generalised labels mainly to objects sharing the same shape on 56.63% of the trials (*SD* = 18.37). With a Bonferroni adjusted alpha level of .016 per test (.05/3), results showed that the shape choices, in the shape training group were statistically significant above chance $t(6) = 3.35$, $p = .015$, 95% CI =

[6.30, 40.29]. In contrast, the participants in the specific word training group generalised labels mainly by shape 37.50% of trials (*SD* = 10.20) but this was not statistically significant from chance *t*(6) = 1.08, *p* = .321, 95% CI = [-5.26, 13.60]. The participants in the shape training group generalised labels by colour similarities in 20.15% (*SD* = 14.46) of all trials and by texture in 23.21% (*SD* =24.39) of all trials which were not statistically significant from chance (colour: *t*(6) = -2.41, *p* = .053, 95% CI = [-26.55, 0.19]; texture *t*(6) = -1.09, *p* = .315, 95% CI = [-32.67, 12.44]). In the specific word training group, participants generalised labels by colour similarities in 26.78% (*SD* =11.24) of all trials, and by texture in 35.71% (*SD* =8.62) of all trials. The percentage of choices was not different from chance for both properties (colour*:* *t*(6) = -1.54, *p* = .175, 95% CI = [-16.94, 3.85]; texture *t*(6) = 0.73, *p* = .492, 95% CI = [-5.59,10.36]).

A comparison between the percentage of shape choices between groups showed a trend towards significance *t*(12) = 2.40, *p* = .033, 95% CI = [1.82, 36.44]. In contrast, the colour and texture choices did not significantly differ between groups (colour: *t*(12) = -0.95, *p* = .357, 95% CI = [-21.71, 8.45]; texture *t*(12) = -1.27, *p* = .225, 95% CI = [-33.81,8.81]) (See Figure 3.9). Thus, while participants in the shape training group chose more shape matching objects, there was only a trend towards significance compared to the shape training group.

A regression analysis was conducted to explore if any of the following variables significantly predicted the percentage of shape choices: Group (shape training group or specific word training group), Expressive vocabulary at the start of the study, Sorting score, and Proportion of looking times towards the target after movement. Results showed only a main effect of Group (*p* =.028) (see Table 3.4). None of the other variables had a significant effect on the first-order generalisation task. Thus, the group that participants were in was the only variable that had a significant influence on the percentage of shape choices in the first-order generalisation, with participants in the shape training group choosing more shape matching objects than participants in the specific word training group.

Figure 3.9 *Percentage of Shape, Colour and Texture Choices in the First-Order and Second-Order Generalisation Tasks*



Note. Dotted lines represent chance level (33.3%). Asterisks indicate significant differences from chance (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$). Error bars represent 95% CIs of the means.

Table 3.4 *Summary of Linear Regression Model Predicting the Percentage of Shape Choices in the First-order Generalisation Task*

	Estimate	**SE**	**t value**	***p***
Intercept	10.92	13.05	0.83	.424
Group	20.27	7.75	2.62	.028*
Sorting score	0.30	0.24	1.20	.258
Expressive vocabulary at the start of the study	0.07	0.06	1.20	.257
Proportion of looking times towards target (after movement)	14.11	14.76	0.95	.364

Note: Asterisks indicate significant values (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

3.3.5 Second-Order Generalisation

In order to assess which property participants in both groups based their second-order generalisations on, the percentage of shape, colour and texture choices were analysed. In the second order generalisation task, with a Bonferroni adjusted alpha level of .016 per test (.05/3), results showed that participants in both groups chose at chance levels objects sharing the same shape (shape training group: M = 39.28%, SD = 13.36, $t(6)$ = 1.17, p = .283, 95% CI = [-6.40, 18.31]; specific word training group: M = 34.69%, SD =18.97; $t(6)$ = 0.19, p = .855, 95% CI = [-16.18, 18.91]). Even though participants in the shape training group chose 4.59% more shape matching choices than the specific word training group, this difference was not statistically different between groups $t(12)$ = 0.52, p = .610, 95% CI = [-14.52, 23.70].

In both groups, the percentage of colour choices did not differ from chance (shape training group: M = 26.78%, SD = 11.24, $t(6)$ = -1.54, p = .175, 95% CI = [-16.94,3.85]; specific word training group: M = 30.35%, SD =17.46, $t(6)$ = -0.45, p = .668, 95% CI = [-

19.12, 13.18]). Similarly, texture choices were also at chance levels (shape training group: M = 32.14%, SD =9.83, $t(6)$ = -0.31, p = .760, 95% CI = [-10.28,7.90]; specific word training group: M = 36.98%, SD =19.33, $t(6)$ = 0.50, p = .634, 95% CI = [-14.22, 21.54]) (See Figure 3.9). The percentage of choices was not statistically different between groups in either colour ($t(12)$ = -0.45, p = .657, 95% CI = [-20.67, 13.53]), or texture choices, ($t(12)$ = -0.59, p = .565, 95% CI = [-22.71, 13.01]). Therefore, I did not find evidence of participants showing a preference towards a specific property in the second-order generalisation task.

A regression analysis was also conducted to assess if the percentage of shape choices in the second-order generalisation task was predicted by any the following variables: Group (shape training group and specific word training group), Expressive vocabulary before the start of the study, Sorting score, and Proportion of looking times towards the target after movement. The results of the regression analysis showed no significant effects (see Table 3.5). Thus, the percentage of shape choices was not predicted by any of the variables in the model.

Table 3.5 *Summary of Linear Regression Model Predicting the Percentage of Shape Choices in the Second-order Generalisation Task*

	Estimate	**SE**	**t value**	***p***
Intercept	44.61	18.10	2.46	.035
Group	5.80	10.75	0.54	.602
Sorting score	-0.27	0.34	-0.80	.441
Expressive vocabulary at the start of the study	-0.01	0.08	-0.15	.879
Proportion of looking times towards target (after movement)	3.73	20.47	0.18	.859

3.3.7 Vocabulary Growth

3.3.7.1 Expressive Vocabulary. The participants' expressive vocabulary size at the start and end of the study was analysed to investigate the effects the interventions had in expressive vocabulary capacity at the end of the study. The participants in the shape training group produced 76.86 words (*SD* = 83.77) at the start of the study, and 149.14 words (*SD* = 151.35) at the end of the study. The participants in specific word training produced 62 words (*SD* = 46.04) at the start of the study, and 146.86 words (*SD* = 109.90) at the end of the study. A 2 (Group: shape training vs specific word training) x 2 (Testing time: before vs after) analysis of variance revealed a main effect of Testing time $F(1,12) = 15.15$ $p = .002$, $\eta_p^2 = .55$, but no significant main effect of Group $F(1,12) = 0.09$, $p = .761$, $\eta_p^2 = .00$, or interaction between Testing time and Group $F(1,12) = 0.02$, $p = .873$, $\eta_p^2 = .00$. Thus, expressive vocabulary growth increased similarly in both groups.

A regression analysis was conducted to explore if any of the following variables significantly predicted participants' expressive vocabulary size at the end of the study: Group (shape training group/specific word training group), Expressive vocabulary size at the start of the study, Sorting score, and Proportion of looking times towards the target after the movement started. A main effect of the number of words in participants' expressive vocabulary at the start of the study was found ($p < .001$). No other main effects were found (see Table 3.6). Thus, participants that started the study with a higher number of words in their expressive vocabulary finished the study with a higher number of words, independently of the group they were in, their sorting score and their proportion of looking times towards the target in the attention task.

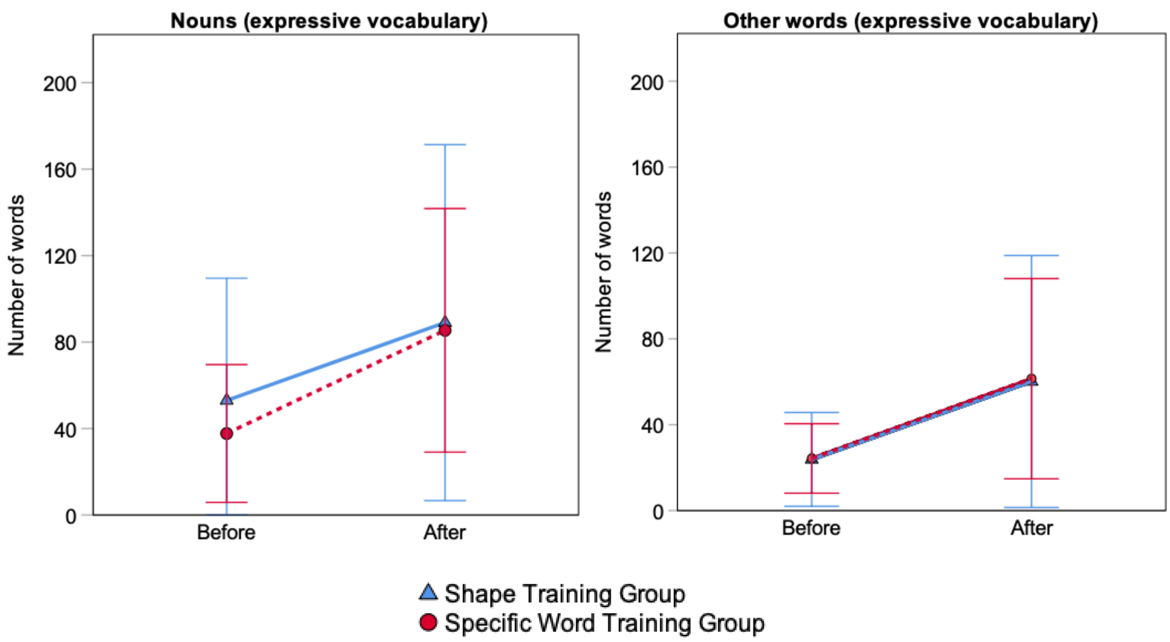
Finally, the numbers of nouns and other words in participants' expressive vocabularies were calculated and means compared between groups to assess if there was any difference in the vocabulary growth of a specific word type. At the start of the study, the participants in the shape training group produced on average 53 nouns (*SD* =61.13) and 23.85 other words (*SD* = 23.61). The participants in the specific word training group produced on average 37.71 nouns (*SD* = 34.43) and 24.28 other words (*SD* = 17.49). At the end of the study, the participants in the shape training group produced on average 89 nouns (*SD* = 89) and 60.14 other words (*SD* = 63.48), while the participants in the specific word training group produced on average 85.42 nouns (*SD* = 60.90) and 61.42 other words (*SD* = 50.41). The number of nouns and other words produced by all participants was then introduced to a 2 (Group: shape training vs specific word training), x 2 (Testing time: before and after) x 2 (Word type: nouns vs other words) ANOVA. Results showed a main effect of Testing time $F(1,12) = 15.15$ $p = .002$, $\eta_p^2 = .55$, and Word Type $F(1,12) = 10.67$, $p = .007$, $\eta_p^2 = .47$. There was no significant main effect of Group $F(1,12) = 0.02$, $p = .873$, $\eta_p^2 = .00$. Similarly, there was no significant interaction between Testing time and Group $F(1,12) = 0.09$, $p = .762$, $\eta_p^2 = .00$, Word type and Group $F(1,12) = 0.49$, $p = .495$, $\eta_p^2 = .04$, and Testing time and Word type, $F(1,12) = 0.42$ $p = .526$, $\eta_p^2 = .03$. The three-way interaction between Testing time, Word type and Group was also not significant $F(1,12) = 0.47$, $p = .504$, $\eta_p^2 = .03$. Thus, participants in both groups had a similar increase in their expressive vocabulary in both word types.

Table 3.6 *Summary of Linear Regression Model Predicting Expressive Vocabulary at the End of the Study*

	Estimate	SE	t value	*p*
Intercept	59.38	59.55	0.99	.344
Group	-20.73	35.38	-0.58	.572
Sorting score	-0.76	1.13	-0.67	.518
Expressive vocabulary at the start of the study	1.77	0.27	6.41	< .001*
Proportion of looking times towards target (after movement started)	13.58	67.37	0.20	.844

Note: Asterisks indicate significant values (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

Figure 3.10 *Nouns and Other Words in Participants Expressive Vocabulary Before and After Training*



Note. Error bars represent 95% CIs of the means.

3.3.7.2 Receptive Vocabulary. To assess receptive vocabulary, the number of words all participants understood at the start and end of the study were calculated and compared between groups. The participants in the shape training group started the study with 288.43 words (*SD* = 87.11) and finished the study with 355.29 words (*SD* = 106.81). The participants in the specific word training group started the study with 207 words (*SD* = 95.96) and finished their study with 263.86 words (*SD* = 107.19). To assess overall receptive vocabulary increase across the study, a 2 (Group: shape training vs specific word training) x 2 (Testing time: before vs after) ANOVA was conducted. Results showed a significant main effect of Testing time $F(1,12) = 17.45$, $p = .001$, $\eta_p^2 = .59$, but no significant main effect of Group $F(1,12) = 2.85$, $p = .117$, $\eta_p^2 = .19$, or interaction between Testing time and Group $F(1,12) = 0.11$, $p = .741$, $\eta_p^2 = .00$. Thus, receptive vocabulary growth increased similarly in both groups.

A regression analysis was conducted to assess if the total number of words in participants' receptive vocabulary at the end of the study was predicted by the following variables: Group (shape training group/ specific word training group), Receptive vocabulary at the start of the study, Sorting score, and Proportion of looking times towards the target after movement. Only a main effect of the number of words in receptive vocabulary at the start of the study was found ($p = .006$) (see Table 3.7). Thus, the participants that started the study with a higher number of words in their receptive vocabulary also finished the study with a higher number of words, independently of the group they were in, their sorting task score and the proportion of looking times towards the target in the attention task.

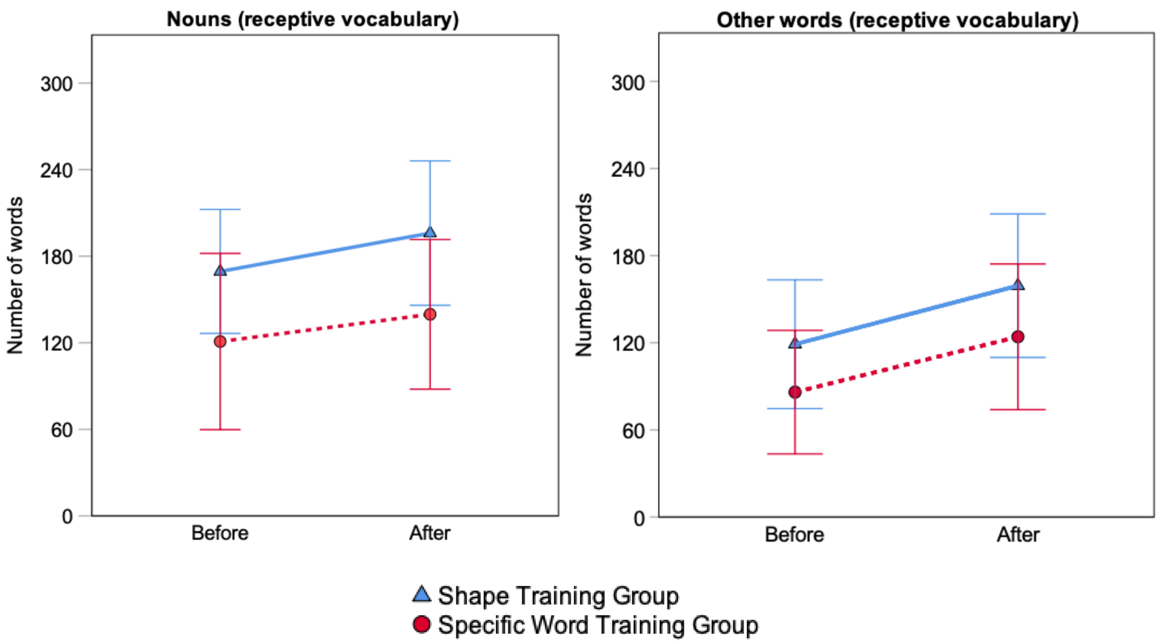
Finally, the number of nouns and other words in participants' receptive vocabulary was calculated and compared between groups to assess if there was a difference in vocabulary growth of a specific word type. At the start of the study, the participants in the shape training group understood on average 169.43 nouns (*SD* = 46.48) and 119 other words (*SD* = 47.92), while the participants in the specific word training group understood on average 120.85 nouns (*SD* = 66.03) and 86 other words (*SD* = 45.97). At the end of the study, the participants in the shape training group understood 198 nouns (*SD* = 54.10), and 159.28 (*SD* = 53.39) other words. The participants in the specific word training group understood 139.71 nouns (*SD* = 56.03), and 124.14 other words (*SD* = 54.23). The number of nouns and other words understood by participants was then introduced to a 2 (Group: shape training vs specific word training), x 2 (Testing time: before and after) x 2 (Word type: nouns vs other words) analysis of variance. Results showed a main effect of Testing time $F(1,12) = 17.53$, $p = .001$, $\eta_p^2 = .59$, and Word type $F(1,12) = 18.70$, $p = .001$, $\eta_p^2 = .60$. There was no main effect of Group $F(1,12) = 2.85$, $p = .117$, $\eta_p^2 = .19$, no significant interaction between Testing time and Group $F(1,12) = 0.11$, $p = .745$, $\eta_p^2 = .00$, no significant interaction between Word type and Group $F(1,12) = 1.33$, $p = .271$, $\eta_p^2 = .10$, and no significant interaction between Testing time and Word type, $F(1,12) = 1.65$, $p = .221$, $\eta_p^2 = .12$. The three-way interaction between Testing time, Word type and Group was also not significant $F(1,12) = 0.04$, $p = .831$, $\eta_p^2 = .00$. Thus, participants in both groups had a similar increase in *nouns* and *other words* over time in their receptive vocabulary.

Table 3.7 *Summary of Linear Regression Model Predicting Receptive Vocabulary at the End of the Study.*

	Estimate	SE	t value	*p*
Intercept	21.41	60.92	0.35	.733
Group – Shape Training	31.54	43.17	0.73	.484
Sorting score	0.60	1.21	0.49	.630
Total number of words before (receptive vocabulary)	0.85	0.24	3.57	.006*
Proportion of looking times towards target (after movement started)	58.70	72.78	0.80	.441

Note: Asterisks indicate significant values (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$).

Figure 3.11 *Nouns and Other Words in Participants Receptive Vocabulary Before and After Training*



Note. Error bars represent 95% CIs of the means.

3.4 Discussion

The main aims of the current study were to assess if late talkers can be taught a shape bias for object naming and generalisation and the effect that this had in vocabulary growth across the study. Two different interventions were administered to two groups of late-talking children: a shape training or a specific word training group. It was predicted that the participants in the shape training group would base their generalisations of known labels (first-order generalisation) and novel labels (second-order generalisations) by shape. It was also predicted that the participants in the specific word training group would not base their generalisation by any specific property. Similarly to Smith and colleagues (2002), it was also predicted that only the shape bias training would boost vocabulary growth.

The current study has three main findings. First, it is apparent that late talkers can be taught to use shape as the main property for generalising known object names. This was shown by their ability to carry out first-order generalisations based on shape similarities. Second, contrary to my initial predictions, no evidence was found that late talkers are able to extend their knowledge about the importance of shape for particular objects and use it for novel objects (second-order generalisation). Thus, a preference towards shape seems to be limited to only objects they have had experience with. Third, contrary to what was predicted, no evidence was found that a shape bias intervention facilitates expressive or receptive vocabulary growth outside the laboratory more than a training programme that teaches specific words. It is important to note that the current findings were achieved with a smaller sample size than required according to the power analysis conducted prior to the start of the study. While the current study had only two participants fewer than the study conducted by Smith and colleagues (2002) and had more participants than other longitudinal interventions for late talkers (e.g. Alt et al., 2014; Weismer et al., 1993), a formal sample size calculation denoted that at least 24 late talkers were required for the study. Therefore, the current results should be taken with caution as further studies with bigger samples are required to confirm these findings.

The current findings support previous research in two ways. First, similarly to previous research (Jones, 2003), I found no evidence that late talkers naturally develop a shape bias. In the current study, participants in the specific word training group study did not show a preference for shape but, contrary to some late talkers in Jones (2003), they did not show a preference for texture either. Second, similarly to Singleton and Anderson (2020), by highlighting shape, late talkers in the shape training group were able to learn to use this property for the generalisation of known labels to exemplars of the same category. In Singleton and Anderson's (2020) study, this was achieved by showing gestures referring to the object's shape while the object was being presented. In the current study, this was done through repetitive exposure with objects organized and named according to their shapes, and with the presentation of contrasting objects. Together, these studies suggest that late talkers are able to learn the importance of shape for first-order generalisation.

3.4.1 Late Talkers Can Learn to Use Shape for Known Objects But do Not Do It For Novel Objects

To understand how a lack of shape bias for second-order generalisation affects vocabulary learning, it is important to understand how the shape bias is developed. Smith and colleagues (2002) proposed that the development of a shape bias is a four-step process. In the first step, infants learn that a specific object they play with has a specific name (e.g. a car). After multiple exposures to other objects also labelled as *car*, the infant learns that all objects with a shape of a car will also be called *car*. This first-order generalisation can allow infants to start forming categories of objects that they have encountered before. In the current study, through repetitive exposure to objects organized by shape and their labels, late talkers in the shape training group were able to map those specific labels to the specific objects that they frequently played with (e.g. the name *zav* referred to a specific yellow round object with three cylindrical arms they played with). Then, after repetitive exposure, they learned that all objects with, for example, a zav-shape would also be called *zav*, and therefore were able to generalise this name to other objects with the same shape. According to Smith and colleagues (2002), after being exposed to multiple sets of objects organized by shape and their names, in the third step, typically developing children start learning that in general objects tend to be organized in categories with clear shape similarities (second-order generalisation). So, finally, they learn that one, in general, can extend known and novel labels to objects based on shape similarities. At this stage, infants do not need repetitive experience with objects and object names in order to be able to know which property is relevant (i.e. shape) for object naming and categorisation. Therefore, developing a shape bias can be considered as a way of learning how to learn nouns.

The fact that late talkers in the current study could only generalise labels of known object by shape suggests that they have not learned that shape is a property that can provide information of what objects are and their names. This could mean that late talkers may require direct and constant experience with the same objects and the same names in order to map the novel word to their referent. This is an inefficient strategy and would require additional effort and time, making noun learning a slower and more complicated process than how it should be. So, a lack of shape bias for second-order generalisation means that late talkers lack a quicker way to learn and generalise nouns.

But why can late talkers learn to use shape for first-order generalisations but not for second-order generalisations? It has been suggested that the development of a shape bias required the development of different cognitive processes (Kucker et al., 2019). Thus, it is possible that late talkers' difficulty for establishing a shape bias may be related to deficits in processes required for the development of the shape bias, and not only in an inability to specifically learn the importance of shape in word learning.

An important word learning mechanism that could be affected in late-talking children is statistical learning. Limited research has been conducted with late talkers. However, research done in children diagnosed with Developmental Language Disorder (DLD) may help to understand the difficulties observed in late talkers. This is because the two are overlapping groups (some late talkers will be diagnosed with DLD, but not all children with DLD were late talkers) and share two important characteristics: a delay in language development and a lack of a shape bias (Collisson, Grela, Spaulding, Rueckl, & Magnuson, 2015). Research has found that children diagnosed with DLD tend to show deficits in statistical learning and in tasks that require fast mapping of words to novel referents (Haebig, Saffran, & Ellis Weismer, 2017; Leonard, 1998). Thus, they require additional exposure to stimuli when learning about new things in order to achieve the desired result (Haebig et al., 2017; Rice, Oetting, Marquis, Bode, & Pae, 1994). It can be suggested that similarly to DLD, late talkers may also require more exposure to learn the same things as their typically developing peers.

Deficits in statistical learning can also be enhanced by the fact that attention abilities can be affected in late talkers. MacRoy-Higgins and Montemarano (2016) found that late talkers, compared to typically developing infants, paid less attention to objects used during their word learning intervention. There is the possibility that late talkers are not attending to the stimuli around them enough to map a word to its referent and to identify that objects of the same category share the same shape and the same name. In the current study, I did not find evidence that children's looking behaviour in the attention task was a predictor of their robustness of the shape bias. However, I did not directly assess participants' attention towards the stimuli presented to them during the training sessions. Instead, I assessed joint and sustained attention as a separate task. I can then hypothesise that a reduced attention towards what is being presented may contribute to a difficulty in learning through statistical regularities and associations.[6] Future studies should look at directly assessing attention towards the objects while they are being trained by potentially recording the training sessions, and comparing this to a typically developing population sample.

Potential deficits in statistical learning and attention, accompanied by deficits in fast-mapping tasks (Ellis Weismer et al., 2013) suggest that late talkers show difficulties in the initial stages of word learning. This can have a negative cascading effect in the development of the shape bias. If late talkers have an initial difficulty in attending to their surroundings and identifying what two objects share in common in order to be called the same, they will struggle to identify that in general, objects can be organised by shape. Thus, they will not develop a rule (i.e. the shape bias) to assist their word learning.

[6] Note that an exploratory comparison between the total looking times in the attention tasks between typically developing children in Chapter 2 and late talkers in this chapter (Chapter 3) showed that on average, late talkers looked similarly than typically developing children towards the first video, but looked less towards the remaining four videos. Note that results of this comparison should be taken with caution because the videos used in both chapters were different, and the age of both participant groups was also different. See Appendix 4.

Similar to the function training study in Chapter 2, one limitation of the current study is that it is not known if seven weeks of training are enough to demonstrate that late talkers do not develop a shape bias as typically developing children. It could be that, since late talkers can generalise labels after multiple exposures, and considering that they may have deficits in statistical learning and fast-mapping, a longer intervention is required. Future studies should look at a modified version of the Smith and colleagues (2002) intervention with potentially more sets of stimuli, more sessions and more repetition to confirm if late talkers do not learn a shape bias or if they do, but require more support than what was offered to them in the seven weeks of the current intervention.

While a shape bias has been shown to be useful for object naming and generalisation, other word learning biases can also be relevant in infancy and early childhood (see Chapter 2). The use of different word learning biases has been investigated in populations where language delays are common, but where children do still acquire words even if a shape bias is not present. For example, research has shown that some children with ASD also lack a shape bias (Tek, Jaffery, Fein, & Naigles, 2008). And while children with ASD can have smaller vocabularies, this is not always the case. I will not go in detail on how children with ASD learn words, however, Tek and Naigles (2017) suggest that the acquisition of words and the shape bias in ASD may not be as interconnected as in typically developing children. Research has shown that they may be using other useful word learning strategies such as generalising by function instead of shape (Tek & Naigles, 2017). As shown in chapter 2, a function bias can be as beneficial as a developing shape bias for word learning and generalisation during the first years of life. Thus, while shape bias has been the typical path to learn words, it is not the only way. Further research assessing if late talkers could benefit from using other word learning biases that are also useful during the first years of life, such as a function bias, should be conducted.

3.4.2 Late Talkers Did Not Show a Significant Vocabulary Growth

No differences in expressive or receptive vocabulary growth were found between the two participant groups in this study. However, the results of the current study still showed an expressive vocabulary increase comparable to Smith and colleagues (2002). In the current study, participants in the shape training group produced 36 more novel object names at the end of the study as reported by their parents. In comparison, participants in Smith and colleagues (2002) produced 41.4 more novel object names. It is important to note that while the number of novel words acquired in both studies was very similar, participants in Smith and colleagues (2002) study were 17 months, and participants in the current study were between 24 and 47 months of age. The increase observed in both groups in the current study was also higher to what late talkers without an intervention can learn (Rescorla et al., 2000). In a study conducted by Rescorla and colleagues (2000), it was shown that late talkers tend to learn between 3.34 and 5.14 words per week, and participants in the current study learned around 8.03 new words per week in the shape training group and 9.42 more words per week in the specific word training group. However, the fact that the increase observed in the current study is similar to the increase observed in 17-month olds that have developed a shape bias (Smith et al., 2002) suggests that participants in this study did not learned as many words as expected for children their age.

When comparing the current results with other longitudinal interventions for late talkers, important differences in expressive vocabulary growth were also found. Expressive vocabulary growth in the current study was higher than the one observed in Robertson and

Weismer (1999) where late talkers between 21 and 30 months of age learned on average, two novel words per week. However, this increase was smaller than the one observed in Alt and colleagues (2014), where it was reported that late talkers between 23 and 29 months of age showed an average increase of 21.60 total words per week. Interestingly, in Alt and colleagues' (2014) study, researchers taught a set of words through cross-situational statistical learning. Researchers proposed that their results were due to the fact that they used highly variable linguistic input variability and contextual diversity. This helped late talkers to identify what was constant during each naming event allowing them to identify what was relevant for object naming and to create a rule on how words could be learned. If we consider that late talkers may have difficulties in identifying regularities in naming experiences, intervention using techniques such as the ones implemented by Alt and colleagues (2014) may help late talkers overcome these deficits.

To my knowledge, no studies have examined how to boost receptive vocabulary in late talkers. It can only be hypothesized that similarly to the expressive vocabulary, even though late talkers in the shape training group learned on average 56.85 new words and participants in the specific training group learned 66.85, they did not learn them fast enough to catch up with their typically developing peers. Future studies should look into this area of word learning to be able to compare if an increase as the one observed in the study is significantly different from what would be expected from late talkers.

Three important limitations could have contributed to a lack of a significant vocabulary growth, and even potentially to a difficulty for a second-order generalisation by shape. First, Smith and colleges' (2002) study focused on boosting expressive language. However, late talkers in the current study had expressive and receptive delays. Therefore, it may be that a shape-based intervention does not provide any significant benefits when additional receptive delays are present. The second limitation was that since both late talkers and children with DLD are characterized by a delay in language development and a lack of a shape bias (Collisson et al., 2015), it is possible that participants in the current study could end up being diagnosed with DLD. To address this limitation, a one year follow up was planned. However, due to university closures in response to the COVID-19 pandemic, I was not able to conduct this follow up with all participants. Only two participants were contacted before the university closures and at that time none of them had received a diagnosis of any additional conditions or disorders. The third limitation was that there was great variability in the number of words children knew and produced at the beginning of the study. Participants' initial expressive vocabulary ranged from 1 word to 186 words, and their receptive vocabulary ranged from 39 words to 396 words. Future studies should look at the whether a shape bias intervention may be only useful for late talkers with certain number of words (e.g. participants with very limited vocabularies, or vocabularies smaller than 50 words) or comparing the benefits for late talkers with only expressive delays and late talkers with expressive and receptive delays.

3.4.3 Conclusions

In summary, this study is one of the first studies to teach the shape bias as an intervention for vocabulary learning in late talkers, and one of the first to highlight shape as a way of promoting word learning (see also Singleton & Anderson, 2020). Results showed that late talkers can learn to use shape as the predominant property for extending known labels (first-order generalisation). However, they cannot extend this knowledge and use it for novel labels (second-order generalisation). Consequently, I have found no evidence that a shape-based intervention adds any additional benefit for general word learning than an intervention focused on teaching specific words. Additional potential deficits in statistical learning and attention may have influenced a lack of shape bias for second-order generalisation. Therefore, a modified version of a shape-based intervention also targeting those additional potential deficits could provide more information regarding whether late talkers can, in fact, acquire a shape bias or not.

CHAPTER 4

Vocabulary and the Shape Bias in Children Born Preterm

Abstract

Children born preterm (before 37 weeks of gestation) often have smaller vocabularies compared to full-term children. In children with language delays, smaller vocabularies have been related to the absence of a shape bias. However, to date no studies have investigated the word learning biases children born preterm use for object naming and generalisation. The main aims of the current pilot study were to explore if children born preterm show a shape bias for noun generalisation, to assess their vocabulary size and composition, and to investigate the relationship between the shape bias and vocabulary size, cognitive and motor development. In the pilot study reported in this chapter, a group of 10 children born preterm (mean GA 31.40 months) and a group of 8 full-term children (mean GA 39.25 months) aged between 24 to 41 months were assessed in two different visits. The participants were presented with a noun extension task that assessed which property participants base their generalisations on, and two standardised tests that assessed their cognitive and motor development. The children's parents filled in a vocabulary checklist and a general development and socioeconomic status questionnaire. The results of the current pilot study showed that children born preterm had a shape bias for noun generalisation, but some of them use it to a lesser extent than their full-term peers. The results also showed that children born preterm can have similar vocabularies to their full-term peers, and that they can perform within the expected range for their chronological age in cognitive and gross motor assessments. Further research is required to confirm these findings as this was a pilot study with a small sample size.

4.1 Introduction

Early word learning is an important component of language development. For young children, being able to understand others and express what they think allows them to communicate successfully. Previous research has shown that children born preterm (born before 37 completed weeks of gestation) are at risk of significant delays in language acquisition, even if they do not have a diagnosis of a severe condition or impairment that could affect their development (Sansavini et al., 2010; Zambrana et al., 2016; Zimmerman, 2018). Therefore, it is important to investigate how children born preterm without any severe conditions, disorders or impairments learn words and which word learning biases influence their vocabulary development.

4.1.1 Vocabulary Learning and the Shape Bias in Children Born Preterm

Typically, studies investigating language development in children born preterm have used standardised language assessments to compare if they are developing in step with their full-term peers. In a meta-analysis conducted by Zimmerman (2018) it was shown that in around 60% of the studies analysed, children born preterm with no severe conditions, disorders, or impairments had lower scores in language assessments compared to full-term children. Therefore, while some children born preterm may seem to be developing as expected for their age, differences in language development can still be observed.

Previous research has found that one important difference between preterm and full-term children is vocabulary size, with children born preterm often having smaller vocabularies than full-term children (e.g. Brósch-Fohraheim, Fuiko, Marschik, Resch, & Liu, 2019; Kern & Gayraud, 2007; Stolt, Haataja, Lapinleimu, & Lehtonen, 2009; Zimmerman, 2018). Research has also shown that the children born preterm with the smallest vocabularies tend to be extremely preterm children, while differences are less substantial for moderately and late preterm children (Foster-Cohen et al., 2007; Kern & Gayraud, 2007). For example, Kern and Gayraud (2007) showed that at 2 years of age, children born extremely preterm can have between 62 and 100 words less than full-term children, children born very preterm can have between 22 and 30 words less, and children born moderately preterm can have only between 13 and 15 words less than full-term children. Stolt, Haataja, Lapinleimu, and Lehtonen (2009) found more striking differences using the Finnish version of the MacArthur Communicative Development Inventory. In their study, full-term children between 9 and 24 months had receptive vocabularies 1.7 times larger than their premature peers. Expressive vocabulary was also 1.6 times larger in full-term children than in children born preterm, but only compared to children born preterm that also had additional conditions or disorders and only at 24 months of age. Children born preterm with no other conditions or disorders in the study conducted by Stolt and colleagues (2009) showed no differences in expressive vocabulary. Thus, some children born preterm may be learning significantly fewer words than full-term children.

A few studies have gone beyond investigating the differences in vocabulary size between premature and full-term children, and have examined differences in the composition of their vocabularies. Results investigating this are mixed. On the one hand, some studies have found no significant differences in the composition of their receptive and expressive vocabularies in most word categories. For example, Stolt and colleagues (2009) found that children born preterm can have the same proportion of nouns, verbs, social terms, and adjectives, but can have a smaller proportion of grammatical function words (i.e. words such as *the, to,* among others). On the other hand, some studies have found significant differences in most types of words, mainly in children born extremely preterm and very preterm. For example, Kern and Gayraud (2007) found that 2-year-olds born extremely preterm and very preterm can have a smaller proportion of nouns and predicates compared to their full-term peers. A smaller proportion of nouns in children's vocabulary is interesting as in typical development *nouns* is the category of words that children learn the most at this age (Booth & Waxman, 2009; Gentner, 1982; Sandhofer et al., 2000). A difference in vocabulary composition (i.e. a smaller proportion of nouns than in full-term children) might mean that their vocabulary development is different from that of full-term children.

So far, we have identified that vocabulary size and composition of children born preterm can differ to that of full-term children in two ways. First, vocabulary size can be smaller in children born preterm (e.g. Brósch-Fohraheim et al., 2019; Kern & Gayraud, 2007; Stolt et al., 2009; Zimmerman, 2018). Second, vocabulary composition in some children born preterm can be different from what would be typically expected (e.g. Kern & Gayraud, 2007). While typically developing full-term children learn mainly object names (i.e. nouns) (Booth & Waxman, 2009; Gentner, 1982; Sandhofer et al., 2000), in some studies, children born preterm do not seem to know the same proportion of nouns than their full-term peers (Kern & Gayraud, 2007). It could be suggested that differences in vocabulary development like these ones can be due to the fact that children born preterm tend to achieve developmental milestones later than full-term children (Cusson, 2003). However, a smaller vocabulary and a different vocabulary composition could also suggest that they are learning words differently.

One way to understand why children born preterm may have smaller vocabularies than full-term children is by assessing the word learning biases that children use during the first years of life. One bias that has strongly been associated with vocabulary development is the shape bias, which typically developing children start using as a word learning strategy at around 24 months of age (Hupp, 2015; Kucker et al., 2019; Landau et al., 1998b; Perry & Samuelson, 2011). Around the same time, an acceleration in vocabulary acquisition occurs

(Gershkoff-Stowe & Smith, 2004; Jones, 2003), mainly for words referring to object names. Thus, it has been suggested that these two events are related to each other (Gershkoff-Stowe & Smith, 2004). Additionally, in populations with language delays, a lack of a shape bias has been linked to a difficulty in the acquisition of words (Colunga & Sims, 2012; Jones, 2003; for a detailed discussion see also Chapter 3). It may be that, similarly to late talkers (see Chapter 3), children born preterm are not using the same word learning biases than typically developing children. Therefore, investigating early vocabulary development and the role of the shape bias in this population can contribute to the understanding of why children born preterm can have smaller vocabularies with a smaller proportion of nouns compared to their full-term peers.

4.1.2 Cognitive and Motor Development in Children Born Preterm

Research has shown that language and cognitive development are two areas of development that are interconnected (Deák, 2014). Thus, language influences cognitive development, and cognitive development can play a role in language development. Previous research has shown that this relationship can also be found for the development of the shape bias (Kucker et al., 2019). According to Kucker and colleagues (2019), the development of the shape bias is influenced by cognitive processes, such as memory and attention skills. Therefore, when assessing vocabulary development and the shape bias, it is also important to investigate how these are related to general cognitive development.

Research investigating cognitive development in children born preterm has found important differences with their full-term peers (e.g. Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2016; Kern & Gayraud, 2007; Marchman, Feldman, Gresch, Loi, & Fernald, 2018; Ross, Demaria, & Yap, 2017; Yaari et al., 2018). For example, studies with children between 3 and 6 years of age have found that children born preterm perform less well than their full-term peers in memory tasks (Baron, Kerns, Mller, Ahronovich, & Litman, 2012; Böhm, Smedler, & Forssberg, 2004; Caravale et al., 2005; Jongbloed-Pereboom, Janssen, Steenbergen, & Nijhuis-van der Sanden, 2012). Interestingly, differences have also been found within premature groups, suggesting that the more premature, the more difficulties children will have in this area (Baron et al., 2012). Children born preterm tend to also perform below their full-term peers in terms of visual-spatial abilities (Caravale et al., 2005; Geldof, van Wassenaer, de Kieviet, Kok, & Oosterlaan, 2012; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2004). This would suggest that even children born preterm that seem to be developing just like their full-term peers can still show deficits that can put them at a disadvantage in different areas of cognitive development.

Since cognitive development in children born preterm has been widely investigated, it is not a surprise that research about general intelligence (IQ) in this population has been undertaken. In general, most children born preterm with no significant conditions, disorders, or impairments tend to have IQ scores within the average range (Böhm et al., 2004; Caravale et al., 2005; Romeo et al., 2012; Sansavini et al., 2010). Nevertheless, their scores tend to be below the scores of full-term children (Böhm et al., 2004; Caravale et al., 2005; Sansavini et al., 2010). Similar results have been found for non-verbal measurements of IQ (Böhm et al., 2004; Magill-Evans et al., 2016). Thus, while children born preterm can seem to perform in the average general intelligence range expected for their age, they can still perform less well than their full-term peers.

Another important area of development that has been linked to language development in children born preterm is motor development. Research has shown that motor development during the first years of life is related to the development of language in typically developing children (Alcock & Krawczyk, 2010; Gonzalez, Alvarez, & Nelson, 2019; Iverson, 2010). But also that delays in early motor development can be related to delays in language and cognitive development in children born preterm (Benassi et al., 2016; Ross et al., 2017; Zuccarini et al., 2017). Motor delays in children born preterm can be observed since the first years of life (Yaari et al., 2018) and are more predominant in preterm children born with very low birth weight (Ross et al., 2017) and less predominant in late preterm children (Prins, von Lindern, van Dijk, & Versteegh, 2010). Thus, when assessing language development, motor development should also be assessed.

4.1.4 The Current Study

The current pilot study had three main objectives: 1) to assess whether children born preterm show a shape bias for noun generalisation 2) to assess vocabulary size and composition, and 3) to investigate the relationship between the shape bias and vocabulary size, cognitive development and motor development. This study was a small-scale pilot study with a small sample size. To my knowledge, no previous research has been conducted regarding the shape bias in children born preterm. Thus, a pilot study can provide preliminary evidence of potential differences between children born preterm and full-term children in terms of the shape bias and its relationship with vocabulary and general cognitive and motor development. Additionally, this study aims to inform future studies with regards to methodologies and analyses that can be used to assess shape bias in children born preterm.

In the current pilot study, preterm and full-term children between 24 to 41 months of age were assessed with a noun extension task and a standardised cognitive test. The noun extension task assessed if participants showed a shape bias for noun generalisation, and the standardised cognitive test assessed if participants showed any cognitive delays. The participants' parents answered a motor development interview and filled in a vocabulary checklist and general development and socioeconomic questionnaire. The motor development questionnaire was used to assess if participants showed any significant motor delays. The vocabulary checklist was used to determine expressive and receptive vocabulary size and composition. The general development and socioeconomic questionnaire was used to assess participants' environment and to identify any factors that could affect their development. Assessing socioeconomic status and general development in children born preterm is important because factors such as mothers' education, socioeconomic status (Gross, Mettelman, Dye, & Slagle, 2001; Patra, Greene, Patel, & Meier, 2016) or birth order (Kern & Gayraud, 2007) can influence their cognitive and language development.

Following previous research, I expected for children born preterm to have a less robust shape bias than full-term children and smaller vocabularies with fewer nouns. I also expected that participants with smaller vocabularies would also show a less robust shape bias. Finally, I also expected for children born preterm to have lower scores than full-term children in all motor and cognitive assessments, but still within the average range of what is expected for their chronological age. Note that chronological age was used instead of corrected age because in clinical assessments, corrected age is typically only used up until 24 months of age for children born preterm that do not have any conditions, disorders or impairments (Bernbaum, 2016; NICE, 2017), and participants in this study were older than that.

4.2 Method

4.2.1 Participants

Eighteen children were divided into two groups: preterm group (10 children, 5 girls, *M* = 34 months; *SD* = 6.35; range: 24 – 41 months) and full-term group (8 children, 3 girls, *M* = 33.50 months; *SD* = 6.36; range: 24 - 41 months). Participants in the preterm group were born between 25 and 37 weeks of gestation (*M* = 31.40, *SD* = 3.94), and participants in the full-term group were born between 38 and 41 weeks of gestation (*M* = 39.25, *SD* = 1.03). Eight participants in the full-term group were age-matched to eight participants in the preterm group in months +/- 3 days. Two participants in the preterm group did not have an aged match participant because two full-term children were not able to be tested due to university closures related to the Covid-19 pandemic.

All participants were monolingual English speakers from Birmingham and the surrounding areas. The participants' parents reported no history of hearing or visual impairments, or developmental, cognitive, or neurological disorders. Parents did not report problems during pregnancy. In the preterm group, parents of 7 children reported problems during or after delivery: six preterm infants required oxygen at birth for a period between one month to 10 months, two had jaundice, and one had sleeping apnea and reflux. In the full-term group, one parent reported problems during or after the delivery: the child had a low heart rate during childbirth, but no further intervention was required. See Table 4.1 for participant characteristics.

The participants' parents did not report any language or motor delays. This was true for both groups. Based on parental report, the participants in the preterm group started talking at 15.22 months (*SD* = 6.11), and the participants in the full-term group started talking at 11.21 months (*SD* = 3.38). Even though children in the preterm group started talking, on average, four months after children in the full-term group, this difference between groups was not significant, $t(14) = 1.55$, $p = .143$. Based on parental report, participants in the preterm group started walking at 15.44 months (*SD* = 2.55), and participants in the full-term group started walking at 15.07 months (*SD* = 5.57). This difference was also not significant between groups, $t(14) = .179$, $p = .860$.

Participants were recruited through community groups, playgroups, and the Infant and Child Lab database of the University of Birmingham. All of the participants were assessed at the Infant and Child Lab (University of Birmingham) during two sessions that lasted approximately 60 minutes each. One additional participant in the preterm group was assessed but withdrew from the study before completing all assessments.

The study was approved by the Ethical Committee of the University of Birmingham. Parents were reimbursed for their travel expenses, and infants received a sticker after each lab visit, as well as a book and a "Junior Scientist" diploma at the final visit.

4.2.1.1 Socioeconomic Status Calculation. The same procedure as in Chapter 2 was used to calculate socioeconomic status in this study, namely by calculating the average of the three following scores: parents' education score, parents' occupation score, and household income score. See below for more information on how each score was calculated. Note that for one participant, no household income was reported, therefore socioeconomic status was based on the mean of the parents' education score and the parents' occupation score.

4.2.1.1.1 Parent Education. A 4-point scale was used to determine each parent's education, with 1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education. The average education score of both parents was calculated and then converted to a value between 0 to 1.

4.2.1.1.2 Parent Occupation. Occupation of all parents was classified using the nine levels of the Office for National Statistics - Standard Occupational Classification Hierarchy (Standard Occupational Classification (SOC), 2010) and each parent was assigned a score from 1 to 9, where 9 was the highest value and 1 the lowest. The average score of both parents was calculated, apart from families with a stay at home parent, for which the occupation score was based only on the parent that worked in paid employment. This score was then converted to a value between 0 and 1.

4.2.1.1.3 Household Income. Income was measured on a 4-point scale (1 = less than £14,000, 2 = £14,001 - £24,000, 3 = £24,001 - £42,000, 4 = more than £42,000). This score was then converted to a value between 0 and 1.

Table 4.1 *Participants Characteristics*

	Preterm group			**Full-term group**		
	n	***M***	***SD***	***n***	***M***	***SD***
Age at start of the study (months)		34.00	6.35		33.50	6.36
Gender						
Male	5			5		
Female	5			3		
Week of pregnancy/gestation		31.40	3.94		39.25	1.03
Weight at birth						
Up to 2lb 3 oz	2			0		
2lb 4 oz to 3lb 5oz	2			0		
3lb 6oz to 5lb 7 oz	5			0		
5lb 8oz to 9ln 14oz	1			7		
9lb 15oz or over	0			1		
Age of first words (months)		15.22[a]	6.11		11.21[a]	3.38
Age when started walking (months)		15.44[b]	2.55		15.07[b]	5.57
Birth order						
1st	3			6		
2nd	7			1		
3rd	0			0		
4th	0			0		
5th	0			1		
Parent 1 education		3[c]			3[c]	
Parent 2 education		3[c]			2[c]	
Family income		4[d]			4[d]	
SES score		0.81[e]	0.11		0.81[e]	0.13

a. One parent in each group reported that their child had not started talking. b. Parents did not provide information for one participant in each group. c. Parent education was measured on a 4-point scale (1 = No formal education, 2 = Less than an undergraduate/bachelor degree, 3 = Undergraduate/bachelor degree, 4 = Postgraduate education). d. Income was measured on a 4-point scale (1 = less than £14,000, 2 = £14,001 - £24,000, 3 = £24,001 - £42,000, 4 = more than £42,000). One participant in the premature group did not report income. e. For more information on how the SES score was calculated, see section 4.2.1.1 Socioeconomic Status Calculation.

4.2.2 Procedure

The current study consisted of two assessments and three questionnaires distributed over two sessions. Each session lasted approximately 60 minutes. All of the sessions were conducted between one week to three weeks apart. All participants in both groups completed the same assessments and questionnaires in the same order. Table 4.2 provides a list of assessments.

Table 4.2 *List of Assessments*

Session 1	Session 2
1. Socioeconomic and general development questionnaire 2. Vineland Adaptive Behavior Scales, Third Edition (Vineland-3) • Gross motor scale • Fine motor scale 3. Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition • Receptive vocabulary • Block Design • Picture Memory • Information • Object Assembly	1. Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition • Zoo locations • Picture Naming 2. Noun extension task 3. Oxford Communicative Development Inventory (O-CDI)

4.2.2.1 Session 1. During the first visit, participants' parents filled in two questionnaires, and participants were introduced to 5 subtests of the Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK). A description of each questionnaire and subtest is provided below.

4.2.2.1.1 Socioeconomic and General Development Questionnaire. The participants' parents filled in a socioeconomic and general development questionnaire (see Appendix 5). This questionnaire examined different areas of the child's development and his/her family. Questions were asked regarding topics such as the mother's pregnancy, the child's birth, the child's general development from birth to when they took part in the study, and the child's family.

4.2.2.1.2 Motor Development Questionnaire. During the first session, parents were presented with the fine motor and gross motor subdomain sections of the Vineland Adaptive Behaviour Scales – Third Edition (VABS - Comprehensive Interview Form). The VABS – Comprehensive Interview Form is a short questionnaire that the researcher filled in by interviewing the parent and asking about their child's motor development.

4.2.2.1.3 Cognitive Assessments. Participants were assessed with the Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK). The first five subtests were presented during the first visit. The subtests presented in this visit and their descriptions are given below.

4.2.2.1.3.1 Receptive Vocabulary Subtest. The receptive vocabulary subtest assessed verbal comprehension. In this subtest, the researcher showed participants different sets of images and asked them to point to a specific image (e.g. the researcher asked the participants to find and point at the picture that represented a *cup* from a set of four images).

4.2.2.1.3.2 Block Design Subtest. The block design subtest assessed visual-spatial abilities. In this subtest, the researcher created different designs using red and white blocks and asked participants to recreate them with some more blocks. Participants had a time limit of between 30 to 90 seconds to finish each design and the time limit depended on the difficulty of the design.

4.2.2.1.3.3 Picture Memory Subtest. The picture memory subtest assessed working memory. In this subtest, participants had to look at either one or several pictures for a few seconds, which were then removed from their view. Then, they had to remember and point to the images previously presented from a set of different images.

4.2.2.1.3.4 Information Subtest. The information subtest assessed verbal comprehension. In this subtest, the researcher asked participants different questions about general knowledge topics (e.g. *What's the colour of most dirt? How old are you?*).

4.2.2.1.3.5 Object Assembly Subtest. The object assembly subtest assessed visual-spatial abilities. In this subtest, participants had to solve different puzzles in less than 90 seconds.

4.2.2.2 Session 2. During the second visit, participants were assessed with the remaining two subtests of the Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK). All participants were also presented with a noun extension task, and parents filled in another questionnaire. A description of the assessments and the questionnaire is provided below.

4.2.2.2.1 Cognitive Assessments. Participants were presented with the two remaining subtests of the Wechsler Preschool & Primary Scale of Intelligence - Fourth UK Edition (WPPSI-IV UK).

4.2.2.2.1.1 Zoo Location Subtest. The zoo location subtest assessed working memory. In this subtest, the researcher presented the child with different animal cards placed in a zoo layout and said: *"Look, this animal lives here"*. The child observed the cards for a few seconds, and then the cards were removed. Afterwards, the researcher asked the child to put back the animals where they live.

4.2.2.2.1.2 Picture Naming Subtest. The picture naming subtest assessed verbal comprehension. In this task, the researcher showed participants different images and asked them to say the name of the objects in the pictures.

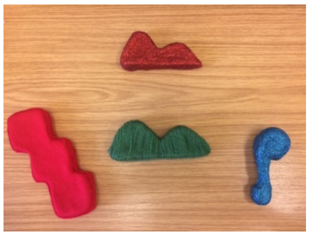
4.2.2.2.2 Noun Extension Task. During the second session, a noun extension task was introduced to all participants. This task consisted of four practice trials and eight test trials.

4.2.2.2.2.1 Practice Trials. Participants were presented with four practice trials to familiarise them with the procedure. In each practice trial, the researcher showed participants a known object (e.g. a yellow plastic banana) while saying: *"Look, this is a banana*". The researcher then showed participants three additional objects (e.g., a green banana, a plastic horse and a yellow chair) which each shared only one property with the exemplar (shape: green banana, texture: plastic horse, colour: yellow chair). The researcher then said: *"Can you give me the other banana?".* Participants were introduced with three more trials with a ball, a spoon and a car as main exemplars. To be able to continue with the test trials, participants had to choose the correct objects in all practice trials. All participants responded correctly to all four practice trials during the first try.

4.2.2.2.2.2 Test Trials. All participants were introduced to eight sets of novel objects. Each set consisted of one exemplar and three further objects that shared only one property with the exemplar (only shape, only colour, only texture) (see Figure 4.1). In each trial, the researcher presented one exemplar and said, for example, *"Look this is a pisk".* Afterwards, the child was shown the three other objects and was asked: *"Can you give me the other pisk?".* The same procedure was used with all eight trials. The trials were presented in one of two possible orders.

4.2.2.2.3 Vocabulary Checklist. During the second visit, parents completed the Oxford Communicative Development Inventory (O-CDI) (Hamilton et al., 2000). This vocabulary checklist assessed receptive and expressive vocabulary through parental report and was used to compare the vocabulary size and composition between both groups.

Figure 4.1 *Sets of Objects Used During the Noun Extension Task*

Trial Set	Description	Trial Set	Description
	Exemplar name: Kiv Target object: White one		Exemplar name: Pisk Target object: Green one
	Exemplar name: Dax Target object: Yellow one		Exemplar name: Zav Target object: Purple one
	Exemplar name: Toma Target object: Red one		Exemplar name: Soob Target object: Green one
	Exemplar name: Bosa Target object: Pink one		Exemplar name: Gip Target object: Orange one

Note. Each set consisted of one exemplar and three additional objects, with one object matching the exemplar in shape only, one in colour only and one in texture only. The target object was always the object with the same shape.

4.2.3 Design and Data Analysis

4.2.3.1 Noun Extension Task. The percentage of shape, colour and texture choices for each participant were calculated and analysed to assess if participants showed a preference for generalising object names by a specific property. A choice was counted as a shape choice if the chosen object matched the exemplar only on shape. A choice was counted as a texture choice if the object matched the exemplar in texture. A choice was counted as a colour choice if the object matched the exemplar only on colour. While this task consisted of eight trials, the total number of trials was different for two participants. For one participant of the preterm group and one participant of the full-term group, the total number of trials was seven because they did not make any choice in one of the trials. Thus, for these two participants, their percentage score was calculated out of seven trials rather than out of eight.

After calculating the percentage of shape, colour and texture choices, I compared the percentage of shape choices against chance using a t-test. Since the participants could choose one of three objects, chance was 33.33%. Then, I compared the percentage of shape choices between the two groups (preterm group and full-term group) using a t-test to assess if preference towards shape was similar between both groups. I conducted the same comparisons for colour choices and texture choices. T-tests were used instead of an analysis of variance because the sum of the percentage of shape, colour and texture choices equals 100% for all participants, and therefore they were not independent of each other.

4.2.3.2 Vocabulary Checklist. To investigate if the vocabulary size of both groups differed, the expressive and receptive vocabulary of all participants as reported by their parents using the O-CDI (Hamilton et al., 2000) was calculated and compared between groups. For expressive vocabulary, I first used a t-test to compare the total number of words between groups. I then divided expressive vocabulary into two different word types: nouns and other words. The *nouns* category included all words referring to object names from the O-CDI (Hamilton et al., 2000). The rest of the words were included in the *other words* category. To investigate if there was any difference in the number of words of a particular word type between groups, I conducted a 2 (Group: preterm group vs full-term group) x 2 (Word type: nouns and other words) ANOVA. Group was the between-participants variable, and word type was a within-participants variable. The dependent variable was the number of words produced. The same analyses were then conducted for receptive vocabulary.

4.2.3.3 Cognitive assessments. Three Primary Index Scales, three Ancillary Index Scales and one Full scale were calculated to assess cognitive development. To calculate each index score, I followed the WPPSI-UK Administration and Scoring Manual guidelines[7]. For all Indexes, a score between 90 and 110 represented an average score.

4.2.3.3.1 Primary Index Scales

4.2.3.3.1.1 Verbal Comprehension Index. This index measured verbal understanding and verbal reasoning and included the scores obtained in the Receptive Vocabulary subtest and Information subtest. To assess any group differences in this index, I compared the two participant groups (preterm vs full-term) using a t-test.

4.2.3.3.1.2 Visual Spatial Index. This index measured how participants organise, process and understand visual information. This index included the following subtests: Visual-Spatial

[7] To calculate each index, I followed the WPPSI-UK Administration and Scoring Manual guidelines. For all indexes, I first converted the raw scores of all subtests to scaled scores according to a participant's age using table A.1 of the Administration and Scoring Manual. Then, I added all scaled scores and converted the sum of scaled scores to each index score. Tables A.2 to A.5 of the Administration and Scoring Manual were used to convert the sum of scaled scores of the *Primary Index Scales*. Tables C.1, C.2 and D.1 of the Technical and Interpretive Manual were used to convert the sum of scaled scores of the *Ancillary Index Scales*.

subtest, Block Design subtest and Object Assembly subtest. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.3.1.3 Working Memory Index. This index measured retention of information for short periods of time, and it included the scores obtained in the Picture Memory and Zoo Locations subtests. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.3.2 Ancillary Index Scales

4.2.3.3.2.1 Vocabulary Acquisition Index. This index measured verbal abilities and included the Receptive Vocabulary and Picture Naming subtests. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.3.2.2 Non-verbal Index. This index measured non-verbal intelligence and included the scores of the following subtests: Block Design subtest, Picture Memory subtest, Object Assembly subtest and Zoo Locations subtest. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.3.2.3 General Ability Index. This index included the scores of the Receptive Vocabulary subtest, Block Design subtest, Information subtest, and Object Assembly. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.3.3 Full Scale. This scale provided a general intelligence measure (IQ) and included the scores of the Receptive Vocabulary subtest, Block Design subtest, Picture Memory subtest, Information subtest and Object Assembly subtest. To assess any group differences in this index, I compared both participant groups (preterm vs full-term) using a t-test.

4.2.3.4 Motor Development Questionnaire. This questionnaire was used to assess motor development and to assess if participants had any significant motor delays. The raw score for the fine motor subdomain and the gross motor subdomain were calculated separately. First, I converted the raw scores of each subdomain to the equivalent ages using table B.2 of the Vineland-3 Manual. I then compared the equivalent age obtained and the chronological age of each participant on each subdomain using t-tests. Then, I calculated the delay in each motor subdomain using the following equation:

(equivalent age in months) – (chronological age in months)

Negative results represented a delay (in months), a value of 0 represented the expected score for their chronological age, and positive results represented a performance above their chronological age (in months). Finally, I compared both participant groups on this delay score using t-tests.

4.2.3.5 Exploratory Analyses

4.2.3.5.1 Gestational Age. This exploratory analysis had as main aim to investigate if the week at which participants were born (gestational age) could be related to the robustness of the shape bias, but also if gestational age could be related to vocabulary size, cognitive development and motor development. Thus, correlational analyses were conducted between gestational age (in weeks), and the following tasks and/or assessments: percentage of shape choices in the noun extension task, all indexes from the cognitive assessment, fine motor delay, gross motor delay, expressive vocabulary size and receptive vocabulary size.

Note that the correlation analyses of fine motor and gross motor delay with gestational age were done using the delay scores obtained as described in section 4.2.3.4. For the correlation analyses with all indexes from the cognitive assessment, the normed scores of all indexes as calculated following the WPPSI-UK Administration and Scoring Manual guidelines were used. Finally, for the correlation analyses with expressive and receptive vocabulary, the raw scores obtained in the vocabulary checklist answered by all parents were used.

4.2.3.5.2 Shape Choices. This analysis had as main aim to assess if the percentage of shape choices was correlated to any of the assessments conducted in the study, but also if any environmental or family variables could also be related to how robust the bias was. Thus, correlational analyses were conducted between the percentage of shape choices in the noun extension task and all indexes from the cognitive assessments, fine motor delay score, gross motor delay score, expressive vocabulary size and receptive vocabulary size. Correlations were also conducted between the percentage of shape choices and age (in months), birth order and socioeconomic status. Note that the correlation analyses of fine motor and gross motor delay with gestational age were done using the delay scores obtained as described in section 4.2.3.4. For the correlation analyses with all indexes from the cognitive assessment, the normed scores of all indexes as calculated following the WPPSI-UK Administration and Scoring Manual guidelines were used. Finally, for the correlation analyses with expressive and receptive vocabulary, the raw scores obtained in the vocabulary checklist answered by all parents were used.

4.3 Results

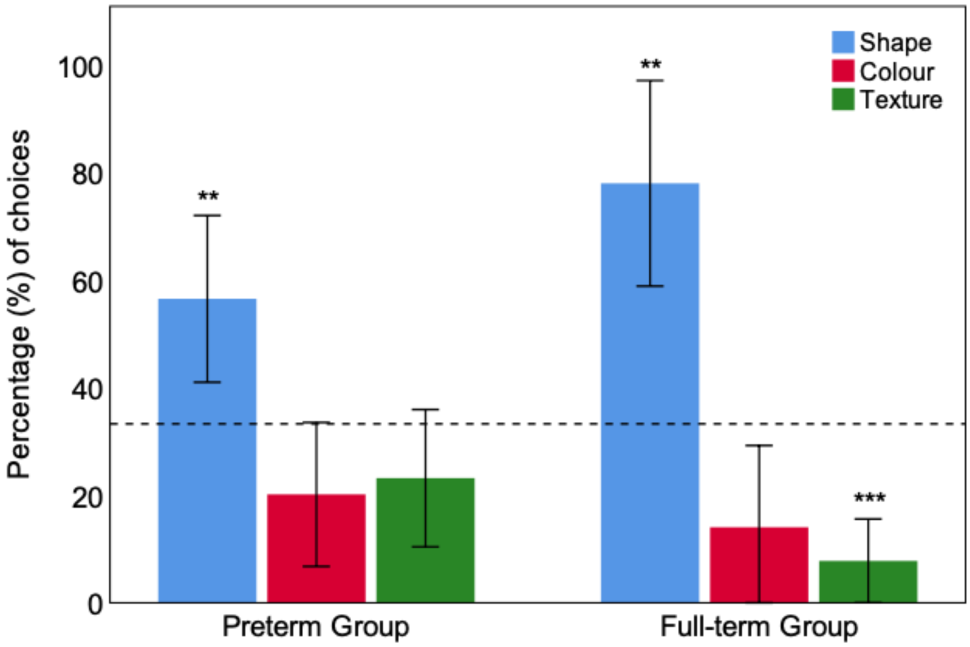
4.3.1 Noun Extension Task

To assess if participants preferred to generalise object names by a certain property, the percentage of shape, colour and texture choices in this task were calculated. The participants in the preterm group chose objects that matched in shape 56.60% of the trials (*SD* = 21.70). The participants in the full-term group chose objects with the same shape on 78.12% of all trials (*SD* = 22.90) (see Figure 4.2). With a Bonferroni adjusted alpha level of .016 per test (.05/3), results showed that the percentage of shape choices in both groups were significantly above chance (with chance being 33.33%) (preterm: $t(9) = 3.39$, $p = .008$, 95% CI = [7.74, 38.80]; full-term: $t(7) = 5.53$, $p = .001$, 95% CI = [25.64, 63.94]). Even though the participants in the full-term group chose 21.52% more shape matching objects than the preterm group, the difference between the groups only approached significance, $t(16) = -2.04$, $p = .058$, 95% CI = [-43.88, 8.84]. Thus, both participant groups generalised object labels mainly by shape similarities, with a potentially stronger shape bias in the full-term group.

For the preterm group, colour and texture choices were numerically below chance, but not to a degree which was statistically reliable (colour: M=20.17%, $SD = 18.74$, $t(9) = -2.21$, $p = .054$, 95% CI = [-26.56, 0.26]; texture: $M = 23.21$%, $SD = 17.87$, $t(9) = -1.78$, $p = .107$, 95% CI = [-22.90, 2.67]) (see Figure 4.2). In the full-term group, texture choices were significantly below chance ($M = 7.81$%, $SD = 9.30$, t (7) = -7.76, $p < .001$, 95% CI = [-33.29, -17.74]), while colour choices were at chance levels ($M = 14.06$%, $SD = 18.22$, t (7) = -2.99, $p = .020$, 95% CI = [-34.50, -4.03]) (see Figure 4.2). There was no significant difference in the percentage of colour choices between the participant groups ($t(16) = 0.69$, $p = .496$, 95% CI = [-12.50, 24.73]), or in the percentage of texture choices between groups ($t(16) = 2.20$, $p = .043$, 95% CI = [0.56, 30.23]).

Taking these results together, while both groups revealed a shape bias, there was a trend towards significance on how much both groups relied on it, with a potentially stronger shape bias in the full-term group.

Figure 4.2 *Percentage of Shape, Colour and Texture Choices in Preterm and Full-term Groups*



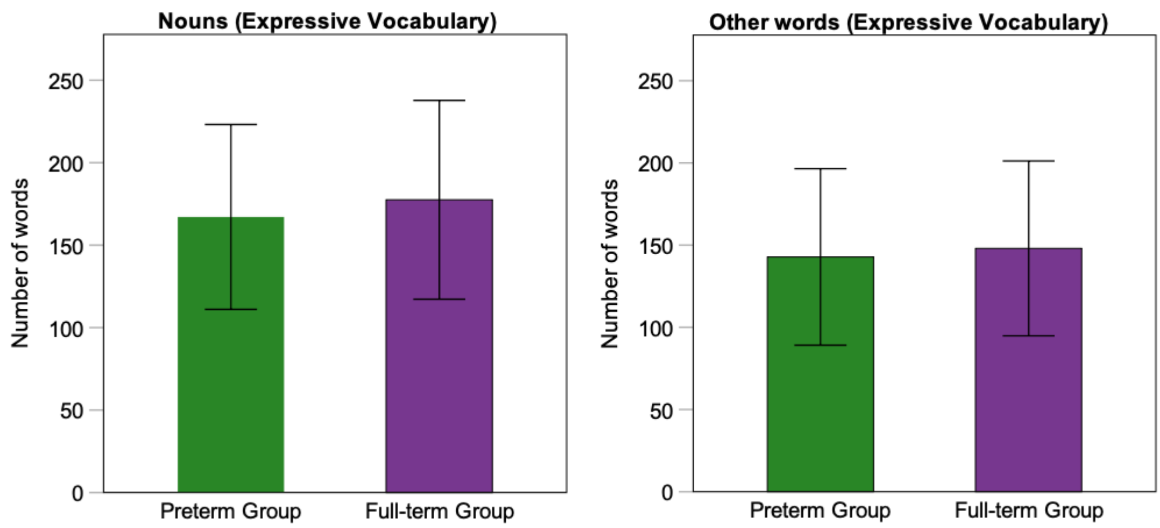
Note. The dotted line represents chance level (33.3%). Asterisks indicate significant differences from chance (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$). Error bars represent 95% CIs of the means.

4.3.2 Vocabulary Checklist

4.3.2.1 Expressive Vocabulary. To assess if participant groups differed in expressive vocabulary size, I first calculated the average number of words in the expressive vocabulary of both participant groups as reported by the participants' parents. The participants in the preterm group produced on average 309.90 words (*SD* = 152.59), and the participants in the full-term group produced on average 325.50 words (*SD* = 135.08). Although the participants in the full-term group had a larger expressive vocabulary, it was not significantly greater than that of the preterm group, $t(16) = -0.22$, $p = .824$, 95% CI = [-161.60, 130.40]. Thus, the participants in both groups had a similar expressive vocabulary size.

The number of *nouns* and *other words* in expressive vocabulary was compared to assess if there were any differences in vocabulary composition between participant groups. The participants in the preterm group produced 167.10 nouns (*SD* = 78.33) and 142.80 other words (*SD* =75.04) (see Figure 4.3). The participants in the full-term group produced 177.50 nouns (*SD* = 72.09) and 148 other words (*SD* = 63.60) (see Figure 4.3). A 2 (Group: preterm group and full-term group) x 2 (Word type: nouns or other words) analysis of variance revealed a significant main effect of Word type $F(1,16) = 52.42$, $p < .000$, $\eta_p^2 = .76$, but no main effect of Group $F(1,16) = 0.05$, $p = .824$, $\eta_p^2 = .00$, or interaction between Word type and Group $F(1,16) = 0.49$, $p = .494$, $\eta_p^2 = .03$. Thus, participants in both groups had similar numbers of nouns and other words in their expressive vocabularies, with nouns being the category of words they produced the most.

Figure 4.3 *Expressive Vocabulary*

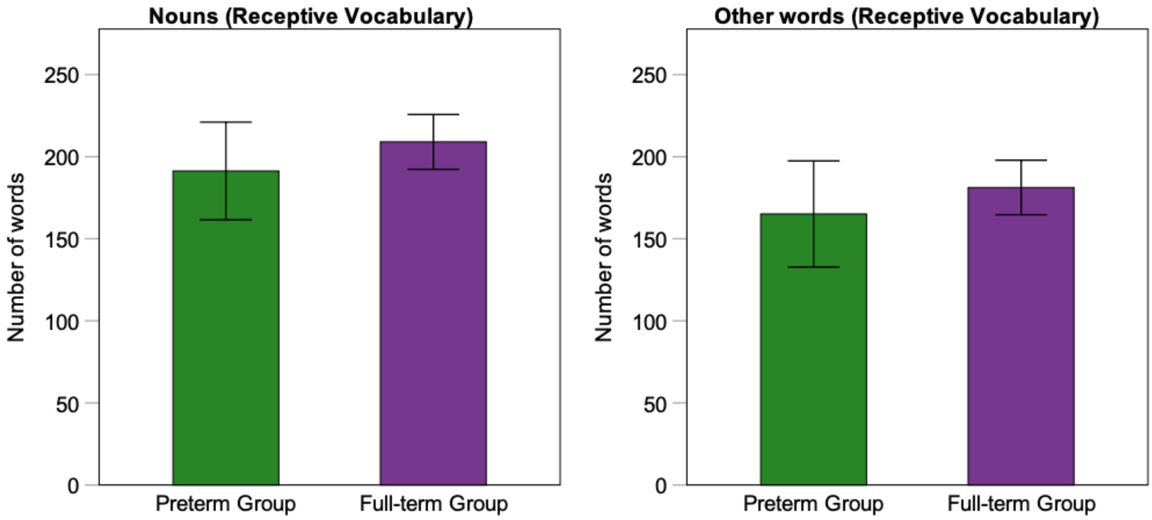


Note. Error bars represent 95% CIs of the means.

4.3.2.2 Receptive Vocabulary. To assess if there were any differences in receptive vocabulary between participant groups, I first calculated and compared the average number of words in their receptive vocabulary. The participants in the preterm group had 356.40 words (*SD* = 86.31) in their receptive vocabulary, while the participants in the full-term group knew an average of 390.25 words (*SD* = 37.74). Even though the participants in the full-term group understood more words, the difference between groups was not statistically significant $t(16) = -1.02$, $p = .319$, 95% CI = [-103.62, 35.92]. Thus, the participants in both groups had a similar receptive vocabulary size.

The number of *nouns* and *other words* was compared to assess if there were any differences in vocabulary composition between participant groups. The preterm group had an average of 191.30 nouns (*SD* = 41.57) and 165.10 other words (*SD* = 45.19) in their receptive vocabularies (see Figure 4.4). The full-term group had an average of 209 nouns (*SD* = 19.96) and 181.25 other words (*SD* = 19.90) in their receptive vocabularies (see Figure 4.4). A 2 (Group: preterm group and full-term group) x 2 (Word type: nouns or other words) analysis of variance revealed a significant main effect of Word type $F(1,16) = 104.47$, $p < .000$, $\eta_p^2 = .86$, but no main effect of Group $F(1,16) = 1.05$, $p = .319$, $\eta_p^2 = .06$, or interaction between Word type and Group $F(1,16) = 0.08$, $p = .773$, $\eta_p^2 = .00$. Thus, both groups knew a similar number of nouns, and both groups knew more nouns than other words.

Figure 4.4 *Receptive Vocabulary*



Note. Error bars represent 95% CIs of the means.

4.3.3 Cognitive Assessments

The results obtained from the seven subtests of the WPPSI-IV were used to calculate three Primary Index Scales, three Ancillary Index Scales and one Full scale. These scales provided information regarding participants development in different areas. Overall, both participant groups had average scores in all indexes (average scores range from 90 to 110) (see Table 4.3).

4.3.3.1 Primary Index Scales. Three Primary Index Scales were calculated: Verbal Comprehension, Index Visual Spatial Index and Working Memory Index.

4.3.3.1.1 Verbal Comprehension Index. The preterm group had a mean score of 93.90 (*SD* = 17.31) in this scale, while the full-term group had a mean score of 105.25 (*SD* = 15.41). Both groups demonstrated a score within the average range of 90 to 110. Even though the full-term group showed higher scores, the between-group difference was not significant $t(16) = -1.44$, *p*

= .167, 95% CI = [-27.95, 5.25]. Thus, I did not find evidence of differences between groups in verbal reasoning and understanding.

4.3.3.1.2 Visual Spatial Index. The preterm group had on average lower scores than the full-term group (preterm: $M = 98.90$, $SD = 11.82$; full-term: $M = 106.88$, $SD = 13.12$). However, both groups had scores within the average range (between 90 and 110). The difference in scores between groups was not significant, $t(16) = -1.35$, $p = .194$, 95% CI = [-7.97, 5.88]. Thus, I did not find evidence of differences on visual-spatial abilities between groups.

4.3.3.1.3 Working Memory Index. Similarly to previous indexes, the preterm group had lower scores than the full-term group, but still within the average range. The preterm group obtained a mean score of 103 ($SD = 10.29$), while the full-term group obtained a mean score of 109 ($SD = 9.21$). The difference between groups was not statistically significant, $t(16) = -1.28$, $p = .217$, 95% CI = [-6.00, 4.66]. Thus, I did not find evidence of differences in working memory skills between groups.

4.3.3.2 Ancillary Index Scales. Three Ancillary Index Scales were calculated: Vocabulary Acquisition Index, Non-verbal Index and General Ability Index. Participants in both groups had scores within the average range in all three Ancillary Index Scales (average scores range from 90 to 110).

4.3.3.2.1 Vocabulary Acquisition Index. The participants in the preterm group had a mean score of 100.40 ($SD = 22.66$), and the participants in the full-term group had a mean score of 106.50 ($SD = 16.22$). There was no significant difference between groups even though the participants in the full-term group had higher scores, $t(16) = -0.64$, $p = .531$, 95% CI = [-6.10, 9.53]. Thus, I did not find evidence of differences between groups regarding their verbal abilities.

4.3.3.2.2 Non-verbal Index. The participants in the preterm group had lower scores than the participants in the full-term group (preterm M = 103.80, SD = 14.86; full-term M = 108.25, SD = 12.54), but the difference between groups was not significant, $t(16) = -0.67$, p = .509, 95% CI = [-4.45, 6.59]. Thus, I did not find differences in non-verbal intelligence between groups.

4.3.3.2.3 General Ability Index. The participants in the preterm group had lower scores than the participants in the full-term group (premature M = 98.20, SD = 14.33; full-term M = 108.13, SD = 15.54). This difference between groups was not significant, $t(16) = -1.40$, p = .179, 95% CI = [-9.92, 7.05]. Thus, I did not find evidence of differences between groups in cognitive abilities.

4.3.3.3 Full Scale. A general IQ score was calculated for participants in both groups. The participants in the preterm group had a mean IQ score of 98.70 (SD = 14.35), and the participants in the full-term group had a mean IQ score of 107.75 (SD = 12.53). The IQ scores from both groups were within the average range. Even though children in the full-term group had higher scores, this difference between groups was not significant, $t(16) = -1.40$, p = .179, 95% CI = [-9.05, 6.44]. Thus, I did not find differences in overall intelligence between participant groups.

Table 4.3 *Scores of Cognitive Tasks in the Preterm and Full-Term Group*

	Preterm group		**Full-term group**	
	M (SD)	**Range**	***M (SD)***	**Range**
Verbal Comprehension Index	93.90 (17.31)	64-129	105.25 (15.41)	89-132
Visual-Spatial Index	98.90 (11.82)	82-117	106.88 (13.12)	88-123
Working Memory Index	103.00 (10.29)	82-121	109.00 (9.21)	97-121
Vocabulary Acquisition Index	100.40 (22.66)	75-148	106.50 (16.22)	85-132
Non-verbal Index	103.80 (14.86)	81-133	108.25 (12.54)	91-127
General Ability Index	98.20 (14.33)	82-128	108.12 (15.54)	94-134
Full Scale	98.70 (14.35)	79-121	107.75 (12.53)	94-125

4.3.4 Motor Development. Fine and gross motor development between participants was compared to assess if there were any significant delays in the preterm group compared to what is expected for their chronological age and also compared to the full-term group.

4.3.4.1 Fine Motor Subdomain. The participants in the preterm group scored the equivalent to 40.60 months (SD = 7.41) in the fine motor subdomain, which was +6.60 months (SD = 6.76) above their chronological age (M = 34 months, SD = 6.35). A comparison between the chronological age and the equivalent age obtained in the preterm group revealed a significant difference $t(9) = 3.08$, $p = .013$, 95% CI = [1.75, 11.44]. Therefore, the participants in the preterm group performed above what was expected for their chronological age in the fine motor subdomain. The participants in the full-term group scored the equivalent to 42.25 months (SD = 8.86) in the fine motor subdomain, which was +8.75 months (SD = 5.60) above their chronological (M = 33.50 months, SD = 6.36). A comparison between the chronological age and the equivalent age obtained of the full-term group revealed that the full-term group also performed significantly above to what was expected for their chronological age $t(7) = 4.42$, $p = .003$, 95% CI = [4.06, 13.43]. A comparison of the difference between the equivalent score and the chronological age between groups revealed that both groups performed similarly in the fine motor subdomain, $t(16) = -0.72$, $p = .481$, 95% CI = [-2.15, 2.98]. Thus, no difference between both participant groups was found, and in both groups, participants had scores above to what was expected based on their chronological ages.

4.3.4.2 Gross Motor Subdomain. The preterm group scored on average the equivalent of 33.60 months (SD = 7.2) in the gross motor subdomain, which was -0.4 months (SD = 8.32) below their chronological age (M = *34* months, SD = 6.35). No significant difference between the chronological age of participants in the preterm group and the equivalent age obtained in the gross motor subdomain was found, $t(9) = -0.15$, $p = .883$, 95% CI = [-6.35, 5.55]. In the full-term group, the participants scored the equivalent of 30.37 months (*SD* = 7.67), which was -3.12 months (*SD* = 4.42) below their chronological age (*M* = 33.50 months, *SD* = 6.36). No significant difference between the chronological age of the full-term group and the equivalent age obtained in the gross motor subdomain was found, $t(7) = -1.99$, $p = .086$, 95% CI = [-6.82, 0.57]. A comparison between the performance of both groups revealed no significant difference, $t(16) = 0.83$, $p = .417$, 95% CI = [-3.83, 9.28]. Thus, both groups performed within the expected range for their chronological age, and this performance was similar between groups.

4.3.5 Exploratory Analyses

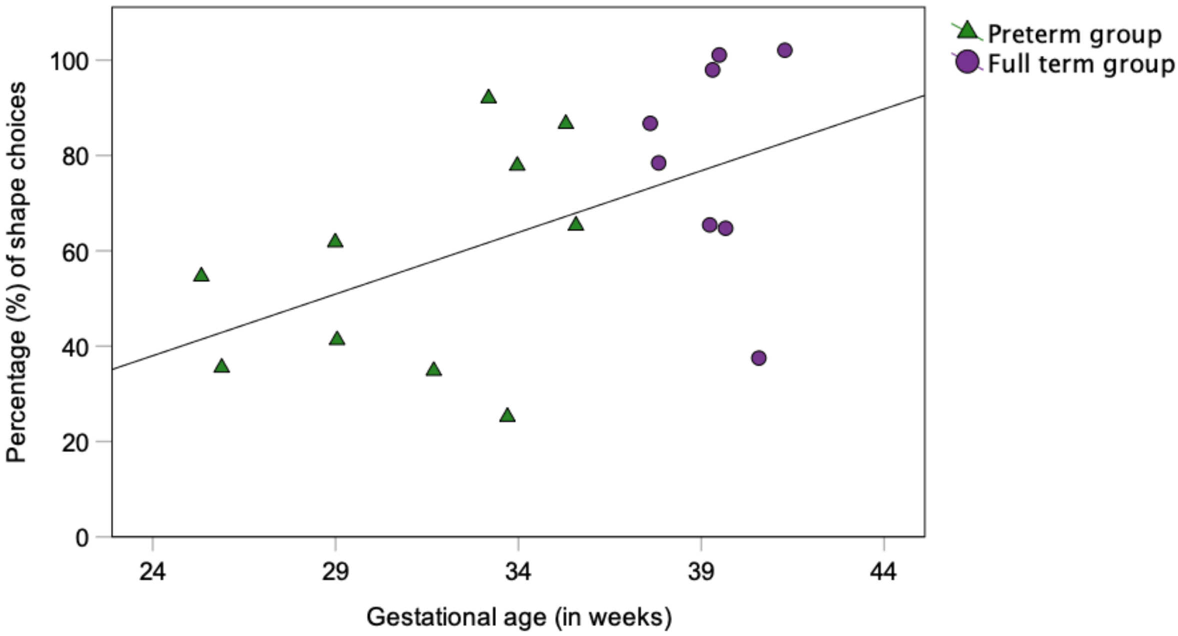
4.3.5.1 Gestational Age. Correlational analyses were conducted to assess if there was any relationship between gestational age and the percentage of shape choices, cognitive development, motor development, and vocabulary size. Results showed a significant positive correlation between gestational age and the percentage of shape choices in the noun extension task ($r = .53$, $p = .023$) (see Figure 4.5). No further significant correlations were found (for a full list of all correlations conducted see Table 4.4). Thus, participants that were born earlier choose fewer objects matching in shape in the noun generalisation task than participants born later.

Table 4.4 *Correlation Analyses with Gestational Age*

	Gestational Age (in months)	
	r	*p*
Percentage of shape choices	.53	.023*
Gross Motor delay score [a]	.12	.619
Fine Motor delay score [a]	.42	.080
Verbal Comprehension Index [b]	.38	.113
Visual-Spatial Index [b]	.43	.068
Working Memory Index [b]	.11	.637
Vocabulary Acquisition Index [b]	.29	.244
Non-verbal Index [b]	.26	.285
General Ability Index [b]	.45	.056
Full-Scale Index [b]	.45	.056
Receptive vocabulary size [c]	.06	.812
Expressive vocabulary size [c]	.22	.375

Note: Asterisks indicate significant values (*$p \leq .05$, **$p \leq .01$, ***$p \leq .001$). a. The delay scores obtained in section 4.3.4 were used for these correlation analyses. b. The normed scores of all indexes as calculated following the WPPSI-UK Administration and Scoring Manual guidelines were used for the correlation analyses. c. The raw scores obtained in the vocabulary checklist answered by all parents were used for the correlation analyses.

Figure 4.5 *Correlation Between Gestational Age and Percentage of Shape Choices*



4.3.5.1 Shape Choices. Correlational analyses were conducted to assess if there was any relationship between the percentage of shape choices and cognitive development, motor development, receptive vocabulary, expressive vocabulary, socioeconomic status score, birth order and age. Significant positive correlations were found between the percentage of shape choices and the following assessments and variables: Verbal Comprehension Index (r = .63, p = .005), Visual-Spatial Index (r = .61, p = .007), Working Memory Index (r = .56, p = .014), Vocabulary Acquisition Index (r = .59, p = .009), Non-Verbal Index (r = .65, p = .003), General Ability Index (r = .65, p = .003), Full Scale Index (r = .64, p = .004), Expressive vocabulary size (r = .60, p = .008) and Receptive Vocabulary size (r = .71, p = .001). No further significant correlations were found (for a full list of all correlations conducted see Table 4.5). Thus, participants with higher scores in the cognitive assessments had a higher percentage of shape choices in the noun extension task. Additionally, participants with higher vocabulary sizes also generalised more object names by shape in the noun extension task.

Table 4.5 *Correlation Analyses With the Percentage of Shape Choices of the Noun Extension Task*

	% shape choices	
	r	***p***
Age	.30	.225
Socioeconomic status	.08	.725
Birth order	-.00	.977
Gross Motor delay [a]	.16	.525
Fine Motor delay [a]	.42	.082
Verbal Comprehension Index [b]	.63	.005*
Visual-Spatial Index [b]	.61	.007*
Working Memory Index [b]	.56	.014*
Vocabulary Acquisition Index [b]	.59	.009*
Non-verbal Index [b]	.65	.003*
General Ability Index [b]	.65	.003*
Full-Scale Index [b]	.64	.004*
Receptive Vocabulary Size [b]	.71	.001*
Expressive Vocabulary Size [b]	.60	.008*

Note: Asterisks indicate significant values ($*p \leq .05$, $**p \leq .01$, $***p \leq .001$). a. The delay scores obtained in section 4.3.4 were used for these correlation analyses. b. The normed scores of all indexes as calculated following the WPPSI-UK Administration and Scoring Manual guidelines were used for the correlation analyses. c. The raw scores obtained in the vocabulary checklist answered by all parents were used for the correlation analyses.

4.4 Discussion

The main aims of the current study were to investigate if children born preterm show a shape bias for noun generalisation, to assess their vocabulary size and composition, and to investigate the relationship between the shape bias and vocabulary size, cognitive and motor development. In two different sessions participants were introduced to a group of cognitive, motor and language assessments and a novel noun extension task. I expected for children born preterm to have a less robust shape bias and smaller vocabularies than their full-term peers. I also expected for children born preterm to have lower scores than full-term children in all cognitive, motor and language assessments, but still within the average range for their chronological age.

The current pilot study has three main findings. First, children born preterm in this study showed a preference for generalising novel object labels to other objects that share the same shape. Second, children born preterm had similar vocabularies to the full-term children. Third, the preterm group scored within the average range expected for their chronological ages in all cognitive and motor assessments, and no significant differences with the full-term group were found. Thus, cognitive and motor development between groups was similar. It is important to note that the results of this study should be taken with caution due to the fact that this was a pilot study with a limited number of participants and low statistical power. Thus, further studies with bigger sample sizes are required to confirm the results.

4.4.1 The Shape Bias and Vocabulary Size in Children Born Preterm

One of the main findings of this pilot study was that children born preterm do show a shape bias for noun generalisation. This would suggest that children born preterm have developed the same word learning bias as typically developing full-term children. It would also mean that, in contrasts to findings of previous studies (Cusson, 2003), some children born preterm can achieve some important milestones at a similar age than their full-term peers. It is important to note that while the preterm group generalised mainly by shape, they did so for 21% fewer trials than the full-term group, which was a trend that approached significance. This could suggest that, while children born preterm use the shape bias, they may rely less on this word learning bias than full-term children. Interestingly, the correlation analysis supported this result as it was found that gestational age was significantly correlated to the robustness of the shape bias. Thus, participants that were born earlier in the pregnancy also showed a less robust preference for generalising nouns by shape compared to children born later in the pregnancy. Taken together these two results, it can be suggested that some children born preterm may be relying less on the shape bias, with very preterm and extremely preterm children being the ones that could be using this bias the least. Further studies with bigger sample sizes are required to confirm if in fact children born preterm do use the shape bias to a lesser extent than full-term children, and if the earlier the birth, a less robust shape bias is developed. A post hoc sample size calculation denoted that with the achieved effect size of 0.96 (Cohen's *d*), an error probability of 0.05 and a power of 0.80, a minimum of 38 participants (19 participants in each group) should be included for future studies to confirm these findings.

In contrast to reports elsewhere, in the current study, I found no evidence of a difference in vocabulary size between children born preterm and full-term children. Stolt and colleagues (2009) showed that full-term children can have receptive vocabularies up to 1.8 times bigger than children born preterm. However, in the current study, full-term children had receptive vocabularies .09 times bigger than children born preterm, which can be considered as a minimal difference. This small difference at the moment is tentative to whether it represents a real effect in the population given the limited sample size. However, it suggests that not all children born preterm have smaller vocabularies. Previous research has also suggested that not only vocabularies in children born preterm can be smaller, but that their vocabulary composition may be different composition (Kern & Gayraud, 2007). Contrary to previous research, children born preterm in the current study had a similar number of *nouns* and *other words* than their full-term peers. Thus, participants in this study had similar vocabularies (in terms of size and composition) than their full-term peers.

The lack of difference in vocabulary size and composition between groups observed in this study could have been due to three main factors. First, all participants were from middle-class families. It is known that children born preterm with higher socioeconomic status tend to show less developmental delays and tend to have higher scores in language tests than premature children from lower socioeconomic status (Marchman, Adams, Loi, Fernald, & Feldman, 2016; Ross, Foran, Barbot, Sossin, & Perlman, 2016). Thus, results from the current study may not apply to children born preterm with different environmental and family characteristics. Second, more substantial differences in vocabulary size tend to be observed when comparing full-term children with very preterm or extremely preterm children (Kern & Gayraud, 2007). However, in the current pilot study, 6 out of 10 participants in the preterm group were either moderately or late preterm which could have contributed to making the overall difference smaller. Thirdly, there are important differences between previous research and the current study in statistical power. It is possible that the small sample size in the current study made it more difficult to find a real difference between groups. Thus, differences between the current study and previous research could have been due to differences in sample characteristics and sample size.

While there was no difference in vocabulary size and composition between both participant groups, results showed that vocabulary size was related to the robustness of the shape bias. More precisely, results showed that participants with smaller vocabularies also had a less robust shape bias, while participants with a bigger vocabulary size showed a more robust shape bias. This result is in line with previous literature suggesting that in typically developing full-term children, vocabulary size during the first years of life can be related to how robust the shape bias is (Gershkoff-Stowe & Smith, 2004; Perry & Samuelson, 2011). This would mean that the relationship that has been found in typically developing full-term children between vocabulary size and the shape bias could potentially also apply for children born preterm.

4.4.2 Children Born Preterm can Perform Within the Expected Range in Cognitive and Motor Assessments

Overall, the preterm group performed similar to the full-term group in the standardised cognitive assessments. These results are in line with previous research that has found that children born preterm can achieve the expected scores for their age (Caravale et al., 2005; Romeo et al., 2012; Sansavini et al., 2010). Interestingly, while as a group preterm children and full-term children had scores within the average range in all cognitive assessments, more variability in scores was observed in the preterm group than in the full-term group. For example, the preterm group had an average score of 98.70 (average scores range from 90 to 110), in the Full Scale of the WPPSI-IV UK which assesses general cognitive and intellectual functioning, and the full-term group had an average score of 107.75 in the same index. However, scores in the preterm group ranged from 79 to 128, while scores in the full-term group ranged from 94 to 125. Similarly, when a non-verbal measurement of general cognitive and intellectual functioning was used (Non-verbal Index of the WPPSI-IV UK), the preterm group had an average score of 103.80, with individual scores that ranged from 81 to 133. The full-term group had an average score of 108.25, with individual scores ranging from 91 to 127. Thus, while the mean score of both participant groups fell within the average range for their age, there was more variability and a bigger range of scores in the preterm group than in the full-term group.

When investigating specific areas of cognitive development, the preterm group also achieved scores within the expected range for children their age, which were also similar to the full-term group. Thus, contrary to previous research (e.g. Baron et al., 2012; Caravale et al., 2005; Geldof et al., 2012; Vicari et al., 2004) children born preterm in this study performed as their full-term peers in working memory and visual-spatial assessments. This would suggest that general cognitive development in the children born preterm of this study was not delayed or impaired. However, similarly to the general IQ assessments, the preterm group also showed greater variability in all cognitive assessments compared to full-term children.

The current results would suggest that even though children born preterm ad lower scores than full-term children in all tasks, the fact that these differences were not significant indicates that cognitive development in our sample was not delayed or impaired. Previous studies had suggested that while children born preterm can perform like their full-term peers, they will achieve scores significantly below full-term children (Böhm et al., 2004; Caravale et al., 2005; Romeo et al., 2012; Sansavini et al., 2010). In the current study, a performance below the average range was observed in only one participant in the preterm group, who consistently scored in the lower average or below average for all assessments. Interestingly, in the preterm group there was also one participant that consistently scored in the high average or above average in all cognitive assessments. Thus, while indeed some children born premature with no obvious conditions, disorders or impairments may show delays in their cognitive development, this does not seem to be the norm for all children born preterm.

One important thing to note is that I used chronological age instead of corrected age in both groups. This is because, in clinical assessments, corrected age is typically only used up until 24 months of age for children born preterm that do not have any conditions, disorders or impairments (Bernbaum, 2016; NICE, 2017). Since no differences were found in cognitive assessments when using chronological age, using corrected age would have made the small differences observed even smaller. This would have been the case even for the one participant that consistently scored below his peers, as he was late preterm, so corrected age would not have improved his scores much and he would have still scored below the average.

Regarding motor development, contrary to previous studies (Prins et al., 2010; Yaari et al., 2018), I found that not only children born preterm did not have a delay in gross motor, they also performed above to what was expected for their chronological age in the fine motor subdomain. While a performance above the expected is an interesting finding, this pattern of performance was also observed in the full-term group. Therefore, rather than being a characteristic of the preterm group, it may be a characteristic of the population from which the sample was recruited.

Interestingly, while no significant differences in cognitive and motor development were found between groups, significant relationships between the shape bias and the scores obtained in all cognitive assessments were found. This result is in line with Kucker and colleagues (2019), which suggest that the shape bias is not just a linguistic process and that cognitive processes such as working memory or attention may be required for its successful development. Results of the correlation analysis could even suggest that cognitive development may influence how robust the shape bias is. Thus, since as a group participants in the preterm group had no significant cognitive delays, then this did not affect their development of a shape bias. Due to the sample size, this relationship is speculative at the moment. Therefore, future research is required to confirm a relationship between cognitive development and the robustness of the shape bias.

4.4.3 Future Directions

In the current pilot study, I found that children born preterm can develop in step with their full-term peers and that some premature children may be relying less on the shape bias. However, the current study also leaves one important question unanswered that future studies should address: are children born earlier in pregnancy also the ones that are developing a less robust shape bias? In the current study I found a correlation between gestational age with the percentage of shape choices suggesting that the earlier the birth, the less robust the shape bias was. However, due to the limited number of participants a comparison within the preterm group was not possible. Future research should investigate how extremely preterm, very preterm, moderate preterm and late preterm children would perform in a noun extension task and investigate any potential differences between these groups. Investigating this can provide more information regarding how much can gestational age influence the development of the shape bias.

Future studies should also address one important limitation found in this study. All participants in the current study had the same socioeconomic characteristics. Since socioeconomic status can affect language development (Gross et al., 2001; Patra et al., 2016) and has been linked to a reduced risk of significant developmental delays (Ross et al., 2016), it is important to assess whether socioeconomic status would affect the presence of a shape bias, and whether this would be more strongly the case for preterm than full-term children. This was not possible in the current study because all participants shared very similar socioeconomic characteristics. It is unlikely that performance in this study was the sole effect of children's socioeconomic characteristics. However, following previous research, they might have contributed to the smaller difference in results obtained between groups in the language assessments. Addressing these limitations in future studies will provide more robust information regarding the presence and role of the shape bias for word learning in children born preterm.

4.4.4 Conclusions

In summary, the main finding of this pilot study was that children born preterm showed a shape bias for noun generalisation, with some children born preterm showing a less robust shape bias than full-term children. Additionally, it was found that children born preterm also had similar vocabularies than their full-term peers, and as a group, performed within what was expected for their chronological age in all cognitive and motor assessments. These results suggest that, in this study, children born preterm were developing in step with their full-term peers. Results also suggest children born preterm that took part in this study have developed the same word learning strategy (i.e. shape bias) than typically developing full-term children. However, it seems that some children born preterm may be relying on the shape bias to a lesser extent than full-term children, with very preterm and extremely preterm being the ones that had a less robust bias. To my knowledge, the current study is the first one to examine the role of the shape bias in children born preterm. Therefore, future research with a greater sample size is needed to confirm if there is a difference in how much children born preterm rely on the shape bias or not, and if in fact they can develop similarly to their full-term peers.

CHAPTER 5

General Discussion

The main aims of this thesis were: 1) to investigate the word learning biases that typically developing children, late talkers and children born preterm use, 2) to investigate how these learning biases affect word learning and vocabulary development, and 3) to explore how these word learning biases can be used as strategies to boost vocabulary growth (see Section 1.3). In this final chapter, I will first summarise the main findings of each experimental chapter. Next, I will discuss the implications that the results of each chapter have on what we know about word learning in typical and atypical development. Finally, I will conclude by discussing some general limitations and suggestions for future research.

5.1 Summary of Findings

In Chapter 2, I investigated whether 17-month-old typically developing infants can learn to use function to generalise known and novel object names, and the effect that a function bias can have in general vocabulary growth. In this study participants in a function-training group were introduced to a 7-week training programme where they were taught that objects with the same function also share the same name. Participants in a control group were exposed to the same objects but were not shown the object's function and did not hear their names. The findings of this study showed that participants in the function-training group can learn to generalise familiar (first-order generalisation) and novel labels (second-order generalisation) by function. In contrast, the control group showed a trend towards generalising known and novel labels by shape, which is in line with previous research that has suggested that towards the end of the second year of life infants start showing a preference for generalising labels by shape (Hupp, 2015; Kucker et al., 2019; Landau et al., 1998b; Perry & Samuelson, 2011). The parental report indicated similar expressive and receptive vocabulary growth across the study in both groups. Thus, infants can learn a function bias for object naming and generalisation. However, it seems that a function bias does not provide an additional benefit for vocabulary growth than a developing shape bias.

In Chapter 3, I investigated whether late talkers can learn a shape bias and the effect that a shape bias training can have in their vocabulary growth. In this study, a group of late talkers were introduced to either a shape bias training or a specific word training. In the shape bias training, I introduced participants to an intervention programme that had the main aim of highlighting that what made two objects being called the same, was their sameness of shape. In the specific word training group, I presented late talkers with different sets of real objects and their names. Results of this study showed that late talkers in the shape training group learned to generalise known labels (first-order generalisation) by shape, but did not show a preference to generalise novel labels (second-order generalisation) by any property. Participants in the specific word training group did not show a preference to generalise object labels by any property. The parental report indicated similar expressive and receptive vocabulary growth in both groups. Thus, while late talkers can learn to generalise specific labels by shape similarities, I did not find evidence that they can learn to use this as a general strategy for general vocabulary learning.

While in Chapter 2 and 3 I introduced a word learning bias that participants did not know, in Chapter 4 I investigated if children born preterm with a typical development (i.e. without any severe conditions, disorders or impairments) showed a shape bias when generalising novel labels. I also investigated their vocabulary size and composition, and their language, cognitive and motor development. Finally, I investigated whether there was a relationship between participants' vocabulary size, cognitive development and motor development with the shape bias. In two different sessions, a group of preterm children and a group of full-term children were introduced to a word extension task, and various cognitive, language and motor tests. Results of the pilot study showed that children born preterm do have a shape bias, but their preference for shape may be less robust than in full-term children. Thus, while children born preterm can also develop a useful word learning strategy (i.e. shape bias) for noun generalisation, they may rely less on it compared to full-term children. Results also showed that children born preterm can have similar vocabularies than full-term children and can achieve similar scores than full-term children in language, cognitive and motor assessments. Thus, development in the preterm group was not delayed or impaired. As mentioned previously, Chapter 4 was a pilot study. Therefore, results should be taken with caution as further research is still required to confirm these findings.

5.2 Towards a Better Understanding of Word Learning in Typical Development

Previous research has shown that towards the end of the second year of life, typically developing infants develop a shape bias (Hupp, 2015; Kucker et al., 2019; Landau et al., 1998b; Perry & Samuelson, 2011). However, objects can also be named and classified according to their functions. It has been suggested that infants and young children cannot use function for object naming and generalisation (Graham et al., 1999; Landau et al., 1998b) because it may be conceptually more difficult than shape (Gathercole & Whitfield, 2001; Gentner, 1982; Gentner & Boroditsky, 2010; Landau et al., 1988). Contrary to previous research, in the training programme conducted in Chapter 2, I found that infants can learn a function bias for object naming and generalisation. These results have important implications for word learning, as they show that 17-month-olds are cognitively ready to learn and use and object's function for object naming and generalisation. Thus, the fact that typically developing children tend to use shape for object naming and generalisation does not mean that they cannot use function.

The findings of Chapter 2 also have important implications for the understanding of why infants naturally develop a shape bias, but not a function bias. Contrary to previous research (Gathercole & Whitfield, 2001; Gentner, 1982; Gentner & Boroditsky, 2010; Landau, Smith, & Jones, 1988), I suggest that infants and young children do not prioritise shape in word learning at the expense of function due to any differences in difficulty. Instead, I suggest that a shape bias is developed because of two main reasons. First, most words infants learn refer to objects organised by shape (Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg et al., 2019). Second, since shape and function tend to be correlated (Deák et al., 2002), understanding and using shape may be enough to know what an object is and therefore its name. For example, a spoon has a long handle and a concave round section. By observing its characteristic shape, we can know that it can be used for scooping food and that it is called *spoon.* In consequence, we do not need to see the spoon being used to know it is a spoon. Therefore, a shape bias may develop because of how objects are organised.

It is important to note that while in Chapter 2 infants were able to learn a function bias, they did so in a tightly controlled environment where participants were explicitly taught the names of specific novel objects. In real life, learning a new word tends not to be as structured as it typically is in a research environment. For instance, learning a new word is not always a direct learning experience where an adult explicitly says the name of an object while holding it in front of the infant for a few minutes. In real life, infants may learn words by only observing and listening to what others are doing and saying. Additionally, if infants are directly shown an object, they may only observe it for a few seconds before something else is presented. If we consider that naming and learning experiences may constantly be changing, infants may need to develop a strategy based on a property that can be quickly identified (i.e. shape) and that does not require direct manipulation to learn it. Therefore, infants may develop a word learning strategy based on shape similarities because it may help them learn words quickly in an environment that may constantly be changing. This not because they cannot understand the importance of function, but because a shape bias is a more efficient strategy during the first years of life. It may be that as suggested by Träuble and Pauen (2007), shape and function are more relevant for language acquisition at different stages of development, with shape being more useful during the first years of life.

In addition to a tightly controlled environment, in Chapter 2, the objects' functions were explicitly explained and demonstrated. However, in real life, functions are not described and presented as they were in the current study. For instance, a mother will not say *"Look, this is a pen and can be used to write"* every time she shows the infant a pen. Instead, she may just say *"Look, this is a pen"*. Thus, while children may be able to understand and use function, the environment may not naturally provide them with the information required to use it or the time to observe it. Thus, studies with a more naturalistic setting could provide more information about a function bias in typical development (see section 5.4 for a discussion of how future studies could address this).

Results from Chapter 2 also have two important implications for research regarding the development of word learning biases. The first implication is that the four-step process by which the shape bias is developed, proposed by Smith and colleagues (2002), could also be used to explain how a function bias is developed and potentially how in general other word learning biases can be developed (see section 1.1.2 for a detailed description of the four-step process). Following this four-step process, in Chapter 2, through repetitive exposure during the training sessions, infants associated a specific word (i.e. *dax*) to a particular object that performed a specific function (i.e. picking up flowers). Then, in the second step, after being presented with different objects during the training sessions that had the same name and the same function (i.e. other objects that were also called *dax* and could also be used for picking up flowers), infants learned that all objects that could be used for picking up flowers could be called *dax*. Therefore, they were able to generalise these known objects based on their similarity in function (first-order generalisation). This was demonstrated by the fact that during the first-order generalisation task, participants in the function-training group generalised the known labels based mainly by function similarities. In the third step, after constant experience with different sets of objects named according to their functions (i.e. *kivs* are objects that could be used to cut Play-Doh*, pisks* are objects that could make noise when shaken*, daxes* are objects that could be used to pick up flowers, and *zavs* are objects that could be used to make circles on Play-Doy), infants learned that in general objects with the same function tend to have the same name. Thus, they created a second-order generalisation rule based on function similarities. This was demonstrated by the fact that they generalised mainly by function in the second-order generalisation task. Hence, even though it was the first time that they encountered a *toma*, they knew that objects could be organised by function and they were able to generalise the label *toma* to another novel object that could be used for the same function (i.e. used to stamp). Finally, by step four, infants had a general rule of how to name and generalise labels. This rule in Chapter 2 was that objects could be named and generalised by their similarities in function.

The second implication that results of Chapter 2 have for research regarding the development of word learning biases is that word learning biases will only be applied in the real word if the bias is related to the type of words infants are learning. While being exposed to objects named and organised by a particular property (i.e. function in Chapter 2) can tune infants' attention towards that property, this bias will only because a useful word learning bias in real life if it is related to the words infants are learning and how objects are organised. For example, Samuelson (2002) introduced a material bias training to a group of infants. Even though researchers followed the exact same methodology as Smith and colleagues (2002), a material bias was not useful for boosting vocabulary learning as most words infants learn during the first years of life are organised by shape (Dansereau, 2016; Samuelson & Smith, 1999; Sandhofer et al., 2000; Schonberg et al., 2019) and not by material. Thus, while initially associating what we see with what we hear may be the first step to develop a word learning bias, this bias will only be useful for general vocabulary learning if it targets a property related to the type objects we are learning and how they are categorised.

Even though in this thesis I focused on the development of word learning biases, results from Chapter 2 can also contribute to explain how, in general, infants and young children learn words. This because the methodology of Chapter 2 involved teaching infants the names of novel objects. Therefore by assessing how these words were potentially learned, we can have a better understanding of how word learning occurs.

As mentioned in Chapter 1, different competing accounts of how infants and young children learn words have been proposed. Some of these theoretical accounts are: the word learning biases, the associative account, the social pragmatic account, and the emergentist coalition model. The word learning biases are assumptions about objects that facilitate word learning (Hollich, Hirsh-Pasek, & Golinkoff, 2000). Some of these assumptions are: the whole object assumption (Markman & Wachtel, 1988), the taxonomic assumption (Markman & Hutchinson, 1984), the mutual exclusivity assumption (Markman & Wachtel, 1988), and the shape bias (Landau et al., 1988). According to the social pragmatic account, infants learn words by using the cues that speakers provide (e.g. eye gaze, gestures) to identify the correct referent of a particular word (Baldwin, 1993a; Baldwin et al., 1996; Baldwin & Moses, 2001). According to the associative account, infants learn words by associating the stimuli that they see with what they hear (Smith et al., 2002; Smith & Yu, 2008; Yu, 2008). While these three previous accounts try to explain word learning differently, the emergentist coalition model suggests that word learning occurs through a mixture of associations, social cues and word learning biases (Hollich, Hirsh-Pasek, Golinkoff, et al., 2000) Thus, neither the associative account, the word learning biases or the social pragmatic account can explain how infants learn words in all possible instances (Hollich, Hirsh-Pasek, Golinkoff, et al., 2000).

In Chapter 2, infants in the training session were introduced to novel objects and their names. By constantly presenting these objects along with their names and their functions, it is possible that during the first few training session infants started by associating a novel name with a novel object with a specific function because they all co-occurred. Additionally, during the presentation of the novel objects, different social cues such as pointing to the objects and looking at the objects were used. Thus, infants might have also used those social cues to identify the referent of a specific word quickly. Then, after mapping different words to their referents, infants were finally able to create a rule of how objects should be named (i.e. that objects can be named and generalised according to their function) and were able to use this rule for known and novel object labels. Hence, they developed a function bias that they were able to use even when encountering new labels. Therefore, associations, social cues and word learning bias might have all contributed to the word learning process observed in Chapter 2. It is important to note that even though in this example I first mentioned associative and social cues, I am not saying that the word learning process should occur in this order. This example is just to demonstrate that, as suggested by Yu and Ballard (2002), these three things are essential for word learning, and they might be used at different stages of the word learning process. Therefore, as the emergentist coalition model suggests (Hollich, Hirsh-Pasek, Golinkoff, et al., 2000), word learning occurs through a mixture of social cues, associations and word learning biases, among other important social, linguistic and cognitive processes.

5.3 Towards a Better Understanding of Word learning in Atypical Development

While typically developing children seem to learn new words at a rapid rate, not all children learn words at the same speed. Research has shown that two populations with small vocabularies are late talkers (Ellis Weismer et al., 2013; MacRoy-Higgins & Montemarano, 2016; Rescorla, 2011) and children born preterm (Brósch-Fohraheim et al., 2019; Kern & Gayraud, 2007; Sansavini et al., 2015). One crucial difference between these groups is that, even though they both tend to have vocabulary delays, children born preterm tend to have additional cognitive and/or motor delays, but late talkers' deficits seem to be mainly about language. Therefore, investigating these two populations that seem to have different developmental characteristics and paths, provided information regarding which areas of development may be influencing the delays in vocabulary acquisition and the development of the shape bias. By understanding the deficits in these two populations, we can also understand what cognitive, developmental and/or motor processes are essential for the successful development of a shape bias, and therefore for word learning. In the following sections I will discuss the implications that the results of Chapter 3 and 4 have in what we know about how word learning occurs in children with vocabulary delays.

5.3.1 Word Learning and Vocabulary Development in Late Talking Children

Previous research has shown that, in contrast to typically developing children, late talkers do not show a shape bias for noun generalisation (Jones, 2003). Thus, a delay in vocabulary acquisition may be related to their lack of a shape bias. To my knowledge, Chapter 3 investigated, for the first time, the use of a shape bias training as an intervention for late talkers.

The fact that late talkers in Chapter 3 were unable to learn a shape bias for second-order generalisation has important implications for research regarding word learning in this population. First, it suggests that vocabulary development in late talkers may be atypical rather than just delayed. If late talkers were achieving the same developmental milestones the same way as typically developing children but at a later age, late talkers in this study would have learned a shape bias using the methodology used in Chapter 3. This because this methodology has been proven to be successful for teaching a shape bias in typically developing children (e.g. Perry, Samuelson, Malloy, & Schiffer, 2010; Samuelson, 2002; Smith et al., 2002) and has also been used for successfully teaching a function bias in typically developing children (See Chapter 2). However, I found no evidence that late talkers can achieve the same milestones or that they learn the same word learning biases but just at a later age. This may indicate that language acquisition occurs via qualitatively different processes than in typically developing children. For instance, it may be that late talkers may require direct and constant interaction with the same objects and the same names to learn the name of those objects. This is an inefficient strategy and would require additional effort and time, making noun learning a slower and more complicated process than it should be.

A further possibility is that the absence of any evidence for a shape bias in the sample of late talkers tested in Chapter 3 may be related to a deficit in other cognitive processes (e.g., statistical learning and/or attention deficits). As suggested by Kucker and colleagues (2019), the shape bias is not just a language specific process and other cognitive abilities may be required for a successful development of the shape bias. Therefore, successful interventions may need to target other potential cognitive deficits besides a language delay. For example, Alt, Meyers, Oglivie, Nicholas and Arizmendi (2014) conducted a cross-situational based intervention for late talkers, where they used highly variable linguistic input and contextual diversity. In this study, not only were late talkers able to learn most taught words, but they also learned 21.60 more words per week outside the research environment. It may be that deficits in cognitive processes required for word learning have a cascading effect where the obvious and visible outcome is a language delay. Thus, it could be that a mixture of the shape bias intervention (Smith et al., 2002) and a cross-situational based intervention (Alt et al., 2014) may be more useful for late talkers, than just a shape bias intervention (see section 5.4 for a discussion of further studies in this population).

The results of Chapter 3 also have important implications for the identification of late talkers. Clinically, late talkers are considered as children with expressive language delays. Additionally, most studies investigating late talkers have mainly recruited participants with only expressive delays or have only reported expressive vocabulary (Alt et al., 2014; Hammer et al., 2017; Paul et al., 1991; Singleton & Anderson, 2020). However, participants in Chapter 3 showed that significant receptive delays can also be found in this population. Thus, when conducting research with late talkers, it is important to also investigate and report potential delays in receptive vocabulary.

One important thing to note is that early language delays could also be a characteristic of other disorders such as Autism Spectrum Disorder (ASD) or Developmental Language Delay (DLD) (Haebig et al., 2017; Rudolph & Leonard, 2016; Tek, Mesite, Fein, & Naigles, 2014). Most participants in Chapter 3, at the time of the study, were waiting for a formal assessment to assess the presence of any additional conditions or disorders. Thus, while their main difficulties were related to language delays, there was no official assessment that could confirm the presence, or absence, of any other additional conditions, disorders or impairments. To address this limitation, in Chapter 3, a one year follow up was planned to assess the long-term effects of the shape bias intervention, but also to know whether participants were diagnosed with a condition or disorder by that time. Due to university closures related to the Covid 19 pandemic, it was not possible to conduct this follow up. Thus I do not have information regarding whether children in this study caught up, continued demonstrating language delays or were diagnosed with an additional condition or disorder. Before the university closures I was only able to contact two participants, and by then none of them had received any diagnosis of additional conditions, disorders or impairments.

5.3.2 Vocabulary and the Shape Bias in Children Born Preterm

While previous research with late talkers has investigated the lack of a shape bias and its relationship with vocabulary development, to my knowledge Chapter 4 provided, for the first time, information regarding the word learning biases that children born preterm use. The results of Chapter 4 have three important implications for research regarding children born preterm. First, the results of the pilot study suggest that children born preterm in this study have developed a shape bias at a similar age to that of full-term children. Second, I found that children born preterm can have similar vocabularies to those of full-term children. Thus vocabulary development is not always delayed. Third, I found no evidence that the children born preterm who were included in Chapter 4 were developing out of line with their full-term peers because they showed similar scores in all cognitive, language and motor assessments. Thus, contrary to Cusson (2003), in this study, children born preterm developed as expected for their chronological age and achieved language milestone at similar ages than their full-term children.

The main finding of Chapter 4 was that children born preterm showed a preference for generalising novel labels by shape. However, there was a trend that approached significance on how much participants relied on the shape bias compared to full-term children. Additionally, I found a relationship between the shape bias and gestational age, with children that were born earlier in the pregnancy also showing a less robust shape bias, and children born later in the pregnancy showing a more robust shape bias. While at the moment a smaller shape bias in some children born preterm is a possibility, Chapter 4 does show that there may be a potential difference in how much children born preterm (or at least some children born preterm) and full-term children rely on the shape bias for word extension. It may be that a significantly less robust shape bias is only found in children born preterm with significantly smaller vocabularies than full-term children, or in premature children born earlier during the pregnancy.

As mention previously, Chapter 4 was a pilot study. While it provided important information regarding language, cognitive and motor development in children born preterm, it also provided important information regarding recruitment and design of future studies investigating the same topic. Chapter 4 showed that the methodology used in this pilot study can provide information regarding the shape bias, vocabulary size and vocabulary composition of children born preterm. The methodology used also provided information about general cognitive and motor development. However, the pilot study also highlighted the importance of recruiting participants from across a wider socioeconomic range. Since previous research has shown that children born preterm from higher socioeconomic status tend to achieve higher scores in language assessments and tend to show less developmental delays than children from lower socioeconomic status (ElHassan et al., 2018; Marchman et al., 2016; Ross et al., 2016), having a sample of only middle-class families may only be representing the developmental characteristics of a subgroup of children born preterm. The pilot study in Chapter 4 also highlighted the importance of dividing children born preterm into groups according to their gestational age and comparing them. Since research has shown that very preterm children and extremely preterm children are the ones that tend to show more significant delays or deficits in vocabulary development (Foster-Cohen et al., 2007; Kern & Gayraud, 2007), this pattern may also be present in the development of a shape bias in children born preterm. If these limitations can be addressed in future studies, results would give more precise information of the shape bias in children born preterm.

5.4 General Limitations

This thesis has two general limitations. First, all interventions and assessments were introduced in a tightly controlled environment. In Chapter 2 and 3, typically developing infants and late talkers only saw one or two objects when a novel label was mentioned, and no potential distractors were in the room. Additionally, both of these objects were the correct referent for a specific word. Thus, it was easier to identify the correct referent of each word. In the real world, word learning does not always occur like this. As proposed by Quine (1960), every time infants hear a novel word, they need to identify the correct referent form a wide range of options because in the real world children are surrounded by infinite possibilities of what a particular word refers to. So, by explicitly introducing only objects that shared a specific characteristic with the same name and nothing else, I made it easier for them to identify what a novel word referred to. Additionally, in Chapter 2 and Chapter 3, I used cues to attract children's attention to the correct referent (e.g. by saying *"Look",* by pointing, among others). However, in the real world, direct cues to indicate the correct referent are not always available (Yu & Ballard, 2007). Therefore, the methodology used could have made it easier for participants to learn by limiting the potential referents a word could have. Future research should explore if typically developing infants and late talkers can learn a function bias or a shape bias in a more naturalistic environment. One way of addressing this could be by conducting the same training programmes or interventions in an environment that is more similar to what children experience in everyday life (e.g. in the participant's house, or a more child-friendly research environment).

The second limitation that this thesis had was the sample size. While in Chapter 2, the sample size suggested by a power analysis was achieved, this was not the case for Chapter 3 and Chapter 4. For Chapter 3, I aimed to recruit 24 participants. However, three reasons contributed to a smaller final sample size than initially planned. First, there was a high attrition rate. Five additional participants started the study but decided to withdraw before completing all assessments. Second, three participants had to be removed from the analysis due to the presence of additional conditions or disorders. Third, due to university closures, testing had to be stopped. Thus, four additional participants that were taking part in the study were not able to complete all assessments. Regarding Chapter 4, I did not conduct a formal sample size calculation as it was a pilot study with the main aim of exploring any potential differences between preterm and full-term children without a priori knowledge of the likely effect sizes of any differences between groups and conditions. A post hoc sample size calculation in Chapter 4 denoted with the achieved effect size of 0.96 (Cohen's *d*), an error probability of 0.05 and a power of 0.80, a minimum of 38 participants (19 participants in each group) should be included for future studies. Thus, further studies with bigger sample sizes, mainly for studies investigating the same as in Chapter 3 and 4 are required to confirm the findings.

5.5 Future Directions

There are some questions left unanswered that future research should address. In Chapter 2, I did not find evidence of differences in vocabulary growth. This could have been due to the fact that both groups developed a useful word learning strategy: the function-training group developed a function bias, while the control group seemed to be developing a shape bias. Future research should assess whether similar results are found when a function bias is compared to no other bias. This could provide more information regarding the potential benefits that a function bias can have for early word learning.

Regarding Chapter 3, a modified version of the shape bias training that also addresses the underlying deficits late talkers may have could provide more information regarding whether late talks can or cannot develop a shape bias for second-order generalisation. Additionally, since previous research has shown that late talkers may be paying less attention to objects that are being shown to them (MacRoy-Higgins & Montemarano, 2016), it would also be essential to assess late talker's attention towards the objects that are being used while the intervention is taking place. Comparing their attention to typically developing children would provide more information regarding the role that attention plays in late talkers' vocabulary development. Future studies investigating the shape bias as a word learning intervention should also investigate if different results are found when comparing participants with expressive and receptive delays (as in Chapter 3) compared to participants with only expressive delays. Finally, while a shape bias has been the typical word learning used during the first years of life, it is not the only useful bias for object naming and generalisation. Research with children diagnosed with ASD has shown that they also tend to lack a shape bias (Tek et al., 2008). However, in some cases, they show a function bias instead (Tek & Naigles, 2017). Since in Chapter 2 I found that typically developing children can learn a function bias, further research assessing if late talkers could benefit from using other word learning biases that are also useful during the first years of life, such as a function bias, should be conducted.

Finally, for Chapter 4, as mentioned previously, future research regarding shape bias in children born preterm should be conducted with a bigger sample size. While a smaller shape bias is speculative at the moment, Chapter 4 does show that there may be a potential difference in how much preterm and full-term children rely on the shape bias for word extension. Additionally, future research should look at if there are any differences in the use of the shape bias between preterm groups (late preterm, moderate preterm, very preterm, and extremely preterm). All this information could provide more information regarding potential underlying reasons why some children born preterm have smaller vocabularies. This may even provide information for potential future interventions specifically aimed at their underlying difficulties for vocabulary acquisition in children born preterm.

5.6 Conclusions

The results of the current thesis provide an insight into four important topics. First, they provided information regarding the word learning biases used by typically developing children, children with language delays (late talkers) and children born preterm. Second, they provided information regarding the influence of word learning biases (shape bias and function bias) in word learning. Third, results provided information regarding ways to boost vocabulary learning in typically developing children and late talkers. Finally, they provided information regarding how deficits in different areas of development may affect how children learn words.

More specifically, in Chapter 2, I found evidence that typically developing children can learn a function bias in infancy. Thus, the preference observed for shape in early word learning, and generalisation may not be because function is more difficult. Instead, since most objects infants learn tend to be organised by shape, and since shape and function tend to be correlated, using the more accessible cue (i.e. shape) can be enough to know what an object is and therefore its name. In Chapter 3, I found evidence that late talkers can learn to generalise known object names by shape, but they do not do this for object names they have never encountered before. I proposed that a lack of a shape bias for second-order generalisation could be related to a deficit in cognitive processes required to develop it, rather than to a difficulty for understanding the importance of shape for object naming and generalisation. Finally, in Chapter 4, I found evidence that children born preterm without any severe conditions, disorders or impairments, also develop a useful word learning strategy (i.e. the shape bias), and can have similar vocabularies to their full-term peers. I also found evidence that they can perform similarly to their full-term peers in cognitive, language and motor assessments. Thus, some children born preterm can achieve important language milestones at the same age as full-term children, and they can also have a general development in step with their full-term peers.

Taken together, the findings of this thesis highlight the important role that word learning biases have in facilitating vocabulary learning and how infants will use strategies related to the words they learn in order to make word learning a more effortless and quicker process. This thesis also showed that word learning does not occur as the direct effect of one linguistic, social or cognitive process. Being able to learn words requires the use of social cues, association of co-occurring events and word learning bias. Finally, this thesis also highlights the relationship between language and cognitive development, and how language delays and a lack of a shape bias, could be related to deficits in cognitive development. Further studies are still required to have a more precise understanding of the word learning biases used in typical and atypical development, how these are developed and their effect in vocabulary development.

REFERENCES

Alcock, K. J., & Krawczyk, K. (2010). Individual differences in language development: Relationship with motor skill at 21 months. *Developmental Science*, *13*(5), 677–691. https://doi.org/10.1111/j.1467-7687.2009.00924.x

Alcock, K. J., Meints, K., & Rowland, C. (2017). UK-CDI Words and Gestures - Preliminary norms and manual.

Alt, M., Meyers, C., Oglivie, T., Nicholas, K., & Arizmendi, G. (2014). Cross-situational statistically based word learning intervention for late-talking toddlers. *Journal of Communication Disorders*, *52*, 207–220. https://doi.org/10.1016/j.jcomdis.2014.07.002

Aussems, S., & Kita, S. (2020). Seeing iconic gesture promotes first- and second-order verb generalization in preschoolers. *Child Development*, *00*(0), 1–18. https://doi.org/10.1111/cdev.13392

Baldwin, D. A. (1993a). Early Referential Universtanding: Infants´Ability to Recognize Referential Actos for What They Are. *Developmental Psychology*, *29*(5), 832–843. https://doi.org/https://doi.org/10.1037/0012-1649.29.5.832

Baldwin, D. A. (1993b). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language*, *20*(2), 395–418. https://doi.org/10.1017/S0305000900008345

Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Jane, M., Baldwin, D. A., … Renee, N. (1996). Infants ' Reliance on a Social Criterion for Establishing Word-Object Relations, *67*(6), 3135–3153. https://doi.org/10.2307/1131771

Baldwin, D. A., & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development*, *10*(3), 309–329. https://doi.org/10.1111/1467-9507.00168

Baron, I. S., Kerns, K. A., Mller, U., Ahronovich, M. D., & Litman, F. R. (2012). Executive functions in extremely low birth weight and late-preterm preschoolers: Effects on working memory and response inhibition. *Child Neuropsychology*, *18*(6), 586–599. https://doi.org/10.1080/09297049.2011.631906

Bates, E., Hartung, J., Marchman, V., Thal, D., Fenson, L., Reilly, J., … Reznick, J. S. (1994). Developmental and Stylistic Variation in the Composition of Early Vocabulary. *Journal of Child Language*, *21*(1), 85–123. https://doi.org/10.1017/S0305000900008680

Beaulieu-Poulin, C., Simard, M. N., Babakissa, H., Lefebvre, F., & Luu, T. M. (2016). Validity of the language development survey in infants born preterm. *Early Human Development*, *98*, 11–16. https://doi.org/10.1016/j.earlhumdev.2016.06.003

Behrend, D. A., Scofield, J., & Kleinknecht, E. E. (2001). Beyond Fast Mapping: Young Children's Extensions of Novel Words and Novel Facts. *Developmental Psychology*, *37*(5), 698–705. https://doi.org/10.1037//0012-1649.37.5.698

Benassi, E., Savini, S., Iverson, J. M., Guarini, A., Caselli, M. C., Alessandroni, R., … Sansavini, A. (2016). Early communicative behaviors and their relationship to motor skills in extremely preterm infants. *Research in Developmental Disabilities*, *48*, 132–144. https://doi.org/10.1016/j.ridd.2015.10.017

Bernbaum, J. C. (2016). Follow-up Care of the Graduate From the Neonatal Intensive Care Unit. In T. K. McInerny, H. M. Adam, D. E. Campbell, T. G. DeWitt, J. M. Foy, & D. M. Kamat (Eds.), *American Academy of Pediatrics Textbook of Pediatric Care* (2nd ed., pp. 1069–1084). American Academy of Pediatrics. Retrieved from https://ebookcentral.proquest.com/lib/bham/reader.action?docID=4612328

Bleses, D., Makransky, G., Dale, P. S., Hojen, A., & Ari, B. A. (2016). Early productive vocabulary predicts academic achievement 10 years later. *Applied Psycholinguistics*, *37*(06), 1461–1476. https://doi.org/10.1017/S0142716416000060

Böhm, B., Smedler, A. C., & Forssberg, H. (2004). Impulse control, working memory and other executive functions in preterm children when starting school. *Acta Paediatrica, International Journal of Paediatrics*, *93*(10), 1363–1371. https://doi.org/10.1080/08035250410021379

Booth, A. E., Schuler, K., & Zajicek, R. (2010). Specifying the role of function in infant categorization. *Infant Behavior and Development*, *33*(4), 672–684. https://doi.org/10.1016/j.infbeh.2010.09.003

Booth, A. E., & Waxman, S. (2002). Object names and object functions serve as cues to categories for infants. *Developmental Psychology*, *38*(6), 948–957. https://doi.org/10.1037/0012-1649.38.6.948

Booth, A. E., & Waxman, S. R. (2009). A horse of a different color: Specifying with precision infants' mappings of novel nouns and adjectives. *Child Development*, *80*(1), 15–22. https://doi.org/10.1111/j.1467-8624.2008.01242.x

Borgström, K., Torkildsen, J. von K., & Lindgren, M. (2015). Event-related potentials during word mapping to object shape predict toddlers' vocabulary size. *Frontiers in Psychology*, *6*, 1–15. https://doi.org/10.3389/fpsyg.2015.00143

Breeman, L. D., Jaekel, J., Baumann, N., Bartmann, P., & Wolke, D. (2016). Attention problems in very preterm children from childhood to adulthood: the Bavarian Longitudinal Study. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *57*(2), 132–140. https://doi.org/10.1111/jcpp.12456

Briganti, A. M., & Cohen, L. B. (2011). Examining the role of social cues in early word learning. *Infant Behavior and Development*, *34*(1), 211–214. https://doi.org/10.1016/j.infbeh.2010.12.012

Brósch-Fohraheim, N., Fuiko, R., Marschik, P. B., Resch, B., & Liu, J. (2019). The influence of preterm birth on expressive vocabulary at the age of 36 to 41 months. *Medicine (United States)*, *98*(6), 1–7. https://doi.org/10.1097/MD.0000000000014404

Buschmann, A., Multhauf, B., Hasselhorn, M., & Pietz, J. (2015). Long-Term Effects of a Parent-Based Language Intervention on Language Outcomes and Working Memory for Late-Talking Toddlers. *Journal of Early Intervention*, *37*(3), 175–189. https://doi.org/10.1177/1053815115609384

Cable, A. L., & Domsch, C. (2011). Systematic review of the literature on the treatment of children with late language emergence. *International Journal of Language & Communication Disorders / Royal College of Speech & Language Therapists*, *46*(2), 138–154. https://doi.org/10.3109/13682822.2010.487883

Caravale, B., Tozzi, C., Albino, G., & Vicari, S. (2005). Cognitive development in low risk preterm infants at 3-4 years of life. *Archives of Disease in Childhood: Fetal and Neonatal Edition*, *90*(6), 474–479. https://doi.org/10.1136/adc.2004.070284

Chilosi, A. M., Pfanner, L., Pecini, C., Salvadorini, R., Casalini, C., Brizzolara, D., & Cipriani, P. (2019). Which linguistic measures distinguish transient from persistent language problems in Late Talkers from 2 to 4 years? A study on Italian speaking children. *Research in Developmental Disabilities*, *89*, 59–68. https://doi.org/10.1016/j.ridd.2019.03.005

Cimpian, A., & Markman, E. M. (2005). The absence of a shape bias in children's word learning. *Developmental Psychology*, *41*(6), 1003–1019. https://doi.org/10.1037/0012-1649.41.6.1003

Cohen, J. (1988). *Statistical Power Analysis for the Behavioural Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Collisson, B. A., Grela, B., Spaulding, T., Rueckl, J. G., & Magnuson, J. S. (2015). Individual differences in the shape bias in preschool children with specific language impairment and typical language development: Theoretical and clinical implications. *Developmental Science*, *18*(3), 373–388. https://doi.org/10.1111/desc.12219

Colunga, E., & Sims, C. E. (2012a). Early-Talker and Late-Talker toddlers and networks show different word learning biases. In *Proceedings of the 34th Annual Conference of the Cognitive Science Society 2012*.

Colunga, E., & Sims, C. E. (2012b). Early talkers and late talkers know nouns that license different word learning biases. In *Proceedings of the 33th Annual Conference of the Cognitive Science Society*.

Colunga, E., & Sims, C. E. (2017). Not Only Size Matters: Early-Talker and Late-Talker Vocabularies Support Different Word-Learning Biases in Babies and Networks. *Cognitive Science*, *41*, 73–95. https://doi.org/10.1111/cogs.12409

Colunga, E., & Smith, L. B. (2008). Shape bias special section: Knowledge embedded in process: The self-organization of skilled noun learning. *Developmental Science*, *11*(2), 195–203. https://doi.org/10.1111/j.1467-7687.2007.00665.x

Cusson, R. M. (2003). Factors influencing language development in preterm infants. *Journal of Obstetric, Gynecologic, and Neonatal Nursing*, *32*(3), 402–409. https://doi.org/10.1177/0884217503253530

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*, 437–447. https://doi.org/10.1044/2014_AJSLP-13-0116

Dansereau, D. R. (2016). Young children, sound-producing objects, and the shape bias.

Psychology of Music, *45*(2), 193–203. https://doi.org/10.1177/0305735616653465

Deák, G. O. (2014). Interrelationship of Language and Cognitive Development (Overview). *Encyclopedia of Language Development*, (September), 284–291. https://doi.org/10.4135/9781483346441.n91

Deák, G. O., Ray, S. D., & Pick, A. D. (2002). Matching and naming objects by shape or function: age and context effects in preschool children. *Developmental Psychology*, *38*(4), 503–518. https://doi.org/10.1037/0012-1649.38.4.503

Desmarais, C., Sylvestre, A., Meyer, F., Bairati, I., & Rouleau, N. (2008). Systematic review of the literature on characteristics of late-talking toddlers. *International Journal of Language & Communication Disorders*, *43*(4), 361–389. https://doi.org/10.1080/13682820701546854

Di Giacomo, D., Ranieri, J., Donatucci, E., Caputi, N., & Passafiume, D. (2016). The semantic associative ability in preschoolers with different language onset time. *Frontiers in Psychology*, *7*, 1–8. https://doi.org/10.3389/fpsyg.2016.01025

Diesendruck, G., & Bloom, P. (2003). How specific is the shape bias? *Child Development*, *74*(1), 168–178. https://doi.org/10.1111/1467-8624.00528

Diesendruck, G., Markson, L., & Bloom, P. (2003). Children´s Reliance on Creator´s Intent in Extending Names for Artifacts. *Psychological Science*, *14*(2), 164–168. https://doi.org/10.1111/1467-9280.t01-1-01436

Dollaghan, C. (1985). Child Meets Word: “Fast Mapping” in Preschool Children. *Journal of Speech & Hearing Research*, *28*, 449–454. https://doi.org/https://doi.org/10.1044/jshr.2803.454

Ebert, K. D., & Kohnert, K. (2011). Sustained Attention in Children With Primary Language Impairment: A Meta-Analysis. *Journal of Speech, Language, and Hearing Research*, *54*(October), 1372–1384. https://doi.org/10.1044/1092-4388(2011/10-0231)a

ElHassan, N. O., Bai, S., Gibson, N., Holland, G., Robbins, J. M., & Kaiser, J. R. (2018). The impact of prematurity and maternal socioeconomic status and education level on achievement-test scores up to 8th grade. *PLoS ONE*, *13*(5), 1–15. https://doi.org/10.1371/journal.pone.0198083

Ellis, E. M., Borovsky, A., Elman, J. L., & Evans, J. L. (2015). Novel word learning: An eye-tracking study. Are 18-month-old late talkers really different from their typical peers? *Journal of Communication Disorders*, *58*, 43–157. https://doi.org/10.1016/j.jcomdis.2015.06.011

Ellis Weismer, S., & Evans, J. L. (2002). The role of processing limitations in early identification of specific language impairment. *Topics in Language Disorders*, *22*(3), 15–29. https://doi.org/10.1097/00011363-200205000-00004

Ellis Weismer, S., Venker, C. E., Evans, J. L., & Jones Moyle, M. (2013). Fast Mapping in Late-Talking Toddlers. *Applied Psycholinguistics*, *34*(1), 69–89. https://doi.org/10.1017/S0142716411000610

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fernald, A., Thorpe, K., & Marchman, V. A. (2010). Blue car, red car: Developing efficiency in online interpretation of adjective-noun phrases. *Cognitive Psychology*, *60*(3), 190–217. https://doi.org/10.1016/j.cogpsych.2009.12.002

Finestack, L. H., & Fey, M. E. (2013). Evidence Based Language Intervention Approaches for Young Late Talkers. In L. Rescorla & P. S. Dale (Eds.), *Late talkers: Language development, interventions, and outcomes.* (pp. 283–302). Baltimore: Paul Brookes

Publishing.

Finneran, D. A., Francis, A. L., & Leonard, L. B. (2009). Sustained Attention in Children With Specific Language Impairment (SLI). *Journal of Speech, Language, and Hearing Research*, *52*(August), 915–929. https://doi.org/10.1044/1092-4388(2009/07-0053)

Foster-Cohen, S., Edgin, J. O., Champion, P. R., & Woodward, L. J. (2007). Early delayed language development in very preterm infants: Evidence from the MacArthur-Bates CDI. *Journal of Child Language*, *34*(3), 655–675. https://doi.org/10.1017/S0305000907008070

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2016). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language*, *44*(3), 677–694. https://doi.org/10.1017/S0305000916000209

Gathercole, V. C. M., & Whitfield, L. C. (2001). Function as a criterion for the extension of new words. *Journal of Child Language*, *28*(1), 87–125. https://doi.org/10.1017/S030500090000458X

Geldof, C. J. A., van Wassenaer, A. G., de Kieviet, J. F., Kok, J. H., & Oosterlaan, J. (2012). Visual perception and visual-motor integration in very preterm and/or very low birth weight children: A meta-analysis. *Research in Developmental Disabilities*, *33*(2), 726–736. https://doi.org/10.1016/j.ridd.2011.08.025

Gentner, D. (1978). What looks like a jiggy but acts like a zimbo: A study of early word meaning using artificial objects. *Papers and Reports on Child Language Development*, *15*, 1–6.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.), *Language Development: Volume 2. Language, Thought and Culture* (pp. 301–334). Hillsdale, N.J.: Lawrence Erlbaum.

Gentner, D., & Boroditsky, L. (2010). Individuation, relativity, and early word learning. In *Language Acquisition and Conceptual Development* (pp. 215–256). https://doi.org/10.1017/cbo9780511620669.010

Gershkoff-Stowe, L., & Hahn, E. R. (2007). Fast mapping skills in the developing lexicon. *Journal of Speech, Language, and Hearing Research*, *50*(3), 682–697. https://doi.org/10.1044/1092-4388(2007/048)

Gershkoff-Stowe, L., & Smith, L. B. (1997). A curvilinear trend in naming errors as a function of early vocabulary growth. *Cognitive Psychology*, *34*(1), 37–71. https://doi.org/10.1006/cogp.1997.0664

Gershkoff-Stowe, L., & Smith, L. B. (2004). Shape and the first hundred nouns. *Child Development*, *75*(4), 1098–1114. https://doi.org/10.1111/j.1467-8624.2004.00728.x

Ghosh, K. (2019). Office for National Statistics. Retrieved May 21, 2019, from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthcharacteristicsinenglandandwales

Gilkerson, J., Richards, J. A., & Topping, K. J. (2017). The impact of book reading in the early years on parent–child language interaction. *Journal of Early Childhood Literacy*, *17*(1), 92–110. https://doi.org/10.1177/1468798415608907

Girolametto, L., Pearce, P. S., & Weitzman, E. (1997). Effects of Lexical Intervention on the Phonology of Late Talkers. *J Speech Lang Hear Res*, *40*(2), 338–348. https://doi.org/10.1044/jslhr.4002.338

Girolametto, L., Weitzman, E., & Earle, C. (2013). From Words to Early Sentences. In L. Rescorla & P. S. Dale (Eds.), *Late talkers: Language development, interventions, and outcomes.* (pp. 261–283). Baltimore: Paul Brookes Publishing.

Goldfield, B. A. (2000). Nouns before verbs in comprehension vs. production: The view from pragmatics. *Journal of Child Language*, *27*(3), 501–520. https://doi.org/10.1017/S0305000900004244

Golinkoff, R. M., & Hirsh-Pasek, K. (2006). The Emergentist Coalition Model of Word LEarning in Children Has Implications for Language in Aging. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan Cognition: Mechanisms of Change*. https://doi.org/10.1093/acprof:oso/9780195169539.003.0014

Gonzalez, S. L., Alvarez, V., & Nelson, E. L. (2019). Do Gross and Fine Motor Skills Differentially Contribute to Language Outcomes? A Systematic Review. *Frontiers in Psychology*, *10*(December), 1–16. https://doi.org/10.3389/fpsyg.2019.02670

Graham, S. A., & Diesendruck, G. (2010). Fifteen-month-old infants attend to shape over other perceptual properties in an induction task. *Cognitive Development*, *25*(2), 111–123. https://doi.org/10.1016/j.cogdev.2009.06.002

Graham, S. A., Nilsen, E. S., Collins, S., & Olineck, K. (2010). The role of gaze direction and mutual exclusivity in guiding 24-month-olds' word mappings. *British Journal of Developmental Psychology*, *28*(2), 449–465. https://doi.org/10.1348/026151009X424565

Graham, S. A., & Poulin-Dubois, D. (1999). Infants' reliance on shape to generalize novel labels to animate and inanimate objects. *Journal of Child Language*, *26*(2), 295–320. https://doi.org/10.1017/S0305000999003815

Graham, S. A., Williams, L. D., & Huber, J. F. (1999). Preschoolers' and adults' reliance on object shape and object function for lexical extension. *Journal of Experimental Child Psychology*, *74*(2), 128–151. https://doi.org/10.1006/jecp.1999.2514

Gross, S. J., Mettelman, B. B., Dye, T. D., & Slagle, T. A. (2001). Impact of family structure and stability on academic outcome in preterm children at 10 years of age. *Journal of Pediatrics*, *138*(2), 169–175. https://doi.org/10.1067/mpd.2001.111945

Haebig, E., Saffran, J. R., & Ellis Weismer, S. (2017). Statistical word learning in children with autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *58*(11), 1251–1263. https://doi.org/10.1111/jcpp.12734

Hamilton, A., Plunkett, K., & Schafer, G. (2000). Infant vocabulary development assessed with a British communicative development inventory. *Journal of Child Language*, *27*(3), 689–705. https://doi.org/10.1017/S0305000900004414

Hammer, C. S., Morgan, P., Farkas, G., Hillemeier, M., Bitetti, D., Maczuga, S., & S., R. (2017). Late talkers: A population-based study of risk factors and school readiness consequences. *Journal of Speech, Language, and Hearing Research Language and Hearing Research*, *50*(March), 607–626. https://doi.org/10.1044/2016_JSLHR-L-15-0417

Hawa, V. V., & Spanoudis, G. (2014). Toddlers with delayed expressive language: An overview of the characteristics, risk factors and language outcomes. *Research in Developmental Disabilities*, *35*(2), 400–407. https://doi.org/10.1016/j.ridd.2013.10.027

Holland, A., Simpson, A., & Riggs, K. J. (2015). Young children retain fast mapped object labels better than shape, color, and texture words. *Journal of Experimental Child Psychology*, *134*, 1–11. https://doi.org/10.1016/j.jecp.2015.01.014

Hollich, G., Golinkoff, R. M., & Hirsh-Pasek, K. (2007). Young Children Associate Novel Words With Complex Objects Rather Than Salient Parts. *Developmental Psychology*, *43*(5), 1051–1061. https://doi.org/10.1037/0012-1649.43.5.1051

Hollich, G., Hirsh-Pasek, K., & Golinkoff, R. M. (2000). What Does it Take to Learn a Word? *Monographs of the Society for Research in Child Development*, *65*(3), 1–16. https://doi.org/10.1111/1540-5834.00091

Hollich, G., Hirsh-Pasek, K., Golinkoff, R. M., Brand, R. J., Brown, E., Chung, H. L., … Rocroi, C. (2000). Breaking the language barrier: an emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development*, *65*(3), i–vi, 1–123. https://doi.org/10.1111/1540-5834.00090

Holt, K. (2011). Early Indications of Delayed Cogntive Development in Preschool Children Borm very Preterm: Evidence from Domain-General and Domain-Specific Tasks. *Infant and Child Development*, *20*, 400–422. https://doi.org/10.1002/icd

Horst, J. S., Oakes, L. M., & Madole, K. L. (2005). What does it look like and what can it do? Category structure influences how infants categorize. *Child Development*, *76*(3), 614–631. https://doi.org/10.1111/j.1467-8624.2005.00867.x

Horst, J. S., & Twomey, K. E. (2013). It's Taking Shape: Shared Object Features Influence Novel Noun Generalizations. *Infant and Child Development*, *22*, 24–43. https://doi.org/https://doi.org/10.1002/icd.1768

Horvath, S., Rescorla, L., & Arunachalam, S. (2018). The syntactic and semantic features of two-year-olds' verb vocabularies: A comparison of typically developing children and late talkers. *Journal of Child Language*, 1–24. https://doi.org/10.1017/S0305000918000508

Horwitz, S. M. C., Irwin, J. R., Briggs-Gowan, M. J., Bosson Heenan, J. M., Mendoza, J., & Carter, A. S. (2003). Language delay in a community cohort of young children. *Journal of the American Academy of Child and Adolescent Psychiatry*, *42*(8), 932–940. https://doi.org/10.1097/01.CHI.0000046889.27264.5E

Hupp, J. M. (2015). Development of the shape bias during the second year. *The Journal of Genetic Psychology*, *176*(2), 82–92. https://doi.org/10.1080/00221325.2015.1006563

Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R. M., & Shigematsu, J.

(2008). Novel noun and verb learning in Chinese-, English-, and Japanese-speaking children. *Child Development*, *79*(4), 979–1000. https://doi.org/10.1111/j.1467-8624.2008.01171.x

Ionio, C., Riboni, E., Confalonieri, E., Dallatomasina, C., Mascheroni, E., Bonanomi, A., … Comi, G. (2016). Paths of cognitive and language development in healthy preterm infants. *Infant Behavior and Development*, *44*, 199–207. https://doi.org/http://dx.doi.org/10.1016/j.infbeh.2016.07.004

Irwin, J. R., Carter, A. S., & Briggs-Gowan, M. J. (2002). The Social-Emotional Development of "Late-Talking" Toddlers. *Journal of the American Academy of Child and Adolescent Psychiatry*, *41*(11), 1324–1332. https://doi.org/10.1097/00004583-200211000-00014

Iverson, J. M. (2010). Developing language in a developing body: The relationship between motor development and language development. *Journal of Child Language*, *37*(2), 229–261. https://doi.org/10.1017/S0305000909990432

Jaswal, V. K., & Hansen, M. B. (2006). Learning words: Children disregard some pragmatic information that conflicts with mutual exclusivity. *Developmental Science*, *9*(2), 158–165. https://doi.org/10.1111/j.1467-7687.2006.00475.x

Jones, S. S. (2003). Late talkers show no shape bias in a novel name extension task. *Developmental Science*, *6*(5), 477–483. https://doi.org/10.1111/1467-7687.00304

Jones, S. S., & Smith, L. B. (2005). Object name learning and object perception: a deficit in late talkers. *Journal of Child Language*, *32*(1), 223–240. https://doi.org/10.1017/S0305000904006646

Jongbloed-Pereboom, M., Janssen, A. J. W. M., Steenbergen, B., & Nijhuis-van der Sanden, M. W. G. (2012). Motor learning and working memory in children born preterm: A systematic review. *Neuroscience and Biobehavioral Reviews*, *36*(4), 1314–1330. https://doi.org/10.1016/j.neubiorev.2012.02.005

Kannass, K. N., & Oakes, L. M. (2008). The Development of Attention and Its Relations to Language in Infancy and Toddlerhood. *Journal of Cognition and Development*, *9*(2), 222–246. https://doi.org/10.1080/15248370802022696

Kemler Nelson, D. G., Frankenfield, A., Morris, C., & Blair, E. (2000). Young children's use of functional information to categorize artifacts: Three factors that matter. *Cognition*, *77*(2), 133–168. https://doi.org/10.1016/S0010-0277(00)00097-4

Kemler Nelson, D. G., Russell, R., Duke, N., & Jones, K. (2000). Two-Year-Olds Will Name Artifacts by Their Functions. *Child Development*, *71*(5), 1271–1288. https://doi.org/10.1111/1467-8624.00228

Kern, S., & Gayraud, F. (2007). Influence of preterm birth on early lexical and grammatical acquisition. *First Language*, *27*(2), 159–173. https://doi.org/10.1177/0142723706075790

Kirkham, N. Z., Slemmer, J. A., & Johnson, S. P. (2002). Visual statistical learning in infancy: Evidence for a domain general learning mechanism. *Cognition*, *83*(2), 4–5. https://doi.org/10.1016/S0010-0277(02)00004-5

Kucker, S. C., Samuelson, L. K., Perry, L. K., Yoshida, H., Colunga, E., Lorenz, M. G., & Smith, L. B. (2019). Reproducibility and a unifying explanation: Lessons from the shape bias. *Infant Behavior and Development*, *54*, 156–165. https://doi.org/10.1016/j.infbeh.2018.09.011

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development*, *3*(3), 299–321. https://doi.org/10.1016/0885-2014(88)90014-7

Landau, B., Smith, L., & Jones, S. (1998a). Object perception and object naming in early development. *Trends in Cognitive Sciences*, *2*(1), 19–24. https://doi.org/10.1016/S1364-6613(97)01111-X

Landau, B., Smith, L., & Jones, S. S. (1998b). Object shape, object function, and object name. *Journal of Memory and Language*, *38*(1), 1–27. https://doi.org/10.1006/jmla.1997.2533

Lean, R. E., Paul, R. A., Smyser, T. A., Smyser, C. D., & Rogers, C. E. (2018). Social Adversity and Cognitive, Language, and Motor Development of Very Preterm Children from 2 to 5 Years of Age. *Journal of Pediatrics*, *203*, 177-184.e1. https://doi.org/10.1016/j.jpeds.2018.07.110

Määttä, S., Laakso, M.-L., Tolvanen, A., Ahonen, T., & Aro, T. (2012). Developmental Trajectories of Early Communication Skills. *Journal of Speech, Language, and Hearing Research*, *55*(4), 1083–1096. https://doi.org/10.1044/1092-4388(2011/10-0305)

MacRoy-Higgins, M., & Kliment, S. (2017). Pragmatic Functions in Late Talkers: A 1-Year Follow-Up Study. *Communication Disorders Quarterly*, *38*(2), 107–111. https://doi.org/10.1177/1525740115627344

MacRoy-Higgins, M., & Montemarano, E. A. (2016). Attention and word learning in toddlers who are late talkers. *Journal of Child Language*, *43*(5), 1–18. https://doi.org/10.1017/S0305000915000379

MacRoy-Higgins, M., & Schwartz, R. G. (2013). Phonology and Lexicon in LateTalkers. In L. Rescorla & P. S. Dale (Eds.), *Late talkers: Language development, interventions, and outcomes.* (pp. 113–128). Baltimore: Paul Brookes Publishing.

MacRoy-Higgins, M., Shafer, V. L., Fahey, K. J., & Kaden, E. R. (2016). Vocabulary of Toddlers Who Are Late Talkers. *Journal of Early Intervention*, *38*(2), 118–129. https://doi.org/10.1177/1053815116637620

Magill-Evans, J., Harrison, M. J., Zalm, J. Van Der, Magill-evans, J., Harrison, M. J., &

Holdgrafer, G. (2016). Cognitive and Language Development of Healthy Preterm Infants at 10 Years of Age. *Physical & Occupational Therapy in Pediatrics*, *2638*(May), 20–23. https://doi.org/10.1080/J006v22n01

Mani, N., & Ackermann, L. (2018). Why Do Children Learn the Words They Do ?, *0*(0), 1–5. https://doi.org/10.1111/cdep.12295

Marchman, V. A., Adams, K. A., Loi, E. C., Fernald, A., & Feldman, H. M. (2016). Early language processing efficiency predicts later receptive vocabulary outcomes in children born preterm. *Child Neuropsychology*, *22*(6), 649–665. https://doi.org/10.1080/09297049.2015.1038987

Marchman, V. A., Feldman, H. M., Gresch, L. D., Loi, E. C., & Fernald, A. (2018). Nonword Repetition and Language Outcomes in Young Children Born Preterm. *Journal of Speech, Language, and Hearing Research*, *61*(5), 1203–1215. https://doi.org/10.1044/2018_jslhr-l-17-0217

Markman, E. M. (1994). Constraints on word meaning in early language acquisition. *Lingua*, *92*(C), 199–227. https://doi.org/10.1016/0024-3841(94)90342-5

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. *Cognitive Psychology*, *16*(1), 1–27. https://doi.org/10.1016/0010-0285(84)90002-1

Markman, E. M., & Wachtel, G. F. (1988). Children's use of mutual exclusivity to constrain the meanings of words. *Cognitive Psychology*, *20*(2), 121–157. https://doi.org/10.1016/0010-0285(88)90017-5

Markman, E. M., Wasow, J. L., & Hansen, M. B. (2003). Use of the mutual exclusivity assumption by young word learners. *Cognitive Psychology*, *47*(3), 241–275. https://doi.org/10.1016/S0010-0285(03)00034-3

Markson, L., Diesendruck, G., & Bloom, P. (2008). Shape bias special section: The shape of thought. *Developmental Science*, *11*(2), 204–208. https://doi.org/10.1111/j.1467-7687.2007.00666.x

Marlow, N. (2004). Neurocognitive outcome after very preterm birth. *Archives of Disease in Childhood: Fetal and Neonatal Edition*, *89*(3), 224–228. https://doi.org/10.1136/adc.2002.019752

Marlow, N., Wolke, D., Bracewell, M., & Muthanna, S. (2005). Neurologic and Developmental Disability at six Years of Age after Extremley PReterm Birth. *New England Journal of Medicine*, *352*(1), 9–19. https://doi.org/10.1056/NEJMoa041367

Mayor, J., & Plunkett, K. (2010). A Neurocomputational Account of Taxonomic Responding and Fast Mapping in Early Word Learning. *Psychological Review*, *117*(1), 1–31. https://doi.org/10.1037/a0018130

Merriman, W. E., Scott, P. D., & Marazita, J. (1993). An appearance-function shift in children's object naming. *Journal of Child Language*, *20*(1), 101–118. https://doi.org/10.1017/S0305000900009144

Mirak, J., & Rescorla, L. (1998). Phonetic skills and vocabulary size in late talkers: Concurrent and predictive relationships. *Applied Psycholinguistics*, *19*(01), 1. https://doi.org/10.1017/S0142716400010559

Morgan, P., Farkas, G., Hillemeier, M., & Scheffner Hammer, C. (2015). 24-Month-Old Children with Larger Oral Vocabularies Display Greater Academic and Behavioral Functioning at Kindergarten Entry. *Child Development*, *86*(5), 1351–1370. https://doi.org/10.1111/cdev.12398

Moster, D., Lie, R. T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *New England Journal of Medicine*, *359*(3), 262–273.

https://doi.org/10.1056/NEJMoa0706475

Moyle, M. J., Weismer, S. E., Evans, J. L., & Lindstrom, M. J. (2007). Longitudinal relationships between lexical and grammatical development in typical and late-talking children. *Journal of Speech, Language, and Hearing Research*, *50*(2), 508–528. https://doi.org/10.1044/1092-4388(2007/035)

Namy, L. L., & Clepper, L. E. (2010). The differing roles of comparison and contrast in children's categorization. *Journal of Experimental Child Psychology*, *107*(3), 291–305. https://doi.org/10.1016/j.jecp.2010.05.013

Nazzi, T., & Bertoncini, J. (2003). Before and after the vocabulary spurt: Two modes of word acquisition? *Developmental Science*, *6*(2), 136–142. https://doi.org/10.1111/1467-7687.00263

NICE. (2017). Developmental follow-up of children and young people born preterm. Retrieved February 15, 2020, from https://www.nice.org.uk/guidance/ng72/chapter/Recommendations

Patra, K., Greene, M. M., Patel, A. L., & Meier, P. (2016). Maternal Education Level Predicts Cognitive, Language, and Motor Outcome in Preterm Infants in the Second Year of Life. *American Journal of Perinatology*, *33*(8), 738–744. https://doi.org/10.1055/s-0036-1572532

Paul, R., Looney, S. S., & Dahm, P. S. (1991). Communication and Socialization Skills at Ages 2 and 3 in "Late-Talking" Young Children. *Journal of Speech and Hearing Research*, *34*(4), 858–865. https://doi.org/10.1044/jshr.3404.858

Pearson, B. Z. (2013). Distinguishing the bilingual as a late talker from the late talker who is bilingual. In L. Rescorla & P. S. Dale (Eds.), *Late talkers: Language development, interventions, and outcomes.* (pp. 67–87). Baltimore: Paul Brookes Publishing.

Pérez-Pereira, M., & Cruz, R. (2018). A longitudinal study of vocabulary size and composition in low risk preterm children. *First Language*, *38*(1), 72–94. https://doi.org/10.1177/0142723717730484

Perry, L. K., & Kucker, S. C. (2019). The heterogeneity of word learning biases in late-talking children. *Journal of Speech, Language, and Hearing Research*, *62*(3), 554–563. https://doi.org/10.1044/2019_JSLHR-L-ASTM-18-0234

Perry, L. K., & Samuelson, L. K. (2011). The shape of the vocabulary predicts the shape of the bias. *Frontiers in Psychology*, *2*(345), 1–12. https://doi.org/10.3389/fpsyg.2011.00345

Perry, L. K., Samuelson, L. K., Malloy, L. M., & Schiffer, R. N. (2010). Learn Locally, Think Globally: Exemplar Variability Supports Higher-Order Generalization and Word Learning. *Psychological Science*, *21*(12), 1894–1902. https://doi.org/10.1177/0956797610389189

Petruccelli, N., Bavin, E. L., & Bretherton, L. (2012). Children with specific language impairment and resolved late talkers: Working memory profiles at 5 years. *Journal of Speech Language and Hearing Research*, *55*(December), 1690–1704. https://doi.org/10.1044/1092-4388(2012/11-0288)

Poll, G. H., & Miller, C. A. (2013). Late talking, typical talking, and weak language skills at middle childhood. *Learning and Individual Differences*, *26*, 177–184. https://doi.org/10.1016/j.lindif.2013.01.008

Preston, J. L., Frost, S. J., Mencl, W. E., Fulbright, R. K., Landi, N., Grigorenko, E., … Pugh, K. R. (2010). Early and late talkers: School-age language, literacy and neurolinguistic differences. *Brain*, *133*(8), 2185–2195. https://doi.org/10.1093/brain/awq163

Prins, S. A., von Lindern, J. S., van Dijk, S., & Versteegh, F. G. A. (2010). Motor

Development of Premature Infants Born between 32 and 34 Weeks. *International Journal of Pediatrics*, *2010*, 1–4. https://doi.org/10.1155/2010/462048

Putnick, D. L., Bornstein, M. H., Eryigit-Madzwamuse, S., & Wolke, D. (2017). Long-Term Stability of Language Performance in Very Preterm, Moderate-Late Preterm, and Term Children. *Journal of Pediatrics*, *181*, 74-79.e3. https://doi.org/10.1016/j.jpeds.2016.09.006

Quine, W. van O. (1960). *Word and Object*. Cambridge,: MA: MIT Press.

Regier, T. (2005). The emergence of words: Attentional learning in form and meaning. *Cognitive Science*, *29*(6), 819–865. https://doi.org/10.1207/s15516709cog0000_31

Rescorla, L. (2011). Late talkers: Do good predictors of outcome exist? *Developmental Disabilities Research Reviews*, *17*(2), 141–150. https://doi.org/10.1002/ddrr.1108

Rescorla, L., & Alley, A. (2001). Validation of the Language Development Survey (LDS): A Parent Report Tool for Identifying Language Delay in Toddlers. *Journal of Speech, Language, and Hearing Research*, *44*(2), 434–445. https://doi.org/10.1044/1092-4388(2001/035)

Rescorla, L., Alley, A., & Christine, J. B. (2001). Word Frequencies in Toddlers' Lexicons. *Journal of Speech, Language, and Hearing Research*, *44*(3), 589–609. https://doi.org/10.1044/1092-4388(2001/049)

Rescorla, L., Mirak, J., & Singh, L. (2000). Vocabulary growth in late talkers: Lexical development from 2;0 to 3;0. *Journal of Child Language*, *27*(2), 293–311. https://doi.org/10.1017/S030500090000413X

Rice, M. L., Oetting, J. B., Marquis, J., Bode, J., & Pae, S. (1994). Frequency of input effects on word comprehension of children with specific language impairment. *Journal of Speech and Hearing Research*, *37*(1), 106–122. https://doi.org/10.1044/jshr.3701.106

Rice, M. L., Taylor, C. L., & Zubrick, S. R. (2008). Language Outcomes of 7-Year-Old Children With or Without a History of Late Language Emergence at 24 Months. *Hearing Research*, *51*(April), 394–407. https://doi.org/10.1044/1092-4388(2008/029)

Robertson, S. B., & Weismer, S. E. (1999). Effects of treatment on linguistic and social skills in toddlers with delayed language development. *Journal of Speech, Language, and Hearing Research*, *42*(5), 1234–1248. https://doi.org/10.1044/jslhr.4205.1234

Romeo, D. M., Guzzardi, S., Ricci, D., Cilauro, S., Brogna, C., Cowan, F., … Mercuri, E. (2012). Longitudinal cognitive assessment in healthy late preterm infants. *European Journal of Paediatric Neurology*, *16*(3), 243–247. https://doi.org/10.1016/j.ejpn.2011.07.012

Ross, G., Demaria, R., & Yap, V. (2017). The Relationship Between Motor Delays and Language Development in Very Low Birthweight Premature Children at 18 Months Corrected Age. *Journal of Speech, Language, and Hearing Research*, *61*(1), 114–119. https://doi.org/10.1044/2017_jslhr-l-17-0056

Ross, G., Foran, L. M., Barbot, B., Sossin, K. M., & Perlman, J. M. (2016). Using cluster analysis to provide new insights into development of very low birthweight (VLBW) premature infants. *Early Human Development*, *92*, 45–49. https://doi.org/10.1016/j.earlhumdev.2015.11.005

Rudolph, J. M., & Leonard, L. B. (2016). Early Language Milestones and Specific Language Impairment. *Journal of Early Intervention*, *38*(1), 41–58. https://doi.org/10.1177/1053815116633861

Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15-20-month-olds. *Developmental Psychology*, *38*(6), 1016–1037. https://doi.org/10.1037/0012-1649.38.6.1016

Samuelson, L. K., & McMurray, B. (2017). What does it take to learn a word? *Wiley Interdisciplinary Reviews: Cognitive Science*, *8*(1–2), 1–10. https://doi.org/10.1002/wcs.1421

Samuelson, L. K., & Smith, L. B. (1998). Memory and Attention Make Smart Word Learning: An Alternative Account of Akhtar, Carpenter, and Tomasello. *Child Development*, *69*(1), 94–104. https://doi.org/10.1111/j.1467-8624.1998.tb06136.x

Samuelson, L. K., & Smith, L. B. (1999). Early noun vocabularies: Do ontology, category structure and syntax correspond? *Cognition*, *73*(1), 1–33. https://doi.org/10.1016/S0010-0277(99)00034-7

Sandhofer, C. M., Smith, L. B., & Luo, J. (2000). Counting nouns and verbs in the input: Differential frequencies, different kinds of learning? *Journal of Child Language*, *27*(3), 561–585. https://doi.org/10.1017/S0305000900004256

Sansavini, A., Bello, A., Guarini, A., Savini, S., Alessandroni, R., Faldella, G., & Caselli, C. (2015). Noun and predicate comprehension/production and gestures in extremely preterm children at two years of age: Are they delayed? *Journal of Communication Disorders*, *58*, 126–142. https://doi.org/10.1016/j.jcomdis.2015.06.010

Sansavini, A., Guarini, A., & Caselli, M. C. (2011). Preterm birth: Neuropsychological profiles and atypical developmental pathways. *Developmental Disabilities Research Reviews*, *17*(2), 102–113. https://doi.org/10.1002/ddrr.1105

Sansavini, A., Guarini, A., Justice, L. M., Savini, S., Broccoli, S., Alessandroni, R., & Faldella, G. (2010). Does preterm birth increase a child's risk for language impairment? *Early Human Development*, *86*(12), 765–772. https://doi.org/10.1016/j.earlhumdev.2010.08.014

Schonberg, C. C., Russell, E. E., & Luna, M. L. (2019). Effects of past language experience and present language context on the shape bias in Spanish–English bilingual children. *Developmental Science*, (June), 1–9. https://doi.org/10.1111/desc.12879

Singleton, N. C., & Anderson, L. (2020). Making object shape explicit for toddlers with late language emergence. *Journal of Speech, Language, and Hearing Research*, *63*(3), 749–763. https://doi.org/10.1044/2019_JSLHR-19-00235

Smith, L., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object Name Learning Provides on-the-Job Training for Attention. *Psychological Science*, *13*(1), 13–19. https://doi.org/10.1111/1467-9280.00403

Smith, L., & Yu, C. (2008). Infants rapidly learn word-referent mappings via cross-situational statistics. *Cognition*, *106*(3), 1558–1568. https://doi.org/10.1016/j.cognition.2007.06.010

Standard Occupational Classification (SOC). (2010). Retrieved from https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc

Stolt, S., Haataja, L., Lapinleimu, H., & Lehtonen, L. (2009). The early lexical development and its predictive value to language skills at 2 years in very-low-birth-weight children. *Journal of Communication Disorders*, *42*(2), 107–123. https://doi.org/10.1016/j.jcomdis.2008.10.002

Stolt, S., Lind, A., Matomäki, J., Haataja, L., Lapinleimu, H., & Lehtonen, L. (2016). Do the early development of gestures and receptive and expressive language predict language skills at 5;0 in prematurely born very-low-birth-weight children? *Journal of Communication Disorders*, *61*, 16–28. https://doi.org/10.1016/j.jcomdis.2016.03.002

Swingley, D. (2010). Fast mapping and slow mapping in children's word learning. *Language Learning and Development*, *6*(3), 179–183. https://doi.org/10.1080/15475441.2010.484412

Tek, S., Jaffery, G., Fein, D., & Naigles, L. R. (2008). Do children with autism spectrum disorders show a shape bias in word learning? *Autism Research*, *1*(4), 208–222. https://doi.org/10.1002/aur.38

Tek, S., Mesite, L., Fein, D., & Naigles, L. (2014). Longitudinal analyses of expressive language development reveal two distinct language profiles among young children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *44*(1), 75–89. https://doi.org/10.1007/s10803-013-1853-4

Tek, S., & Naigles, L. (2017). The shape bias as a word-learning principle: Lessons from and for autism spectrum disorder. *Translational Issues in Psychological Science*, *3*(1), 94–103. https://doi.org/10.1037/tps0000104

Thal, D. J., Oroz, M., & McCaw, V. (1995). Phonological and lexical development in normal and late talking toddlers. *Applied Psycholinguistics*, *16*(1995), 407–424. https://doi.org/https://doi.org/10.1017/S0142716400066017

Träuble, B., & Pauen, S. (2007). The role of functional information for infant categorization. *Cognition*, *105*(2), 362–379. https://doi.org/10.1016/j.cognition.2006.10.003

Tsybina, I., & Eriks-Brophy, A. (2007). Issues in Research on Children With Early Language Delay. *Contemporary Issues in Communication Science and Disorders*, *34*(2), 118–133. https://doi.org/https://doi.org/10.1044/cicsd_34_F_118

Van Baar, A. L., Van Wassenaer, A. G., Briët, J. M., Dekker, F. W., & Kok, J. H. (2005). Very preterm birth is associated with disabilities in multiple developmental domains. *Journal of Pediatric Psychology*, *30*(3), 247–255. https://doi.org/10.1093/jpepsy/jsi035

Vandormael, C., Schoenhals, L., Hüppi, P. S., Filippa, M., Borradori Tolsa, C., & Montirosso, R. (2019). Language in Preterm Born Children: Atypical Development and Effects of Early Interventions on Neuroplasticity. *Neural Plasticity*, *2019*.

https://doi.org/10.1155/2019/6873270

Vicari, S., Caravale, B., Carlesimo, G. A., Casadei, A. M., & Allemand, F. (2004). Spatial working memory deficits in children at ages 3-4 who were low birth weight, preterm infants. *Neuropsychology*, *18*(4), 673–678. https://doi.org/10.1037/0894-4105.18.4.673

Vuksanovic, J., & Bjekic, J. (2013). Developmental relationship between language and joint attention in late talkers. *Research in Developmental Disabilities*, *34*(8), 2360–2368. https://doi.org/10.1016/j.ridd.2013.04.017

Ware, E. A., & Booth, A. E. (2010). Form follows function: Learning about function helps children learn about shape. *Cognitive Development*, *25*(2), 124–137. https://doi.org/10.1016/j.cogdev.2009.10.003

Warren, S. F. (2000). The Future of Early Communication and Language Intervention. *Topics in Early Childhood Special Education*, *20*(1), 33–37. https://doi.org/10.1177/027112140002000106

Weismer, S. E., Murray-Branch, J., & Miller, J. F. (1993). Comparison of two methods for promoting productive vocabulary in late talkers. *Journal of Speech and Hearing Research*, *36*(5), 1037–1050. https://doi.org/10.1044/jshr.3605.1037

Wood, N. S., Marlow, N., Costeloe, K., Gibson, A. T., & Wilkinson, A. (2000). Neurologic and Developmental disability After Extremley Preterm Birth. *The NEw England Journal of Medicine*, *343*(6), 378–384. https://doi.org/10.1056/NEJM200008103430601

Yaari, M., Mankuta, D., Harel-Gadassi, A., Friedlander, E., Bar-Oz, B., Eventov-Friedman, S., … Yirmiya, N. (2018). Early developmental trajectories of preterm infants. *Research in Developmental Disabilities*, *81*(April 2017), 12–23. https://doi.org/10.1016/j.ridd.2017.10.018

Yu, C. (2008). A Statistical Associative Account of Vocabulary Growth in Early Word

Learning. *Language Learning and Development*, *4*(1), 32–62. https://doi.org/10.1080/15475440701739353

Yu, C., & Ballard, D. H. (2007). A unified model of early word learning: Integrating statistical and social cues. *Neurocomputing*, *70*(13–15), 2149–2165. https://doi.org/10.1016/j.neucom.2006.01.034

Yu, C., & Smith, L. B. (2016). The Social Origins of Sustained Attention in One-Year-Old Human Infants. *Current Biology*, *26*(9), 1235–1240. https://doi.org/10.1016/j.cub.2016.03.026

Zambrana, I. M., Vollrath, M. E., Sengpiel, V., Jacobsson, B., & Ystrom, E. (2016). Preterm delivery and risk for early language delays: A sibling-control cohort study. *International Journal of Epidemiology*, *45*(1), 151–159. https://doi.org/10.1093/ije/dyv329

Zimmerman, E. (2018). Do infants born very premature and who have very low birth weight catch up with their full term peers in their language abilities by early school age? *Journal of Speech, Language, and Hearing Research*, *61*(1), 53–65. https://doi.org/10.1044/2017_JSLHR-L-16-0150

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*(August), 140–152. https://doi.org/10.1016/j.ridd.2017.06.002

APPENDIX 1

UNIVERSITY OF BIRMINGHAM

Participant code:______________

GENERAL DEVELOPMENT AND FAMILY QUESTIONNAIRE

Please complete the following questionnaire. All the information provided will be handled as strictly confidential. Note that if you wish not to answer a specific question or you feel uncomfortable disclosing certain information, feel free to leave the space in blank.

Child´s date of birth: _______________________

Sex of child: ☐ Male ☐Female

FAMILY

Parent/Guardian 1 (mother)

Date of birth: ____

Highest level of education: ____

Occupation: ____

Parent/Guardian 2 (father)

Date of birth: ____

Highest level of education: ____

Occupation: ____

Number of siblings the child has: ____

Please state the child´s birth order (e.g. first-born, second-born): ___________________

Is the child a twin/multiple birth? ☐ Yes ☐ No

Is any language besides English spoken in the child´s home?

☐ No

☐Yes, please list the languages _______________________________________

Please state the main language used at home: ______________________

Number of people living with the child at home including yourself: ___________________

Is this house/apartment:

☐ Owned by you or someone in this household.

☐ Owned by you or someone in this household with a mortgage or loan.

☐ Rented.

☐ Occupied without payment of rent.

What is your overall household income (before tax) per year in your child´s main home?

☐ £0 - £ 14,000

☐ £14,001 - £24,000

☐ £24,001 - £42,000

☐ £42,001 or more

PREGNANCY AND BIRTH

Did the mother have any illness/complications during the pregnancy?

☐ No ☐Yes, please explain ____________________________________

At what week of pregnancy was the child born?

☐ Week 33 or before ☐ Week 34 to week 36 ☐Week 37 or later

How much did the child weight at birth?

☐ Up to 5 lb 8 oz ☐ 5 lb 9 oz to 9lb 14 oz ☐9lb 15 oz or over

Did the child have any problems during or after the delivery that required medical attention? (e.g. difficulty breathing)

☐ No

☐Yes, please explain ____

INFANCY AND EARLY CHILDHOOD

Does the child like to play near or be with family and friends? ☐ No ☐Yes

At present, who takes care of the child on a daily basis and where is the child being taken care of?

____

Does the child have any eating problems?

☐ No

☐Yes, please specify ____

Does the child have any sleeping problems?

☐ No

☐Yes, please specify ____

Does the child have any allergies?

☐ No

☐Yes, please specify ____

Does the child follow simple instructions?

☐ No

☐Yes

Does the child participate in any social groups, play groups or activities?

☐ No

☐Yes, please specify ____

Has the child started using words to communicate (not just imitating words)?

☐ No, how does he/she communicate? (e.g. uses sounds, points):

____

☐Yes, at what age did he/she start using words to communicate:

____

Does the child respond to his/her name when you call her/him?

☐ No

☐Yes

When you point at something, does the child look in the direction you are pointing?

☐ No

☐Yes

Does the child have any conditions, illnesses or physical disabilities?

☐ No

☐Yes, please specify ____

Is the child currently on any medication?

☐ No

☐Yes, please specify ____

Has the child had any serious injuries or accidents:

☐ No

☐Yes, please specify ____

Does the child have a hearing or visual impairment?

☐ No

☐Yes, please specify ____

Has the child suffered from any of the following conditions?

☐ Frequent ear infections

☐ Problems with ears or hearing

☐ Problems with eyes or vision

☐ Convulsions or other neurological condition

☐ Head trauma or concussion

Is there anyone in the child´s family (brothers/sisters/parents only) with a speech or language difficulty?

☐ No

☐Yes, please specify ____

Have you noticed anything regarding the child´s development that concerns you?

☐ No

☐Yes, please specify ____

Has anyone expressed concerns about the child's behaviour or development?

☐ No

☐Yes, please specify ____

You have finished!

Thank you for your time and effort

APPENDIX 2

In this appendix I provide information regarding the additional analyses conducted for Chapter 2.

Attention task

For the attention task, the proportion of looking times towards each ROI (face ROI, distractor ROI and action ROI) in both time windows (before and during action) were calculated (see Table SM.1).

Table SM.1 *Proportion of Looking Times Towards Each ROI in the Attention Task of Chapter 2*

Group	Region of Interest	Before action *M* (*SD*)	During action *M* (*SD*)
Function training group	Face ROI	0.64 (0.13)	0.14 (0.05)
	Action ROI	0.16 (0.07)	0.72 (0.11)
	Distractor ROI	0.19 (0.08)	0.13 (0.09)
Control group	Face ROI	0.53 (0.23)	0.13 (0.07)
	Action ROI	0.17 (0.09)	0.66 (0.25)
	Distractor ROI	0.29 (0.22)	0.20 (0.26)

In order to assess if participants in both groups looked less towards the face ROI during the action than before the action, a 2 (Group: Function-training vs Control) x 2 (Time window: Before action vs During action) analysis of variance (ANOVA) was conducted. Results showed a main effect of Time, $F(1, 20) = 140.59$, $p < .001$, $\eta_p^2 = .87$, but no main effect of Group, $F(1, 20) = 1.83$, $p = .191$, $\eta_p^2 = .08$, nor an interaction between Group and Time, $F(1, 20) = 1.75$, $p = .200$, $\eta_p^2 = .08$. Thus, participants in both groups looked significantly more towards the face ROI before action than during action.

To assess if participants in both groups looked less towards the distractor ROI during the action than before the action, a 2 (Group: Function-training vs Control) x 2 (Time window: Before action vs During action) analysis of variance (ANOVA) was conducted. Results showed a main effect of Time, $F(1, 20) = 12.68$, $p =.002$, $\eta_p^2 = .38$, but no main effect of Group, $F(1, 20) = 1.34$, $p = .261$, $\eta_p^2 = .06$, nor an interaction between Group and Time, $F(1, 20) = 0.44$, $p = .514$, $\eta_p^2 = .02$. Thus, participants in both participant groups looked significantly more towards the distractor ROI before action started than during action.

In other to investigate if participants preferred a specific ROI before the action was performed, two comparisons between the action ROI and the remaining two ROIs were conducted. Participants in the function-training group looked significantly more towards the face ROI before the action was being performed than towards the action ROI $t(10) = -8.36$, $p <.001$, 95% CI = [-0.61, -0.35]. Participants in the function-training group looked similarly to the action ROI and the distractor ROI $t(10) = -1.24$, $p = .243$, 95% CI = [-0.09, 0.02]. The control group also looked significantly more towards the face ROI before the action was being performed compared to the action ROI $t(10) = -4.27$, $p =.002$, 95% CI = [-0.54, -0.17]. Participants in the control group looked similarly to the action ROI and the distractor ROI $t(10) = -1.69$, $p = .121$, 95% CI = [-0.28, 0.03]. Thus, participants in both groups looked significantly more towards the face ROI than the two remaining ROIs before the action was being performed.

Two comparisons between the action ROI and the remaining two ROIs were conducted to assess if participants looked more towards the action ROI than towards any of the other ROIs while the action was being performed. Participants in the function-training group looked significantly more towards the action ROI while the action was being performed than towards the remaining two ROIs (face ROI: $t(10) = 12.78$, $p < .001$, 95% CI = [.47, .67]; distractor ROI $t(10) = 9.55$, $p < .001$, 95% CI = [.45, .72]). The control group also looked significantly more towards the action ROI while the action was being performed compared to the rest of the ROIs (face ROI: $t(10) = 6.69$, $p < .001$, 95% CI = [.35, .70]; distractor ROI $t(10) = 2.90$, p , 95% CI = [.10, .80]). Thus, participants in both groups looked significantly more towards the action ROI than the two remaining ROIs while the action was being performed.

Vocabulary Growth

Expressive Vocabulary

One additional analysis was conducted to assess the difference in vocabulary growth in nouns for which function plays an important role compared to nouns that are not function-based. This analysis was conducted because it is possible that the function training promoted attention towards nouns with clear functions compared to other types of nouns. Thus, a 2 (Group: function-training vs control group) x 2 (Testing time: before vs after training) x 2 (Noun type: function-based vs other nouns) ANOVA was also conducted. The *function-based nouns* included all nouns from the section "small household items" in the UK-CDI. The *other nouns category* included the rest of the nouns in the UK-CDI. Participants in the function-training group started the study with an average of 4.08 function-based nouns ($SD = 7.91$) and an average of 31 other nouns ($SD = 40.33$). Participants in the control group started the study with an average of 2 function-based nouns ($SD = 3.13$) and an average of 19.91 other nouns ($SD = 27.31$). At the end of the study, participants in the function-training group produced on average 10.08 function-based nouns (*SD* = 11.44) and an average of 73.25 other nouns (*SD* = 54.02). Participants in the control group produced an average of 6.83 function-based nouns (*SD* = 7.42) and an average of 52.50 other nouns (*SD* = 41.15). Results of the 2 x 2 x 2 analysis of variance showed a significant main effect of Time ($F(1, 22) = 64.24$, $p < .001$, $\eta_p^2 = .74$), and Noun Type ($F(1, 22) = 31.98$, $p < .001$, $\eta_p^2 = .59$), but no significant main effect of Group ($F(1, 22) = 0.91$, $p = .349$, $\eta_p^2 = .04$). The analysis also showed a significant interaction between Noun Type and Time, ($F(1, 22) = 73.39$, $p < .001$, $\eta_p^2 = .76$) with the function-based category growing less than the remainder of the nouns. There was no significant two-way interaction between Time and Group ($F (1, 22) = 1.02$, $p = .322$, $\eta_p^2 = .04$), neither a two-way interaction between Noun Type and Group ($F(1, 22) = 0.95$, $p = .340$, $\eta_p^2 = .04$), nor a three-way interaction between Group, Time, and Noun Type ($F(1, 22) = 1.29$, $p = .267$, $\eta_p^2 = .05$). Thus, both participant groups showed similar vocabulary growth in the function-based noun category and other nouns.

Receptive Vocabulary

Similarly to expressive vocabulary, one additional analysis was conducted to assess the difference between groups on nouns that refer to objects for which function plays an important role compared to nouns that are not function-based in the same way.

Participants in the function-training group started the study with an average of 14.91 function-based nouns (*SD* = 10.51) and an average of 92.75 other nouns (*SD* = 43.39) in their receptive vocabularies. Participants in the control group started the study with an average of 13.75 function-based nouns (*SD* = 9.44) and an average of 80.16 other nouns (*SD* = 45.79) in their receptive vocabularies. At the end of the study, participants in the function-training group had on average 26.08 function-based nouns (*SD* = 8.46) and an average of 138.41 other nouns (*SD* = 33.53). Participants in the control group had an average of 20.91 function-based nouns (*SD* = 8.84) and an average of 126.16 other nouns (*SD* = 36.67) in their receptive vocabularies. Results of the 2 x 2 x 2 analysis of variance showed a significant main effect of Time, $F(1, 22) = 58.67$, $p < .001$, $\eta_p^2 = .72$, and Noun Type $F(1, 22) = 229.82$, $p < .001$, $\eta_p^2 = .91$, but no significant main effect of Group $F(1, 22) = 0.70$, $p = .412$, $\eta_p^2 = .03$. The analysis also showed a significant interaction between Noun Type and Time, $F(1, 22) = 52.72$, $p < .001$, $\eta_p^2 = .70$, with the function-based category growing less than the rest of the nouns. There was no significant two-way interaction between Time and Group, $F(1, 22) = 0.06$, $p = .801$, $\eta_p^2 = .00$, or a two-way interaction between Noun Type and Group, $F(1, 22) = 0.60$, $p = .447$, $\eta_p^2 = .02$), nor a three-way interaction between Group, Time, and Noun Type, $F(1, 22) = 0.18$, $p = .672$, $\eta_p^2 = .00$. Thus, both participant groups showed similar vocabulary growth in both types of nouns.

APPENDIX 3

Participant code:______________ UNIVERSITY OF BIRMINGHAM

GENERAL DEVELOPMENT AND FAMILY QUESTIONNAIRE

Please complete the following questionnaire. All the information provided will be handled as strictly confidential. **Note that if you wish not to answer a specific question or you feel uncomfortable disclosing certain information, feel free to leave the space empty.**

Child´s date of birth: ____

Sex of child: ☐ Male ☐Female

FAMILY

Parent/Guardian 1 (mother):

Date of birth: ____

Highest level of education: ____

Occupation: ____

Parent/Guardian 2 (father):

Date of birth: ____

Highest level of education: ____

Occupation: ____

Number of siblings the child has: ____

Please state the child´s birth order (e.g. first-born, second-born): ___________________________

Is the child a twin/multiple birth? ☐ Yes ☐ No

Is any language besides English spoken in the child´s home?

☐ No

☐Yes, please list the languages ____

Please state the main language used at home: ____________________________

Number of people living with the child at home including yourself: _________________________

Is this house/apartment:

☐ Owned by you or someone in this household.

☐ Owned by you or someone in this household with a mortgage or loan.

☐ Rented.

☐ Occupied without payment of rent.

What is your overall household income (before tax) per year in your child´s main home?

☐ £0 - £ 14,000

☐ £14,001 - £24,000

☐ £24,001 - £42,000

☐ £42,001 or more

PREGNANCY AND BIRTH

Did the mother have any illness/complications during the pregnancy?

☐ No ☐Yes, please explain ____

At what week of pregnancy was the child born?

☐ Week 33 or before ☐ Week 34 to week 36 ☐Week 37 or later

How much did the child weigh at birth?

☐ Up to 5 lb 8 oz ☐ 5 lb 9 oz to 9lb 14 oz ☐9lb 15 oz or over

Did the child have any problems during or after the delivery that required medical attention? (e.g. difficulty breathing)

☐ No

☐Yes, please explain ____

INFANCY AND EARLY CHILDHOOD

Does the child like to play near or be with family and friends? ☐ No ☐Yes

At present, who takes care of the child on a daily basis and where is the child being taken care of?

____

____

Does the child have any eating problems?

☐ No

☐Yes, please specify ____

Does the child have any sleeping problems?

☐ No

☐Yes, please specify ____

Does the child have any allergies?

☐ No

☐Yes, please specify ____

Does the child follow simple instructions?

☐ No

☐Yes

Does the child participate in any social groups, play groups or activities?

☐ No

☐Yes, please specify ____

Has the child ever been part of a word learning intervention (or similar programme)?

☐ No

☐Yes, please specify ____

Has the child started using words to communicate (not just imitating words)?

☐ No, how does he/she communicate? (e.g. uses sounds, points): ___________________

☐Yes, at what age did he/she start using words to communicate: _____________________

Does the child respond to his/her name when you call her/him?

☐ No

☐Yes

When you point at something, does the child look in the direction you are pointing?

☐ No

☐Yes

Does the child have any conditions, illnesses or physical disabilities?

☐ No

☐Yes, please specify ____

Is the child currently on any medication?

☐ No

☐Yes, please specify ____

Has the child had any serious injuries or accidents:

☐ No

☐Yes, please specify ____

Does the child have a hearing or visual impairment?

☐ No

☐Yes, please specify ____

Has the child suffered from any of the following conditions?

☐ Frequent ear infections

☐ Problems with ears or hearing

☐ Problems with eyes or vision

☐ Convulsions or other neurological condition

☐ Head trauma or concussion

Is there anyone in the child´s family (brothers/sisters/parents only) with a speech or language difficulty?

☐ No

☐Yes, please specify ____

Have you noticed anything regarding the child´s development that concerns you?

☐ No

☐Yes, please specify ____

Has anyone expressed concerns about your child's behaviour or development?

☐ No

☐Yes, please specify ____

Has the child been part of a research study in the past*?*

☐ No

☐Yes, please specify the type of research and date

____

Is the child currently taking part of a research study (not including this one)?

☐ No

☐Yes, please specify ____

You have finished!

Thank you for your time and effort

Please hand the completed questionnaire to the researcher.

APPENDIX 4

In this appendix I provide information regarding the additional analyses conducted for Chapter 3.

Attention task

For the attention task, the proportion of looking times towards each ROI (face ROI, distractor ROI and action ROI) in both time windows (before and during movement) were calculated (see Table SM.2).

Table SM.2 *Proportion of Looking Times Towards Each ROI in the Attention Task of Chapter 3*

Group	Region of Interest	Before movement *M* (*SD*)	During movement *M* (*SD*)
Shape training	Face ROI	0.61 (0.40)	0.27 (0.12)
	Target ROI	0.15 (0.12)	0.68 (0.11)
	Distractor ROI	0.23 (0.29)	0.04 (0.03)
Specific Word Training	Face ROI	0.53 (0.27)	0.27 (0.22)
	Target ROI	0.23 (0.19)	0.67 (0.21)
	Distractor ROI	0.23 (0.09)	0.05 (0.02)

To assess if infants' attention towards the face ROI was equally attracted before and during movement started, a 2 (Group: shape training group vs. specific word training group) x 2 (Time window: before vs. during movement) ANOVA was conducted. Results showed a significant main effect of Time Window, $F(1,10) = 12.92$, $p = .005$, $\eta_p^2 = .56$. But no significant main effect of Group, $F(1,10) = 0.08$, $p = .771$, $\eta_p^2 = .00$, or interaction between Group and Time window, $F(1,10) = 0.28$, $p = .607$, $\eta_p^2 = .02$. Thus, infants in both groups looked more to the face ROI before than after movement started.

An additional 2 (Group: shape training group vs. specific word training group) x 2 (Time window: before vs. during movement) ANOVA was conducted to assess if infants' attention to the distractor ROI was equally attracted before and during movement started. Results showed a significant main effect of Time window, $F(1, 10) = 0.00$, $p = .928$, $\eta_p^2 = .00$, but no significant main effect of Group, $F(1, 10) = 0.00$, $p = .955$, $\eta_p^2 = .00$, or interaction between Group and Time window, $F(1, 12) = 0.20$, $p = .661$, $\eta_p^2 = .01$. Thus, infants in both groups looked towards the distractor ROI more before movement started than after.

In order to assess if participants looked longer to the target ROI than the remaining two ROIs before movement, two t-tests were conducted. Before movement, the participants in the shape training group looked similarly to the target ROI than to the face ROI $t(4) = -2.00$, $p =.116$, 95% CI = [-1.10, 0.17], and to the distractor ROI $t(4) = -0.92$, $p =.407$, 95% CI = [-0.32, 0.16]. The participants in the control group looked similarly to the target ROI than to the face ROI $t(6) = -1.66$, $p =.147$, 95% CI = [-.72, 0.13], and also similarly to the target ROI and the distractor ROI $t(6) = 0.11$, $p =.909$, 95% CI = [-0.12, 0.14]. Thus, before movement participants in both groups did not show a preference for any of the ROIs.

In order to assess if participants showed a significant preference for looking at the target ROI after movement, compared to the remaining two ROI (face ROI and distractor ROI) two comparisons were made between the target ROI and the two ROI separately. In the shape training group, the participants looked longer to the target ROI that to the face ROI $t(4) = 3.83$, $p = .019$, 95% CI = [0.11, 0.70], and they also looked more to the target

ROI than to the distractor ROI $t(4) = 13.47$ $p <.001$, 95% CI = [0.50, 0.77]. In the control group, a trend which approached significance was found between the target ROI and face ROI $t(6) = 2.37$, $p = .055$, 95% CI = [-.01, 0.79], but the difference between the proportion of looking times between the target ROI and the distractor ROI was significant $t(6) = 8.20$, $p <.001$, 95% CI = [0.34, 0.80]. Thus, participants in the shape training groups looked significantly more towards the target ROI and participants in the specific word training group showed a trend that approached significance in the same direction.

Attention Task: Comparison between late talkers (Chapter 3) and typically developing children (Chapter 2)

In Chapter 3, I discussed that it is possible that late talkers show a difficulty for developing a shape bias because they may have deficits in areas required for its development. Previous research has shown that late talkers look less towards objects that are being shown to them compared to typically developing children (MacRoy-Higgins & Montemarano, 2016). Considering that the shape bias involves cognitive processes, such as attention skills (Kucker et al., 2019), it is possible that deficits in attention are affecting the development of a shape bias in late talkers.

In Chapter 3, I did not include a group of typically developing children, therefore I was not able to compare attention between late talkers and typically developing children. However, since in Chapter 2, typically developing children were introduced to a similar attention task, I conducted an analysis to investigate if there is a difference on how much late talkers (Chapter 3) and typically developing children (Chapter 2) attend to objects that are being shown to them.

Note that results from these comparisons have to be taken with caution due to three important reasons. First, while the methodology used in both studies was the same, the stimuli used was different. Videos in Chapter 2 showed a person performing a function with some unusual objects, while videos used for Chapter 3 showed a person moving some unusual objects. Second, the age of both participant groups was different. Participants in Chapter 2 were all 17 months at the start of the study, while participants in Chapter 3 were on average 33 months (range from 25 to 39 months) at the start of the study. Third, it is possible that since participants in Chapter 3 (late talkers) were older, they could have found less interesting the task than participants in Chapter 2 (typically developing children).

For these analyses two typically developing children from Chapter 2 and two late talkers from Chapter 3 were removed because they did not look to any of the five videos of the attention task. To compare if there is a difference on how much late talkers (Chapter 3) and typically developing children (Chapter 2) attend to objects that are being shown to them, first, I calculated the total looking times towards the target ROI in both participant groups (see Table SM.3).

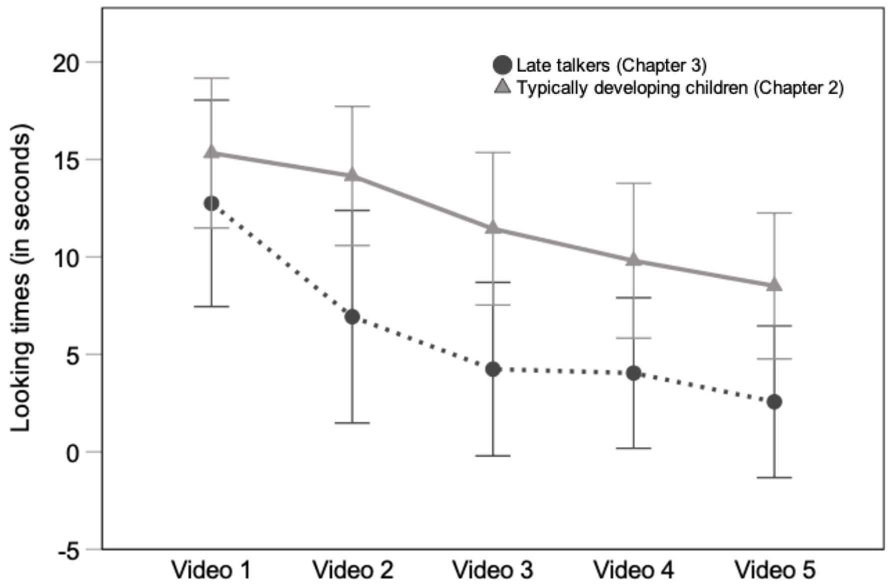
Table SM.3 *Mean Looking Times of the Typically Developing Group and the Late Talkers Group*

	Typically developing children (Chapter 2)	**Late Talkers (Chapter 3)**
	***M* (*SD*)**	***M* (*SD*)**
Video 1	15.33 (8.66)	12.74 (8.33)
Video 2	14.15 (8.04)	6.93 (8.58)
Video 3	11.44 (8.82)	4.24 (7.00)
Video 4	9.80 (8.96)	4.04 (6.07)
Video 5	8.51 (8.44)	2.56 (6.12)

Then, I compared the looking times towards the target ROI in the five videos of the attention task between groups. This comparison had the main aim of assessing if both participant groups attended equally to the videos in the attention task. Results of a 2 (Group: late talkers vs typically developing children) x 5 (Video: analysis of variance) showed a significant main effect of Video $F(4,128) = 12.28$, $p =.001$, $\eta_p^2 = .27$, and Group $F(1,32) = 5.83$, $p = .022$, $\eta_p^2 = .15$. No significant interaction between Video and Group was found $F(4,128) = 0.97$, $p = .425$, $\eta_p^2 = 02$.

A post hoc comparison between both groups revealed that initially participants looked similarly to the first video, $t(32) = -0.84$, $p = .407$, 95% CI = [-8.83, 3.67]. However, from video 2 to video 5, participants in the late talkers group looked on average for less time towards the videos than the typically developing group (Video 2 $t(6) = -2.44$, $p = .020$, 95% CI = [-13.24, -1.20]; Video 3 $t(6) = -2.43$, $p = .021$, 95% CI = [-13.22, -1.17]; Video 4 $t(6) = -1.98$, $p = .056$, 95% CI = [-11.67, 0.15]; Video 5 $t(6) = -2.14$, $p = .040$, 95% CI = [-11.58, -0.29]). Results suggest that initially late talkers and typically developing children may look similarly at objects being shown to them. However, late talkers quickly reduce their looking times as shown in video 2 to video 5. Thus, overall late talkers may be looking towards objects being shown to them for less time than typically developing children.

Figure SM.1 *Looking Times To Each Video In the Typically Developing Children Group and the Late Talkers Group*



Note. Error bars represent 95% CIs.

APPENDIX 5

UNIVERSITY OF BIRMINGHAM

Participant code:______________

GENERAL DEVELOPMENT AND FAMILY QUESTIONNAIRE

Please complete the following questionnaire. All the information provided will be handled as strictly confidential. Note that if you wish not to answer a specific question or you feel uncomfortable disclosing certain information, feel free to leave the space in blank.

Child´s date of birth: _______________________

Sex of child: ☐ Male ☐Female

FAMILY

Parent/Guardian 1 (mother)

Date of birth: ____

Highest level of education: ___________________________________

Occupation: ____

Parent/Guardian 2 (father)

Date of birth: ____

Highest level of education: ___________________________________

Occupation: ____

Number of siblings the child has: ______________________________________

Please state the child´s birth order (e.g. first-born, second-born): _____________________

Is the child a twin/multiple birth? ☐ Yes ☐ No

Is any language besides English spoken in the child´s home?

☐ No

☐Yes, please list the languages ___________________________________

Please state the main language used at home: ________________________

Number of people living with the child at home including yourself: _____________________

Is this house/apartment:

☐ Owned by you or someone in this household.

☐ Owned by you or someone in this household with a mortgage or loan.

☐ Rented.

☐ Occupied without payment of rent.

What is your overall household income (before tax) per year in your child´s main home?

☐ £0 - £ 14,000

☐ £14,001 - £24,000

☐ £24,001 - £42,000

☐ £42,001 or more

<u>PREGNANCY AND BIRTH</u>

Did the mother have any illness/complications during the pregnancy?

☐ No ☐ Yes, please explain ____

At what week of pregnancy was the child born? ______________________________________

What was the child’s expected due date? ____

How much did the child weight at birth? ____

Did the child have any problems during or after the delivery that required medical attention? (e.g. difficulty breathing)

☐ No

☐Yes, please explain ____

<u>INFANCY AND EARLY CHILDHOOD</u>

Does the child like to play near or be with family and friends? ☐ No ☐Yes

At present, who takes care of the child on a daily basis and where is the child being taken care of?

____

Does the child have any eating problems?

☐ No

☐Yes, please specify ____

Does the child have any sleeping problems?

☐ No

☐Yes, please specify ____

Does the child have any allergies?

☐ No

☐Yes, please specify ____

Does the child follow simple instructions?

☐ No

☐Yes

Does the child participate in any social groups, play groups or activities?

☐ No

☐Yes, please specify ____

Has the child started using words to communicate (not just imitating words)?

☐ No, how does he/she communicate? (e.g. uses sounds, points): _____________

____

☐Yes, at what age did he/she start using words to communicate: _______________

Does the child respond to his/her name when you call her/him?

☐ No

☐Yes

When you point at something, does the child look in the direction you are pointing?

☐ No

☐Yes

Does your child move around walking, rather than crawling on his/her hands?

☐ No

☐Yes, at what age does your child started walking? ______________________

Does the child have any conditions, illnesses or physical disabilities?

☐ No

☐Yes, please specify ____

Is the child currently on any medication?

☐ No

☐Yes, please specify ____

Has the child had any serious injuries or accidents:

☐ No

☐Yes, please specify ____

Does the child have a hearing or visual impairment?

☐ No

☐Yes, please specify ____

Has the child suffered from any of the following conditions?

☐ Frequent ear infections

☐ Problems with ears or hearing

☐ Problems with eyes or vision

☐ Convulsions or other neurological condition

☐ Head trauma or concussion

Is there anyone in the child´s family (brothers/sisters/parents only) with a speech or language difficulty?

☐ No

☐Yes, please specify ____

Has the child been part of a research study in the past?

☐ No

☐Yes, please explain the type of research study and the date __________________

Is the child currently taking part of a research study (not including this one)?

☐ No

☐Yes, please explain ____

Have you noticed anything regarding the child´s development that concerns you?

☐ No

☐Yes, please specify ____

Has anyone expressed concerns about the child's behaviour or development?

☐ No

☐Yes, please specify ____

You have finished!

Thank you for your time and effort