Using Gesture to Support Language

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Thesis in fulfilment of the degree of Doctor of Philosophy

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May 2017

Declaration of Authorship

I Charlotte Wray hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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Abstract

This thesis presents a series of studies which investigated the link between gesture and language in children with developmental language disorder (DLD), in comparison to typically developing (TD) children and children with low language and educational concerns (LL). This thesis explores parent and child gesture skill using measures of gesture imitation and elicited gesture production, and spontaneous gestures across narrative and problem-solving tasks.

Study 1 explored children's gesture production; children with DLD showed weaknesses in gesture accuracy in comparison to TD peers, but no differences in gesture rates. Also, children with DLD produced proportionally more extending gestures than TD peers, suggesting that they may use gesture to replace words that they are unable to verbalise. Study 2 investigated parent gesture in relation to child language ability. Parents of children with DLD used gesture more frequently than parents of TD or LL children, but only during parent-child interaction. Parent gesture frequency was positively associated with child gesture frequency, but negatively associated with child language ability. Study 3 explored parent responses to children's extending gestures; there were no group differences in the types of parent responses; parents of all groups predominantly responded with positive feedback. Finally, in a gesture training study gesture cues did not enhance verbal recall of new words; but did increase multi-modal responses, however only when children were explicitly instructed to attend to and imitate gestures.

The findings indicate that children with DLD are motivated to use gesture during communication despite difficulties with gesture accuracy. Also, parent gestures reflect children's language deficits, rather than associating with increased linguistic skill. The limited benefit of gesture for word learning and the nature and impact of parent translations of child extending gestures calls into question the causal role of gesture in language acquisition, at least for school aged children.

Dissemination of Findings

Publications

Wray, C., Saunders, N., McGuire, R,. Cousins, G., & Norbury, C. F. (2017). Gesture production in language impairment: it's quality not quantity that matters. *Journal of Speech Language and Hearing Research.*

Conference presentations

Wray, C., & Norbury, C. F. (2016) *Gesture production in specific language impairment: it's quality not quantity that matters.* Oral presentation at the Symposium on Research in Child Language Disorders, June 2016, Madison, Wisconsin.

Wray, C., & Norbury, C. F. (2015). *The relationship between parent and child gesture.* Oral presentation at the BPS developmental and cognitive section conference, September 2015, Manchester.

Wray, C., & Norbury, C. F. (2015). *Gesture use in children with SLI and their parents.* Poster presented at the Child Language symposium, July 2015, Warwick

Wray, C., & Norbury, C. F. (2015). *Gesture use in children with SLI and their parents*. Poster presented at the Gesture Workshop, child Language symposium, July 2015, Warwick.

Acknowledgements

I would like to thank my supervisor, Courtenay Norbury, for her invaluable help, knowledge and advice over the last three years. Without her constant encouragement and support my PhD experience would not have been as rewarding or as enjoyable as it has been.

I would also like to thank my colleagues and friends Debbie Gooch and Rebecca Lucas, for their friendship, support and calming words of wisdom over the course of my PhD. I would also like to acknowledge fellow PhD student Katie Whiteside for providing some much needed office entertainment. I would also like to say a huge thank you to Claire Sears not only for drawing the wonderful animal pictures that make up the referential task but also her continued support and motivation.

I am eternally grateful to all of the children and parents that took part in my project. Visiting all of the families and seeing the children develop across the course of my project was the highlight of my PhD. Without their continued support, commitment and enthusiasm, this project would not have been possible. I would particularly like to thank Rowan Norbury who was an excellent guinea pig when I was pilot testing my tasks.

This thesis was also supported by my funding from the Waterloo Foundation and Royal Holloway, University of London.

I would like to thank my partner Matt, for being patient, keeping me motivated and for helping me see the light at the end of the tunnel.

Finally, I would like to thank all of my family and friends, for never doubting that I would get here eventually. In particular my mum and stepdad, for instilling in me a love of learning from a young age, providing me with invaluable opportunities and for always being there when I needed advice or guidance.

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Chapter 1: Introduction

"…communication in humans is a resilient phenomenon; when prevented from coming out the mouth it emanates almost irrepressibly from the fingers" (Goldin-Meadow & Morford, 1985, p. 146).

1.1.Thesis Overview

Language and gesture appear to be integrated in early childhood, with both gesture and speech developing in parallel. However, there is some debate as to how these two communication modalities interact with each other and whether they are part of the same communication system or two distinct systems, in which gesture simply facilitates spoken language. One way to explore this debate is to measure gesture in children whose language is not developing typically; if gesture and language are seen to break down together, this would be highly suggestive of an integrated system. Alternatively, if gesture use is relatively intact, this would not only suggest separate systems, but also a gesture system that could enable compensation for oral language weaknesses.

In the first chapter of this thesis, key issues regarding the link between gesture and language in typical development will be discussed. The chapter begins with an overview of the different theories about ways in which gesture and language are associated, followed by an overview of gesture development and use in typically developing populations, and how gesture training supports language development. The chapter concludes by introducing research regarding gesture in atypical populations.

1.2. Gesture and Language

1.2.1. What is gesture?

When we talk, our spoken utterances are often accompanied by spontaneous hand movements, or gestures (McNeill, 1992). It is thought that early gestural communication pre-dates the evolution of spoken communication (Corballis, 2012). Despite the fact that we can communicate complex information verbally, we continue to produce gestures alongside speech. This raises the question why we gesture, and in particular, how these gestures complement, facilitate and extend spoken language.

There are a number of different types of gesture that co-occur with speech, these are: Deictic, Representational, Conventional and Beats (McNeill, 1992). *Deictic* gestures are variations on pointing gestures and are usually used to draw attention to a particular object, person or location in the environment. *Representational* gestures combine both iconic and metaphoric gestures. These are gestures that show a close relationship to the object, action, idea or concept to which they refer (e.g. raising a hand to indicate height). Iconic gestures develop before metaphoric gestures, as such studies vary in whether the terms iconic and metaphoric are used separately or combined under the label 'representational'. For consistency the term representational will be used throughout this thesis to refer to both iconic and metaphoric gestures. *Conventional* gestures are gestures that are culturally specific and convey meaning without the need for speech, for example, "thumbs up". Finally, *Beats* are movements which emphasise aspects of speech.

When they co-occur with speech, these gestures can be redundant in nature and serve to reinforce the verbal message (Rowe, 2012b). For example, redundant gestures highlight important aspects of speech, but they do not add any extra information to the utterance that has not been verbalised (e.g. "the cat has a curly tail", while producing a *curly* gesture). Alternatively, gestures can extend the spoken message in new ways; these extending gestures add information that is not present in speech (e.g. "It's facing that way", while *pointing* to the right).

1.2.2. The relationship between gesture and speech

There is considerable debate as to whether gesture and speech are the same or separate communication systems and the extent to which the primary function of gesture is to communicate. On the one hand, it has been hypothesised that gesture and spoken language form two separate communication systems and that gesture simply facilitates and enhances spoken communication (Hadar, Wenkert-Olenik, Krauss, & Soroker, 1998; Krauss & Hadar, 1999; Rauscher, Krauss, & Chen, 1996). Proponents of this view suggest that the purpose of gesture is not to communicate, as the formation of a gesture precedes the formulation of communicative intention and that gesture is not influenced by the packaging of the verbal message (Krauss, Chen, & Chawla, 1996; Krauss, Chen, & Gotfexnum, 2000).

This theory is exemplified by the Lexical Retrieval Hypothesis (Rauscher et al., 1996) which suggests that the function of gesture is to facilitate word retrieval during speech production. This is supported by studies which have shown that prohibiting gesture affects lexical retrieval (Pine, Bird, & Kirk, 2007; Rauscher, Krauss, & Chen, 1996). Rauscher et al. (1996) reported that for adults, dysfluency increased when gesture was prohibited. This suggests that word finding difficulties may be exacerbated with the prohibition of gestures; for example, Pine et al. (2007) induced 'tip of the tongue state' (ToT) in children aged 6-8 during a picture naming task. During this task children were allowed to gesture freely for half of the pictures and gesture was prohibited for the other half (their hands were placed in mittens attached with Velcro to the desk). Children named more pictures when gesture was allowed than when gesture was prohibited. In addition, when gestures were allowed children were more likely to resolve their tip of the tongue state (75%) than when gesture was prohibited (46%). When children were free to gesture they produced more gestures with a correct response and more gestures when in a ToT state than when not in a ToT state.

Others have hypothesised that gesture and speech form an integrated communication system, and that gesture plays a central role in the conceptual planning and packaging of an utterance, rather than simply a facilitative role in language production (McNeill, 1992). For example, McNeill's (1992) Growth Point Theory suggests that gesture and speech emanate from the same underlying representation and that the growth point of an utterance contains both imagistic and linguistic information. Imagistic information is expressed as gesture and linguistic information as speech, but crucially both contribute to the production of language. The Information Packaging hypothesis (Kita, 2000), builds on this hypothesis and proposes that gesture is specifically involved in the organisation and packaging of spatio-motoric imagery into segments that can then be used for speech. Support for this theory comes from Hostetter, Alibali and Kita (2007) who asked adult participants to describe ambiguous dot patterns. In one condition the dots were connected with lines to create a geometric shape while in a second condition patterns comprised dots only. When packaging information was made more difficult (dot only condition), participants produced more gestures than when information-packaging was not challenging (geometric shape condition).

Consistent with these theories, studies of typical language development demonstrate that spoken language and gesture develop in tandem (Goodwyn & Acredolo, 1993) and both aid language comprehension (Goldin-Meadow, Kim, & Singer, 1999). For instance, Kelly, Özyürek, and Maris (2010) explored the effect of both gesture and speech on language comprehension. Participants were shown a video prime (e.g. someone chopping vegetables) followed by a similar video including a gesture and speech cue. The test videos manipulated the congruency and strength of speech and gesture cues. For example, in one condition speech was related to the target (e.g. *chop*) and the gesture cue was either strongly incongruent (*twist*) or weakly incongruent (*cut*). In a second condition, gesture was related to the target (*chop*) and speech was either strongly incongruent (*twist*) or weakly incongruent (*cut*). Participants were asked to press 'yes' if either the gesture or speech matched the prime video or 'no' if neither gesture or speech matched the prime video. Slower reaction times were evident when either gesture or speech were strongly incongruent, suggesting that both cues were influencing language comprehension. In a further manipulation, participants were instructed to focus on whether or not the speech was different from prime. Despite not needing the gesture cue to complete the task, more errors occurred when gesture was strongly incongruent with speech, thus demonstrating that utilising gesture during language comprehension may be automatic, as gesture impacts on language comprehension even when it is irrelevant to the task. This supports the notion of an integrated system and implies a bi-directional relationship between gesture and speech (Kelly et al., 2010).

Alibali, Kita, and Young (2000) explicitly tested both the Lexical Retrieval and Information Packaging Hypotheses in typically developing children using a conservation task. Children were asked to either, solve the task and explain the answer (conceptually demanding), or describe how two test items looked different (lexically demanding). The investigators hypothesised that if the purpose of gesture is to facilitate expressive language, then gesture rates between the two tasks should be similar. However, if gesture has a role in the conceptual planning and packaging of language, then children would produce more gestures during the explanation task. Indeed, a larger number of gestures were produced during the explanation task, indicating that gestures may be used for conceptual planning and packaging of an utterance. It was acknowledged by the authors that the discourse demands of each task also differ. For example, explaining how they solved the task may have resulted in longer more syntactically complex responses, resulting in higher cognitive and linguistic load. As such it is possible that this may explain the differences in gesture use across tasks.

Extending these theories Kita and Özyürek (2003) proposed the Interface System Hypothesis. This theory posits that gestures are formulated by an action generator and speech by a message generator. However, although these are distinct systems, they communicate bi-directionally with each other during the planning of an utterance (Figure 1.1). Crucially, both gesture and speech are shaped simultaneously. In this instance, gesture production is influenced by spatial/motoric information in working memory, a communication planner (communicative intention, modality selection) and direct feedback from the formulator via the message generator. In this model, the action generator and message generator shape the utterance by exchanging information bi-directionally. Thus, gesture is influenced by the way that language is packaged. This model is somewhat different from McNeill's Growth Point as it is able to account for instances where something is expressed in gesture that is not in speech. The Growth Point theory on the other hand does not have an interface for the exchange of information between gesture and language, instead it proposes that imagery and language information combine to form an utterance.

The Interface Hypothesis is supported by cross-linguistic studies of gesture use (Kita et al., 2007; Kita & Özyürek, 2003). Kita and Özyürek (2003) asked American, Turkish and Japanese adults to re-tell a cartoon during which a cat swings across the street in an arc trajectory. This motion was selected because in Japanese and Turkish languages there is no direct verb for "to swing", thus enabling the authors to explore gesture use when expressive resources are limited. The Interface Hypothesis suggests that if gesture is influenced by the way that language is packaged, then both Japanese and Turkish speakers will produce gestures that do not include the trajectory shape (arc), whilst English speakers will. It also predicts that gestures will express information from the video that is not expressed in speech. For example, there is evidence that lateral movements (left to right) are often represented through gesture but not through speech; the Interface Hypothesis predicts that all speakers would gesture a left-right trajectory in gesture, even if the way the gestures were presented differed across cultures, influenced by the packaging of language.

The majority of participants encoded the ‘swing event’ in speech. English speakers used the word ‘swing’, but Japanese and Turkish speakers were more likely to use words that indicated change in location (e.g. "iku", to go). As predicted, Japanese and Turkish speakers were more likely to produce a straight gesture, to indicate trajectory compared to English speakers who were more likely to produce an arc gesture. In addition, participants of all languages represented left to right trajectories that were not verbalised. These findings suggest that gesture is influenced not only by linguistic constraints, but also by spatial information that is not verbalised.

While this model demonstrates how gesture is influenced by speech and vice versa, it is unclear how this communication system works if there is an impairment in language processing. Given the bi-directional relationships, impairments in language may also be evident in gesture, as a language impairment would limit the extent to which utterances are effectively planned and packaged. Indeed it has been proposed that adult patients with aphasia produce fewer words and gestures per <u>minute</u> than controls (McNeill, 1992). However, because aphasic patients produce smaller speech units, the number of gestures per <u>word</u> is higher for aphasic patients than controls (Feyereisen, 1983). Thus, although both speech and gesture are reduced in aphasic patients, this reduction is more pronounced for speech than gesture, suggesting that when there is a language breakdown, gesture may serve to compensate for reduced verbal language (Ruiter & Beer, 2013).

In sum, there is strong evidence that gesture and language form an integrated communication system. However, the opposing studies also suggest that at times the gestures that we produce may not have a primary communicative purpose (lexical retrieval). As Alibali et al. (2000) conclude, it may be the case that the theories are not mutually exclusive. For example, it may be that gesture plays multiple roles during language acquisition, language processing, problem solving and communication. Two lines of evidence could elucidate the relationships between language and gesture, longitudinal studies of the link between language and gesture in typical populations and language and gesture in children with developmental language disorder (DLD).

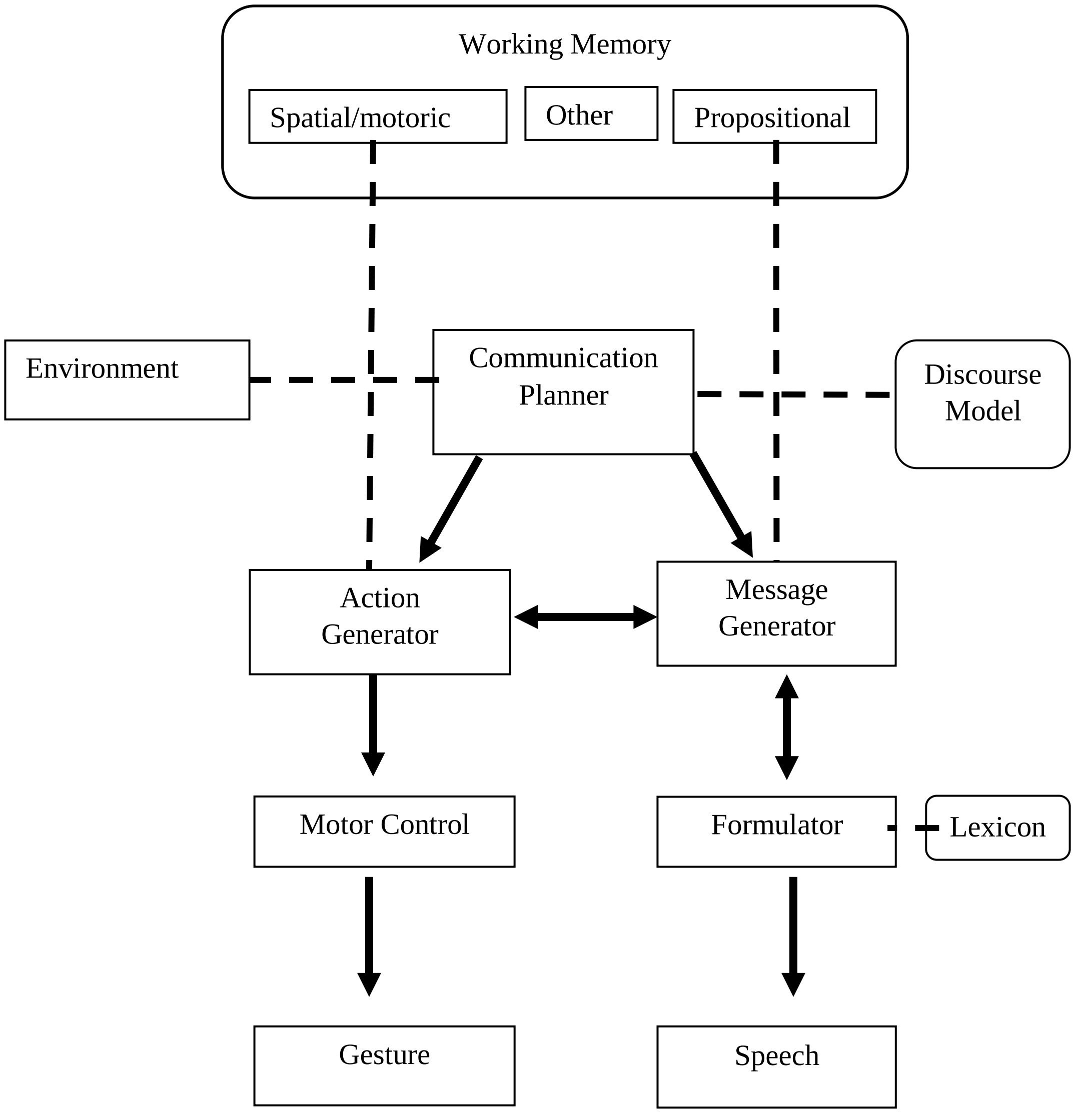


Figure 1.1. The Interface Hypothesis model from Kita and Özyürek (2003), demonstrating that gesture and speech are shaped simultaneously.

1.3. Gesture and Typical Language Development

The following section will begin by considering gesture use in naturalistic contexts for young TD children. Given the interactive nature of communication this warrants an examination of how parent gesture is related to both child gesture and child language development. This will be followed by discussion of studies with older TD children, which illustrate how manipulating parent or child gesture impacts on language learning and problem solving.

1.3.1. Gesture development in early childhood

Gesture and language typically develop in tandem, with gesture emerging slightly before the onset of spoken communication (Goodwyn & Acredolo, 1993); for example, infants express nouns through deictic gestures three months before the same nouns are produced through speech (Iverson and Goldin-Meadow, 2005). During the first year of life, infants produce significantly more gestures than spoken words when trying to communicate (Volterra, Caselli, Capirci, & Pizzuto, 2005) and these gestures are often used to replace words that they cannot verbalise (Stefanini, Caselli, & Volterra, 2007). For example, Rowe, Özçalışkan, & Goldin-Meadow (2008) reported that at 14 months of age, 89% of children's utterances are gestures only.

Children first begin to produce gestures between eight to ten months: these first gestures include deictic, "giving" and conventional gestures (Bates, 2014; Bates, Camaioni, & Volterra, 1975; Folven & Bonvillian, 1991) followed by more complex representational gestures. Gesture rates increase steadily until 22 months, when gesture rate begins to plateau (Rowe et al., 2008). At 22 months, children are producing similar numbers of gestures during parent-child interaction as their parents (Rowe et al., 2008).

As language develops, children begin to produce gesture - speech combinations, enabling them to express more complex information across two modalities. Early in infancy gestures - speech combinations are predominantly redundant, meaning gestures convey the same information as speech; for example, a child may point to a dog while saying “dog” (Capirci, Iverson, Pizzuto, & Volterra, 1996). Later, children combine words with extending gestures to produce more complex utterances; for example pointing to a lolly and saying “eat” (Masur, 1982). The frequency with which children produce gesture - speech combinations is a significant predictor of their later two word combinations (Iverson & Goldin-Meadow, 2005) and their ability to produce complex sentences (Rowe & Goldin-Meadow, 2009).

1.3.2. Child gesture supports typical language and communication development

Early child gesture not only predates spoken language but also predicts later oral language abilities (Capirci et al., 1996). In early infancy children’s gesture vocabulary is positively associated with later receptive vocabulary (Rowe & Goldin-Meadow, 2009a, 2009b; Rowe et al., 2008), demonstrating that those children who convey more varied meanings in gesture also have more varied vocabularies. Rowe and Goldin-Meadow (2009b) reported that child gesture vocabulary at 18 months significantly predicts individual differences in child receptive vocabulary at 42 months. Combined spoken and gesture vocabulary at 18 months explained 30.9% of the variance in oral vocabulary size at 42 months. In contrast, gesture - speech combinations did not predict later vocabulary but did significantly predict later sentence complexity, after controlling for verbal MLU (Rowe & Goldin-Meadow, 2009b). Consistent with this, Rowe et al. (2008) observed 53 children for 90 minutes every four months between the ages of 14 and 34 months and assessed vocabulary (Peabody picture vocabulary test) at the age of 42 months. Child gesture at 14 months was a significant predictor of vocabulary outcome at 42 months, even when child and parental spoken words and SES at 14 months were taken into account. However, this study is limited as they do not report whether gesture later in development (e.g. 24 or 30 month observations) was predictive of later vocabulary. This would have provided a clearer idea of whether gesture continues to predict language as both gesture and language develop. In addition, all of these studies focus on receptive vocabulary and so the extent to which early gesture predicts expressive vocabulary is uncertain.

Given that children use different proportions of gesture types at different ages, an interesting question is whether different types of gesture play the same role in language development. It is possible that pointing and representational gestures facilitate language learning in different ways. For example, deictic gestures map closely to the intended referent, and are less cognitively demanding as one gesture can be used to refer to multiple referents (Özçalışkan, Adamson, & Dimitrova, 2016). Representational gestures, on the other hand, use symbols to represent referents, and vary in form and function dependent on the referent, making them more complex to learn, produce and comprehend. It is therefore not surprising that children's early deictic gestures are more closely related to the development of noun vocabulary (Iverson & Goldin-Meadow, 2005). Özçalışkan et al. (2016) reported that pointing gestures were related to later vocabulary but other types of gestures (conventional and 'give' gestures) were not. Unfortunately, due to participant age (18 months), the incidence of representational gestures was too low to explore the relationship between representational gestures and later language. It therefore remains possible that there are developmental changes in the types of gestures children use, and the extent to which different types of gesture support language learning.

It has been proposed that representational gestures have a different developmental relationship with language acquisition relative to deictic gestures (Özçalışkan, Gentner, & Goldin-Meadow, 2014). Özçalışkan et al. (2014) investigated the emergence of verbs in spoken language and in gesture. Rather than preceding onset in spoken language, representational action gestures developed six months after the emergence of verbs in spoken language. At first glance this suggests that representational gestures do not facilitate verb development. However, the production of verbs and representational gestures increased in frequency between 22 and 26 months. However, once representational gestures have emerged, only 18% of representational gestures depicted actions for verbs already in speech, whereas 42% of representational gestures expressed action meanings uniquely in gesture. Thus representational gestures may help to facilitate vocabulary growth, and in particular verbs, but only after children have acquired some knowledge about verbs and are already producing them in speech (Özçalışkan et al., 2014). This highlights the differing relationships between gesture and the onset and development of nouns and verbs.

Although these studies demonstrate relationships between early gesture and later language the mechanism behind this is unclear. One possibility is that early gesture use may just be an indication of language learning potential, rather than playing an active role in facilitate in language learning (cf. Rowe & Goldin-Meadow, 2009b). For example, children who learn and produce complex gesture-speech combinations more easily may also learn spoken language more readily. Alternatively, gesture may play a more active role in language learning. One hypothesis is that early pointing gestures facilitate language acquisition by encouraging joint attention. On this view, early gestures are used by parents to draw children's attention to objects and vice versa, ensuring that verbal labels used by parents coincide with the child's attention focus (Tomasello & Todd, 1983). Another hypothesis is that gesture enables children to practice and express more complex utterances through gesture and speech than with speech or gesture alone (Iverson & Goldin-Meadow, 2005; Stefanini, Caselli, & Volterra, 2007). For example, Ozçalişkan and Goldin-Meadow (2005) reported that children produce predicate and predicate combinations through speech and gesture (e.g. "help me" with a 'open' gesture) before speech alone ("help me open").

In addition, child gesture may elicit communication from adults, which in turn may facilitate language acquisition. For example, parents routinely translate the gestures that their children produce and in doing so provide a verbal label for an object that the child currently cannot verbalise. For example, if a child points to a dog and a mother replies "yes, that's the dog", she thus provides the child with a verbal label for that animal (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). However, this theory relies on parents being aware of the non-verbal communication attempts of their child, in order to provide contingent verbal feedback to their gestures.

In summary, as depicted in Figure 1.2, early child gesture predicts children's later language abilities (path a). The mechanism behind this is still unclear, but there is evidence that child gesture elicits parent responses (path b) which may provide children with more frequent and richer linguistic input, leading to greater language learning (path c).

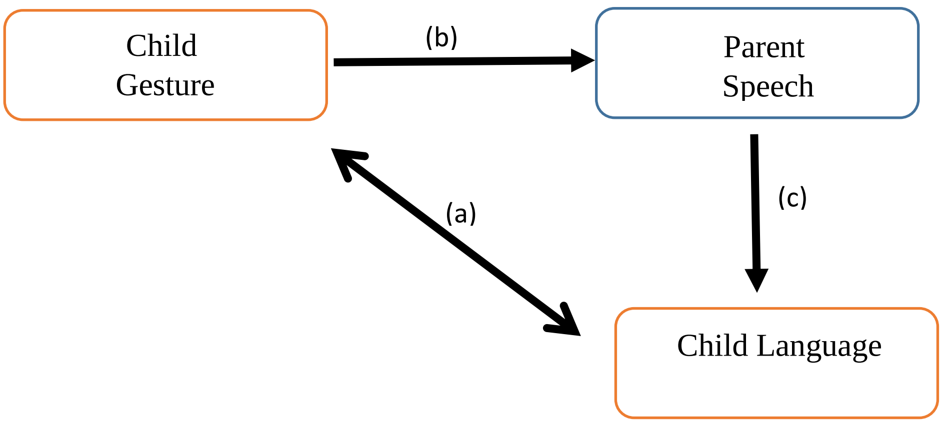


Figure 1.2. Relationships between child gesture, parent speech and child language.

1.3.3. Parent gesture supports typical language and communication development

Parent input is critical for language acquisition (Pan, Rowe, Singer, & Snow, 2005; Rowe, 2008, 2012a; Tamis-LeMonda, Kuchirko, & Song, 2014). It is through early parent-child interaction that children learn the semantic and linguistic structures and social cues required for language (Snyder-McLean & McLean, 1978). As such it is necessary to consider whether parent gesture is an important component of the input that supports language acquisition.

Given that children understand the gestures of others by 12 months (Butterworth & Grover, 1999), parent gestures may be a useful communication strategy to help support children's understanding of verbal language and also may help to direct and maintain children's attention to target referents. The following section will discuss the relationship between parent gestures and child language and the possible mechanisms by which parent gesture may facilitate language.

1.3.3.1. Parent gesture supports language

In the same way that parents produce child directed speech, parents also produce child directed gestures (Iverson, Capirci, Longobardi, & Caselli, 1999). These gestures function to encourage joint attention, by helping to draw and maintain children's attention to objects (de Villiers Rader & Zukow-Goldring, 2010). Parents use larger, more simplistic gestures when communicating with their child, in comparison to when talking to an adult (Brand, Baldwin, & Ashburn, 2002; Iverson et al., 1999; Özçaliskan & Goldin-Meadow, 2005).

1.3.3.2. Parent gesture, child gesture and child language

As with parental language input, parent gesture can have a positive impact on both child gesture and child language. For example, parents who gesture frequently have children who also gesture frequently (Goodwyn & Acredolo, 1993; Iverson et al., 1999; Liszkowski, Brown, Callaghan, Takada, & de Vos, 2012; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). Goodwyn and Acredolo (1993) demonstrated that symbol use develops earlier in those children whose parents have actively modelled gesture-word pairs while interacting with their child. In addition, parent gesture may also be positively related to child language (Iverson et al., 1999; Pan et al., 2005). For example, parents who produced high numbers of pointing gestures during parent-child interaction have children with larger vocabularies aged 14 months (Pan et al., 2005) and 16 months (Iverson et al., 1999).

However, further research has indicated that parent gesture only indirectly influences child language development, through its effects on child gesture use (Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). Rowe et al. (2008) demonstrated that parent gesture vocabulary (number of different words expressed in gesture) at 14 months significantly predicted child gesture vocabulary at 14 months, which subsequently predicted children's spoken vocabulary at 42 months. However, there was no direct relationship between parent gesture vocabulary at 14 months and later child language, suggesting that the role of parent gesture on child language may be mediated by child gesture use. Similarly, once Iverson et al. (1999) and Pan et al. (2005) controlled for parent verbal language, the significant relationship between parent gesture and child language disappeared, suggesting that parent language may play a more direct role in oral language development. However, parent gesture may still be important to the extent that it increases the child's use of gesture, which then may have beneficial impact on child language as discussed earlier.

As can be seen by Figure 1.3, parent gesture appears to have an indirect influence on child language (path c), whereby parent gesture signals to children that gesture is a useful communication strategy, increasing child gesture use (path a). This in turn helps to facilitate children's language development, by providing children with opportunities to practice and express complex syntax through gesture and speech (path b). In addition, child gesture may also elicit verbal responses from parents (path d), which in turn leads to enriched linguistic input from children which helps to facilitate language (path e). What this model demonstrates is that these relationships are reciprocal and child gesture may influence parent behaviour as much as parent gesture influences child behaviour.

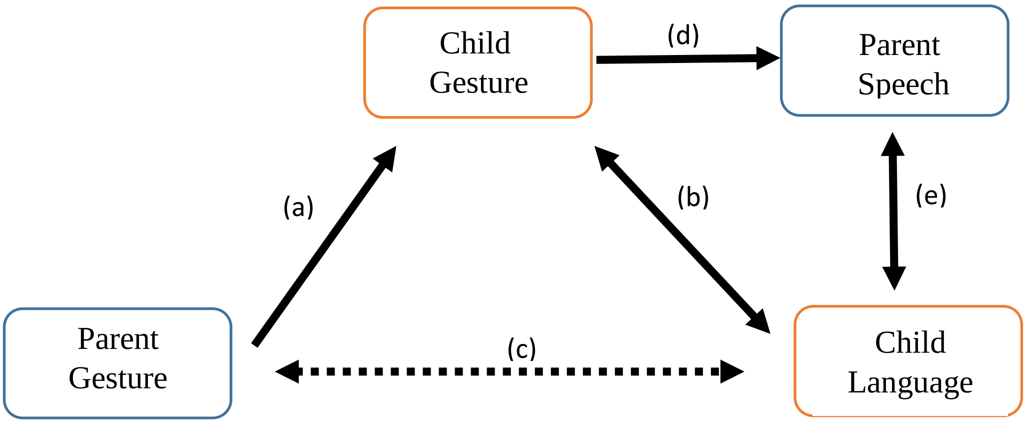


Figure 1.3. Relationships between parent gesture, child gesture, parent speech and child language.

Extending this work, Rowe and Goldin-Meadow (2009a) explored other influences on child gesture and vocabulary development. They reported significant positive relationships between both socio-economic status (SES) and parent gesture with child gesture at 14 months. Mediation analysis revealed that SES was no longer significantly related to child gesture once parent gesture was included in the model. In other words, parent gesture mediates the relationship between SES and child gesture. They also reported that child gesture mediates the relationship between SES and child vocabulary at 52 months. Thus, disparities between vocabularies in high and low SES children may, in part, be due to early communication experiences. In particular, gesture use at home may be a significant factor in explaining the links between vocabulary variations in later childhood.

Early in development child gesture directly influences child language acquisition; parent gesture is also important, possibly because of its influence on child gesture. However, less is known about the long term impact of early gesture exposure. Given that intervention studies have not found long-term benefits to encouraging early gesture use (Goodwyn, Acredolo, & Brown, 2000) then the extent to which gesture continues to drive language development may be limited. In addition, few studies have explored other factors such as SES that may also influence variation in children's language ability (Rowe & Goldin-Meadow, 2009a).

In conclusion, the research literature to date suggests that whilst parent gesture influences child gesture, child gesture subsequently influences the verbal input they receive from parents, and it is this that may in turn facilitate language learning. Such findings signal reciprocal relationships whereby child language and gesture behaviour may influence parent language and gesture behaviour as much as parent behaviours drive child language and gesture development (Figure 1.3). However, this model may only be appropriate for typical development. For example, it does not consider these relationships in atypical populations where social engagement may be more challenging. In addition, other aspects of development also need to be considered in these relationships. For example, difficulties with motor skill may limit the extent to which children can imitate and use the gestures that they are exposed to and thus may limit the verbal input they subsequently receive.

1.3.4. The role of gesture in later childhood learning

1.3.4.1. Gesture use in school aged children

Although in the early years infants show a preference for gestural communication, this begins to decrease around 20 months, when verbal communication becomes the dominant mode of communication (Capone & McGregor, 2004; Iverson, Capirci, & Caselli, 1994). Nevertheless, school-aged children continue to produce gestures alongside speech and gestures can often help them express information that they cannot verbalise. Church and Goldin-Meadow (1986) assessed 28 children aged five to eight on Piagetian conservation tasks. They reported that 82 % of children's explanations were accompanied by gesture and that 40% of these were gestures expressing information that did not match speech (gesture-speech mismatches), revealing knowledge they were not expressing in verbal language. For example, whilst explaining their answer to a Piagetian conservation task a child would say "the glass is taller", whilst producing 'width' gesture, that reveals that they were aware that the glasses were different widths as well as heights. Church and Goldin-Meadow (1986) proposed that children that produce gesture-speech mismatches are in a state of transitional knowledge, and that gesture use reflects a readiness to learn.

Gesture can also be used for a child's own language and cognitive processing. For example, gesture production facilitates problem solving in complex cognitive tasks (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). This is evident by the contrast in performance when children are instructed to gesture, in comparison to contexts in which gesture is prohibited. Alibali and DiRusso (1999) instructed children to count coins and to either point to each coin, touch each coin, not point or touch, or given no instructions. Children did not perform as well when they were unable to gesture compared to when gesture (pointing or touching the chip) was encouraged. This is consistent with Goldin-Meadow, Nusbaum, Kelly and Wagner (2001) who asked participants to solve a maths problem while also remembering letters. Participants who were allowed to gesture remembered more of the letters than those participants who were prohibited from gesturing. This suggests that the act of gesturing may "lighten the cognitive load" imposed by the maths problem, creating more available space in working memory to remember the letters. However, prohibiting gesture may have imposed greater cognitive demands on the children in that condition, leading to poorer performance because they had to inhibit their natural propensity to gesture.

Goldin-Meadow, Cook, and Mitchell (2009) demonstrated that the accuracy of gestures that children produce may also influence the impact gesture production has on problem solving tasks. Children were taught to either produce the correct gesture for solving a problem, a partially correct gesture, or were not encouraged to gesture at all. Those children who produced the correct gesture solved more of the problems than children in the other two conditions. Also, those who were taught only partially correct gestures outperformed children who produced no gestures at all. This not only supports the idea that gesture helps children learn new concepts and ideas, but also indicates that the more accurately children produce gesture, the more benefit gesture has for supporting task performance.

1.3.4.2. Teacher gestures and their influence on learning

As children get older, much language learning occurs in the classroom. Alibali and Nathan (2007) demonstrated that teachers may tailor their utterances and use of gesture in line with the needs of the children in their class. For example, the teacher they observed gestured more frequently when presenting concepts that were new or more complex, and her use of gestures decreased as children became more familiar with the concept. In addition, gesture use changed in response to children's questions, for example the teacher gestured significantly more following a question than before the question. This study demonstrates that teachers may use gestures to help scaffold children's understanding, in particular when teaching concepts that are either new or more challenging. However, this study only observed one class teacher and so the extent to which these findings can be generalised to other classrooms is questionable.

Other studies, however, have demonstrated that children learn more from lessons when their teacher gives instructions through gesture and speech, rather than speech alone (Church, Ayman-Nolley, & Mahootian, 2004). Church et al. (2004) taught children about conservation, either with gesture and speech or speech alone. Children were given a conservation problem before and after the conservation lesson. They demonstrated that 91% of children taught using gesture and speech showed a significant improvement in their understanding of conservation, in comparison to only 53% during the speech alone lesson. This is consistent with Valenzeno, Alibali and Klatzky (2003) who also reported that pre-school children taught symmetry using gesture and speech were able to solve twice as many symmetry problems compared to those taught using only speech. However, from these studies it is unclear why teacher gestures led to an improved understanding of the task. It may be that teachers' gestures simply capture attention more readily than when teachers use speech alone, so that children were more engaged in the lesson. However, further studies that manipulated gesture use have suggested that gesture may play more of a casual role in learning and problem solving. Singer and Goldin-Meadow (Singer & Goldin-Meadow, 2005) instructed teachers to produce either no gestures, gestures that conveyed the same information as speech or gestures that conveyed a different solution in gesture and speech (mismatch), during a maths lesson. Children were most effective in solving the maths equations when gesture conveyed different information to speech (providing two strategies) than when gesture conveyed the same information (providing one strategy in speech and gesture). This indicates that children's receptiveness to the gestures of others may also be an important factor in how gesture aids learning, not only in language development but also in other areas of learning.

The positive effect of teachers' gestures appear to have on learning may be at least partially attributable to the notion that when children observe their teachers gesturing they too are more likely to gesture. Cook and Goldin-Meadow (2006) found that this was the case and that those children who did imitate teacher gestures were more likely to correctly solve maths problems than those that did not imitate their teachers' gestures.

The available evidence suggests that gesture plays an integral role in children's language development and appears to not only precede but also predict language outcomes at school entry. In addition, gesture continues to play a crucial role in children's later learning and problem solving, not only for language skills but also in other areas of cognitive development. The research highlights the importance of not only parents, but also teachers becoming aware of their children's gestures and responding by increasing the complexity of their gesture-speech productions. Not only do children reveal aspects of their knowledge solely through gesture, but the presence of gesture-speech mismatches also may be indicative of a child's learning state. It has also been shown that through gesture children can in fact influence the way in which they are taught and elicit verbal responses from parents that may help facilitate learning.

1.3.5. Gesture as a focus of intervention

As indicated earlier in the chapter gesture plays an important role in children's early language development. However, studies demonstrating this link are predominantly observational, meaning that the mechanisms behind this gesture advantage are not clear. This raises the question of whether we can experimentally manipulate gesture use, and whether increasing gesture use subsequently has an impact on child gesture or language abilities.

1.3.5.1. Can parent and child gesture use be increased?

By increasing gesture use in either parents or children, studies have aimed to explore whether this has subsequent positive effects on children's language development. Goodwyn, Acredolo and Brown (2000) trained 103 parents to either increase their verbal labelling (n=32), or increase their verbal and symbolic gestural input (n=32). In addition their study included a control group who received no intervention (n=39). Children's language was measured using a variety of expressive and receptive language assessments at 15, 19, 24, 30, and 36 months. Goodwyn et al. (2000) reported that those children whose parents had been encouraged to use gesture achieved significantly higher scores on measures of receptive language at ages 19 months and 24 months. In addition, they achieved higher scores on measures of expressive vocabulary at 15 and 24 months. Children whose parents had been encouraged to gesture also demonstrated the largest gesture repertoire. However, child gesture was measured from parent report during fortnightly phone interviews, and thus may have provided a biased estimate of gesture use. For example, parents were not blind to intervention status and so those parents told to gesture are likely to notice and remember gesture more than those not told to gesture. The fact that the gesture trained group did not show language gains at all time points suggests the extent to which gesture was facilitating language development may be limited. Finally, they did not directly measure the impact child gesture had on child language and it may be that parent gesture use is impacting on children's language indirectly through child gesture use, as demonstrated by Rowe et al. (2008). One further limitation of this study is that they do not report how children were recruited or how they were allocated to training groups. Thus, if children were not randomly allocated to training groups then it is possible that training effects were a result of a cognitively or linguistically more advanced group, rather than training.

LeBarton, Goldin-Meadow and Raudenbush (2015) demonstrated that it is possible to directly increase child gesture use during a six week training study. Fifteen children (aged 16- 18 months) were assigned to one of three conditions: child and experimenter gesture, experimenter gesture or no gesture. Training consisted of a structured play session during which the experimenter and child interacted with two picture books. One picture on each page was verbally labelled; for the experimenter condition, the experimenter also pointed to the picture, and for the experimenter and child condition, the child was also instructed to point to the picture. Children's spontaneous verbal and non-verbal communication was measured through pre-test and post-test (2 weeks after training) during observation of unstructured parent-child interaction.

Those children instructed to gesture showed the greatest increase in the number of different gestures produced during spontaneous parent-child interaction at follow-up. However, there was only a borderline effect of intervention group on number of words produced at follow-up, though any effect of the experimental manipulation on children's language was mediated by child gesture. The instruction to gesture significantly increased child gesture repertoire, which predicted the number of different words produced at follow-up. This study demonstrates that child gesture use can be experimentally manipulated and may further help those words to enter the child's verbal lexicon. LeBarton et al. (2015) suggest that increasing children's use of gestures may have influenced children's language by providing opportunities for parents to translate their children's gestures. In addition, parent gesture may also have played a more direct role. LeBarton et al. (2015) reported that when children were explicitly taught to gesture, parent gestures also increased across the study, despite no specific parent training. Thus, it is not clear whether children's increase in gesture use was solely due to the training, or whether increases in parent gesture use also influenced this effect. Whilst this study explored the impact of encouraging gesture on spontaneous speech, there was no direct measure of whether children told to gesture learnt the target words more easily than children in the other conditions. Such data would provide further insight into the mechanisms by which child gesture is related to language acquisition.

The extent to which these studies can be compared is limited as these studies differ in the type of gestures that they are measuring. Goodwyn et al. (2000) taught symbolic gestures, whereas LeBarton et al. (2015) encouraged pointing gestures. As demonstrated earlier in the chapter, the impact of either pointing or representational gestures may influence language development in different ways.

1.3.5.2. Is gesture beneficial to language development?

To fully understand the role of gesture in learning language we need to examine studies that have used gesture during more structured language learning experiments. In early childhood, experimentally manipulating children's gestures has a positive impact on children's word learning (Capone & McGregor, 2005; McGregor, Rohlfing, Bean, & Marschner, 2009). For example, Capone and McGregor (2005) taught young children, aged 27-30 months old, six novel object words. When labelled, these words were either accompanied by a function gesture, a shape gesture or no gesture. Children were tested on object recognition, object function and word retrieval tasks. After one exposure, children were better able to recall words taught in the shape gesture condition. However, after more exposures children recalled more words and could name more object functions when words were taught in either of the gesture conditions, in comparison to the control condition. This indicates that shape gestures may be useful for fast mapping of new words, whereas for slow mapping function and shape gestures are comparable (Capone & McGregor, 2005). The findings further suggest that gestures may have helped enrich semantic knowledge of the target words, making for easier word recall. However, during the object recognition test, object words taught in the control condition were just as easily recognised as words taught in the two gesture conditions. Recognition of an object during forced choice test may not require such well-developed semantic representations as object naming, thus gesture may not be needed to facilitate this kind of task. While gesture may enhance word recall, it could also be that gestures made the task more engaging, which may also lead to better recall. However, Singleton (2012) demonstrated that this is not the case. They replicated and extended Capone and McGregor's (2005) study by replacing the no gesture control group with a pointing gesture only control, thus directing the child's attention to the target, but not providing any representational information about the object. Singleton (2012) reported that children were better able to recall words taught in either the shape or function condition. In addition, children were more likely to extend words taught with shape gestures, relative to other conditions. Thus the role of gesture in word learning extends beyond simple attention grabbing. In addition, the type of semantic enrichment gained from gesture may determine how easily children can extend new words to other situations.

Kapalková, Polišenská, and Süssová (2016) reported that gesture may also be more beneficial than other non-verbal cues such as pictures during word learning tasks. During a 10 week intervention, Kapalková et al. (2016) taught two year old children ten novel words either accompanied by a picture or a gesture. Children were randomly allocated to a training group so that each training group comprised nine children. Children received 15 group training sessions across four weeks. Children in both groups were asked to produce the novel words during training, but the gesture group were also encouraged to produce the gestures. Word production was measured at three time points (one day after training, 2 week and 6 week follow-up). Children in the gesture group correctly produced more novel words than children in the picture group. However, this study is limited by small sample size (eight children in each condition), and more importantly, the investigators did not control for the number of word exposures each group received. As the authors do not report the number of exposures for each intervention group it is therefore possible the group differences are due to differences in the number of word exposures and not training modality *per se*.

In later childhood similar gesture advantages for word learning have also been reported. For example, Rowe, Silverman and Mullan (2013) taught four year old monolingual and bilingual children with high and low language abilities "alien" words for six familiar objects. Words were taught in three conditions: word alone, word and picture together, or word and gesture together, with two words taught per condition. Children were assessed on word and object recognition. They reported that neither the presence of gesture nor a picture had a positive impact on immediate word recall. However, bilingual children with low language proficiency were better able to recognise objects taught either with picture or gesture cues relative to the word alone condition. This advantage was not seen for children with better language abilities. However, at follow-up one week later, children with higher language abilities could identify more of the words taught in the word and picture condition relative to those with low language abilities (both monolingual and bilingual children). These findings provide further evidence that non-verbal cues may play different roles in fast and slow mapping of new words, but do not suggest that gesture conveys a privileged advantage as a cue for word learning. However, bilingual children with low language abilities achieved higher scores on the comprehension task for words taught in the gesture condition, relative to monolingual children with low language. At one week follow-up, however, this group difference was attenuated. Whilst this study demonstrated that gestural cues had short term benefits to word comprehension for children with the lowest language abilities (bilingual-low language), this was only reported in relation to monolingual children with low language. The study did not report the impact of non-verbal cues on monolingual or bilingual children with low language specifically, in relation to more verbally able peers. In addition, this study only taught children six new words (two per condition), thus restricting the extent to which learning can be assessed as the maximum score children could achieve under each condition was two.

Tellier (2008) however, did find a gesture advantage when teaching children new labels for known words. Tellier (2008) taught twenty 4-5 year old monolingual French children eight English words, in either a word and picture or word and gesture condition (10 children per condition). Crucially, during the word and gesture condition children were also asked to <u>produce</u> the gesture. They found that children were better able to produce words that had been accompanied by gestures during training both directly after training at one week follow up. One explanation for the disparity between this study and Rowe et al. (2013) is that children were asked to produce, rather than simply observe the gesture during learning. It may be that exposure to gesture does not necessarily lead to better word learning, but producing gestures may help to solidify the semantic representation of the word, thus making it more likely that that word will enter the child's lexicon. In addition, gesture production may benefit word recall by facilitating lexical retrieval. This study again replicates word learning for second language learners and is important in demonstrating that gesture production may facilitate learning a second language. Whether the same gesture advantages are evident in first language learning remains an empirical question.

As well as supporting word learning, gesture may also facilitate children's understanding of complex language. McNeil, Alibali and Evans (2000) gave thirteen pre-school children (aged 3;6 to 4;8) either complex or simple instructions to a block building task. They reported that when instructions were complex, reinforcing gestures helped children comprehend and complete the task. However, when the instructions were simple, gesture did not impact on children's understanding. Thus, gesture may be most effective during complex tasks when task demands are high. In a similar study, they reported that for kindergarten children (4;9 to 6 years), reinforcing gestures did not facilitate understanding. However, conflicting gesture-speech combinations used during instruction hindered children's comprehension of task instructions (McNeil et al., 2000). This again suggests that gesture does not just capture children's attention to speech, but that children are using information conveyed in gesture to support language comprehension. If gesture simply aided communication by making language more engaging, then regardless of whether the gesture reinforced or matched speech, we would expect children to perform similarly.

Atypical populations may provide further insight into how gesture manifests when spoken language and communication is compromised. If gesture and speech form separate communication systems, then children with DLD may show relative strengths in gestural communication, in comparison to speech. However, if gesture and speech form an integrated system, children with DLD may present with co-occurring difficulties with gesture production. The following section will discuss gesture use in atypical populations. This will explore how gesture is used when deficits in motor skills, social engagement and/or conceptual knowledge are present. If gesture is founded on good motor skills, social engagement and conceptual knowledge, then this may impact the extent to which children with DLD can utilise gesture as a communication strategy. Thus, the following section will help to inform predictions of how gesture is used by children with DLD.

1.4. Gesture in Atypical Development

Studies of early typical language development suggest that child gesture drives language acquisition. However, in atypical populations, gesture is often regarded as a compensatory tool, rather than a driver of language acquisition. This assumption raises the question as to how gesture and language interact when language follows an atypical trajectory which may also be accompanied by co-occurring developmental challenges. For example, co-occurring difficulties in non-verbal cognition, social engagement, working memory and motor development are often present in developmental disorders such as DLD, Down syndrome (DS) and autism spectrum disorder (ASD). These deficits may impact on children's abilities to produce accurate gestures, their motivation to use gesture to compensate for oral language weaknesses and use gesture to enhance understanding for their conversational partner. Increased gesture frequency alone may not be sufficient to compensate for language deficits, as gestures may only be beneficial if the conversational partner understands the intended message.

In addition, the long-term benefits of gesture use on language acquisition have not been established which raises the question of whether developmental relationships change over time. Gesture may be particularly important in the early years when there is no alternative, however the main function of gesture may be to support communication rather than promote language learning across the lifespan. If this is the case, then instead of positive relationships between language and gesture, in later childhood we might expect to see negative relationships, especially in children with atypical language development for whom communication is difficult. This would simply reflect the need to gesture more when the verbal message is inadequate. In addition, if children with atypical language do have difficulties with gestural communication, then it is possible that early gesture use may be a useful marker for early identification of atypical development (Luyster, Seery, Talbott, & Tager-Flusberg, 2011). The next sections review gesture use in populations that vary according to language, cognitive, motor and social development profiles.

1.4.1. Down Syndrome

Down syndrome (DS) is characterised by a mild to moderate intellectual disability and often more severe expressive language impairments in comparison to receptive language (Laws & Bishop, 2003). In particular, children with DS have difficulties acquiring and using syntax (Chapman, 2006; Laws & Bishop, 2003), and also produce shorter, less complex sentences (Caselli, Monaco, Trasciani, & Vicari, 2008; Price et al., 2008). Although children with DS show delayed acquisition of vocabulary (Berglund, Eriksson, & Johansson, 2001) there is evidence that receptive language develops in line with cognitive abilities (Laws & Bishop, 2003). Children with DS show relative strengths in pragmatic language use, and conversational skills (Martin, Klusek, Estigarribia, & Roberts, 2009). Another important characteristic of DS to consider is co-occurring oral motor difficulties, which may lead to articulation and phonology difficulties and speech intelligibility (Stoel-Gammon, 1997). As a result of this, children with DS may utilise gesture more often to make their message clearer.

Children with DS follow the same gesture development trajectories as TD children (Chan & Iacono, 2001), and there is evidence that the relationship between language and gesture in DS echoes that of TD children. For example, Zampini and D'Odorico (2011) reported that the total number of gestures produced during observation at 24 months was associated with vocabulary at 26 months. Consistent with this, Mundy, Sigman, Kasari and Yirmiya (1988) reported that non-verbal requesting gestures were positively associated with children's expressive language ability.

However, there is evidence that children with DS differ from their TD peers in the frequency with which gesture is used and the extent to which gesture supports children's expressive language (te Kaat- van den Os, Jongmans, Volman, & Lauteslager, 2015). For example, while TD children show a preference for verbal communication, children with DS have a preference for gesture production (Chan & Iacono, 2001; Zampini & D'Odorico, 2009, 2011). Indeed gesture production in children with DS has been reported as a relative strength in comparison to their oral language skills (Caselli et al., 1998; Chan & Iacono, 2001). Children with DS are observed to gesture at similar (Iverson, Longobardi, & Caselli, 2003; Zampini & D'Odorico, 2009, 2011), if not higher rates than their TD peers (Caselli et al., 1998; Franco & Wishart, 1995; Stefanini et al., 2007).

Consistent with this, Caselli et al. (1998) reported that children with DS have a larger gesture repertoire than younger, language matched TD children. The fact that children with DS gesture more frequently than peers indicates that this group of children are able to utilise gesture to compensate for their language weaknesses. This suggests that, intact social pragmatic skills and a drive to communicate may be key to children using gesture to facilitate communication. Given that gesture use in DS is a predictor of later language outcomes (Zampini & D'Odorico, 2009) gesture based interventions may be beneficial to supporting language and communication within this group.

In addition, children with DS also benefit from observing the gestures of parents and teachers. Wang, Bernas and Eberhard (2001) demonstrated that 7-year-old children with DS showed better attention to the task and were more likely to successfully complete a task, if their teacher used gestures during the lesson. Thus children with DS not only use gesture to facilitate language production but can also utilise gesture cues to support language comprehension. However, these studies of gesture use in DS focus on gesture frequency and it is therefore unclear whether co-occurring motor deficits impact on the accuracy of the gestures that children with DS produce.

1.4.2. Autism Spectrum Disorder

Autism spectrum disorder (ASD) is characterised by difficulties with social communication and restricted repertoire of interests and behaviours (American Psychological Association, 2013) and effects approximately 1% of children in the UK (Baird et al., 2006). In particular, children with ASD have difficulties with pragmatic language and understanding social norms (Ochs & Solomon, 2004). In addition, 50-70% of children with ASD have non-verbal abilities of less than 70 (Matson & Shoemaker, 2009). It is of interest to explore gesture use within this population as first, gesture ability is used during the diagnosis of ASD (American Psychological Association, 2013) and second, as a group, children with ASD present with varied language and cognitive abilities. Children with ASD present with a diverse range of language abilities, from severely below average to above average expressive and receptive language abilities. For example Kjelgaard and Tager-Flusberg (2001) measured language abilities of 89 children (aged 4-14) with ASD. They demonstrated that only 44 children were able to complete the CELF assessment (total language composite: receptive language, expressive language and grammar). Of the children who could complete the CELF; 48% scored below 70, indicating significant levels of language impairment; 22% had language scores within the 'normal' range (more than 80) and 30% had borderline language scores ranging 70-84, underscoring the diverse range of language abilities across children with ASD.

Children with ASD as a group display atypical gesture development (Goodhart & Baron-Cohen, 1993). Children with ASD are reported to gesture less frequently than TD peers (Bono, Daley, & Sigman, 2004; Camaioni, Perucchini, Muratori, & Milone, 1997; Medeiros & Winsler, 2014) and their gestures are often less accurate (Smith, 1998; Smith & Bryson, 2007). In addition, in early childhood (2-3 years) it is rare for children with ASD to use gestures to add information to speech (Sowden, Clegg, & Perkins, 2013).

Longitudinal studies further indicate that early gesture use may be a good diagnostic tool for ASD. LeBarton and Iverson (2016) conducted a longitudinal study of children who are high-risk of ASD (all children had an older sibling with ASD). They reported that high-risk children who later received a diagnosis of ASD produced fewer gestures at age 2 years than high-risk children who did not subsequently receive a diagnosis of ASD. This is consistent with Mitchell et al. (2006), who also reported that high-risk children later diagnosed with ASD produced fewer gestures aged 12 and 18 months in comparison to high-risk children not diagnosed with ASD and low-risk controls. On the whole the findings suggest that early gesture could be used as an early indicator of ASD in infants who have an older sibling with ASD. However, this study also reports that high risk-ASD group also expressed fewer words; as a result it is possible that the lower gesture rate reflects reduced speech and thus fewer opportunities to produce gestures. Indeed, when amount of speech is controlled, children with ASD do not differ from TD controls in the frequency of their gesture use (Attwood, Frith, & Hermelin, 1988; de Marchena & Eigsti, 2010).

In addition, children with ASD also display gesture differences relative to children with other developmental disorders. Mastrogiuseppe, Capirci, Cuva, & Venuti (2015) reported that young children with ASD produce fewer gestures than TD children and children with DS matched for developmental age. This suggests that different developmental disorders utilise gesture to different degrees during communication. This may be explained by key differences between DS and ASD such as social communication abilities and potential mismatches between verbal and non-verbal cognitive abilities. For example, children's drive to communicate may lead to more frequent opportunities for children to use gesture, or explore alternative means of communicating.

Gesture in ASD appears to support language learning and processing in a similar fashion to TD children. Studies have reported a positive relationship between the number of gestures produced, language comprehension and expressive language in 20-51 month old children (Braddock et al., 2015). Similarly, Medeiros and Winsler (2014) observed older ASD children's (4-18 years) gesture use during a parent-child interactive problem solving task and again found a positive relationship between child receptive vocabulary and child gesture rate. In addition, gesture use (as measured by MacArthur-Bates Communicative Development Inventories) predicts expressive and receptive language abilities in toddlers with ASD.

Contrary to this So, Wong, Lui and Yip (2014) reported no significant relationship between gesture and language (narrative assessment). However, they did report a significant relationship between the number of gestures and scores on the social communication questionnaire. This indicates that the more severe a child's communication and social functioning, the fewer gestures they produced. These findings imply that in this group of children the socio-communicative functions of gesture are disrupted. Such findings highlight the importance of the social function of gesture, in addition to consideration for how gesture drives language development or compensates for language weaknesses.

Such findings suggest that both language abilities and autism symptom severity may impact on the extent to which children with ASD utilise gesture during communication.

DS children appear to show similar, but delayed developmental trajectories than TD children, but crucially children with DS have a preference for gestural communication over spoken language. Children with ASD, on the other hand, appear to show early deficits in gesture use, which may depend on severity of language and/or autism severity. Gesture use in these two developmental conditions leads to the suggestion that children with DLD may gesture as frequently as peers, given their typical drive to communicate, similar to children with DS. However, this may depend on the severity of their language impairment and any other co-occurring difficulties which may inhibit their ability to use gesture to compensate for language weaknesses.

Models of the gesture-speech relationship suggest that gesture is a complex task which involves the integration of cognitive, motor, language and social skills, in addition to contributions from external influences (parent gesture and parent speech). This poses the question as to how children with primary deficits in language acquisition develop and use gesture. In order to answer this question, we need to know more about the nature and causes of DLD and how this might impact on gesture production, which will be discussed in the following chapter.

Chapter 2: Developmental Language Disorder

The preceding chapter outlined theories of the gesture-language relationship in typical development and raised questions about the ways in which gesture is used when development does not follow a typical course and language may be impaired. This chapter begins with an overview of developmental language disorder (DLD), including language characteristics, diagnostic criteria, prevalence estimates and the causes and consequences of DLD. This chapter then explores gesture use in children with DLD, the extent to which gesture can be used to compensate for language weaknesses, the limitations of the current literature and an outline of how this thesis will address these limitations.

2.1. Early Language Delay

In early infancy some children present with delayed language acquisition, often termed ‘Late-talkers’. ‘Late-talker’ is usually defined as a child having expressive vocabulary in the bottom 10^{th} percentile at two years of age (Dale, Price, Bishop, & Plomin, 2003). Although, a large proportion of these children catch up and develop language skills within the normal range, it is likely that their language scores will still be below their TD peers (Paul, Bishop, & Leonard, 2000; Rescorla, 2005; Thal & Katich, 1996). In addition, for some children these early language deficits are an indication of a more persistent language deficit.

It is important for researchers and clinicians to be able to differentiate between children with early language delay and those with a persistent language disorder as this may assist with prioritisation of early language intervention (Dale et al., 2003). Literature in this area is still unclear about what differentiates these two groups, although studies suggest that factors such as the severity of children’s early language delay (Dale et al., 2003; Zambrana, Pons, Eadie, & Ystrom, 2014), severity of non-verbal communication deficits (Thal & Tobias, 1992), body movement imitation (Dohmen, Bishop, Chiat, & Roy, 2016), family risk of speech and language difficulties (Reilly et al., 2010; Zambrana et al., 2014), maternal education, and/or socio-economic status (Reilly et al., 2010) may help to identify those children displaying transient early language delay and those with more persistent language disorder.

2.2. What is language disorder?

Developmental language disorder (DLD) has been traditionally diagnosed when children's language is below chronological age expectation, despite adequate opportunity for language learning and in the context of otherwise typical development (Bishop, 1992). It is often considered a diagnosis by exclusion, meaning that language deficits occur in the absence of other developmental concerns, sensory impairments or global developmental delays. However, there has been considerable debate regarding the correct terminology and diagnostic criteria in relation to DLD (Reilly, Bishop, & Tomblin, 2014), issues that are outlined below.

2.2.1. Terminology and diagnosis

Terms that have been used in the literature include specific language impairment, language impairment, specific language disorder, language delay, developmental language disorder, and developmental dyspraxia (Bishop, Snowling, Thompson, Greenhalgh, & Consortium, 2016). Inconsistencies are not only evident within research but also by clinical professionals (Dockrell, Lindsay, Letchford, & Mackie, 2006). Recently, a consensus for the term developmental language disorder (DLD) has emerged amongst clinicians, researchers, educators and key stakeholder groups (Bishop, Snowling, Thompson, & Greenhalgh, 2016) and this term will therefore be used throughout this thesis to refer to studies that have used all of the above terminology.

Diagnostic criteria have also been variable and controversial. DSM-V defines developmental language disorder as:

"persistent difficulties in the acquisition and use of language across modalities (i.e. spoken, written, sign language and/or other symbol systems) and involve comprehension or production deficits in one or more of the following domains: (1) vocabulary (word knowledge and use), (2) sentence structure (ability to put words and word endings together to form sentences based on the rules of grammar and morphology), and/or (3) discourse (ability to use vocabulary and connect sentences to explain or describe a topic or series of events or have a conversation)" (APA, 2013).

A crucial difference to DSM- IV criteria is that DSM-V does not stipulate that a discrepancy between verbal and non-verbal abilities is required for a diagnosis of language disorder.

ICD-10 (World Health Organization, 1992) uses different diagnostic criteria and stipulates a severe language deficit of -2SD below the mean, an average non-verbal ability and a significant discrepancy between verbal and non-verbal abilities. Different diagnostic criteria may impact on children who fall between diagnostic categories. For example, a child with severe language and communication deficits, but non-verbal abilities that are slightly below the 'normal' range would not meet criteria for DLD nor would they meet criteria for learning disabilities because their non-verbal deficits are not severe enough. Thus, children who fall between these categories may miss out on receiving any support. Relaxing the non-verbal criteria in DSM-V reduces the chances of children missing out on important intervention solely because of their non-verbal cognitive abilities. In addition, differences in diagnostic criteria may influence prevalence estimates and also the number of children receiving language and communication support (Norbury, Gooch, et al., 2016).

Non-verbal IQ criteria has been particularly contentious. It is argued that a requirement of average non-verbal ability should not be included in diagnostic criteria as both non-verbal ability and language are often significantly correlated, with those with the most severe language difficulties also presenting with the most severe non-verbal difficulties (Conti-Ramsden & Durkin, 2012). In addition, there is little difference in genetic influences on language disorder between children who have a discrepancy between their verbal and non-verbal abilities, and those who do not (Bishop, 1994) and no evidence that children with lower non-verbal abilities do not respond to intervention (Bowyer-Crane, Duff, Hulme, & Snowling, 2011). In addition, children with differing levels of IQ do not yield dramatically different clinical presentations (Norbury, Gooch, et al., 2016). Comparisons of children with DLD with average (>-1SD) and low-average (between -2SD and -1SD) NVIQ scores indicated that groups did not differ on a total language composite score, symptom severity, socio-economic status or academic attainment (Norbury, Gooch, et al., 2016).

2.2.2. Prevalence

DLD impacts approximately 7% of children at school entry (Norbury, Gooch, et al., 2016; Tomblin et al., 1997). In a study of kindergarten children Tomblin et al. (1997) reported a prevalence rate of 7.4% of children with DLD at school entry. To meet criteria for DLD children had language scores of -1.25*SD* or more below normative mean on two out of five language composite scores and a non-verbal IQ of more than 85. A more recent prevalence study demonstrated a similar rate of 7.58% (Norbury et al., 2016); however, this study used a more severe cut-off of -1.5 SD or more below the normative mean on two out of five composite language scores, and only excluded children with non-verbal abilities below 70. Following this, Norbury et al. (2016) applied Tomblin's criteria to their own data and report a prevalence estimate of 7.74%, however, once the non-verbal criteria was relaxed, in line with the new DSM-V criteria, this prevalence estimate increased to 11.11%. This highlights that differences in prevalence rates may be influenced by the inclusion or exclusion of children with low non-verbal abilities and also the severity of the cut off.

In addition, Norbury et al. (2016) indicated that only 11% of children who met criteria for DLD achieved a good level of development on the Early Years Foundation Stage Profile. This suggests that psychometric assessments map closely to functional impairment. Further to this, it has been highlighted that even children with language scores of -1SD below the mean experience functional language deficits, particularly in academic attainment (Reilly, Tomblin, et al., 2014).

2.2.3. Clinical Features

Bloom and Lahey (1978)proposed that there are three main components of language: Form (syntax, morphology and phonology), Content (semantics and vocabulary knowledge) and Use (pragmatics). The clinical features of DLD will be discussed in relation to these three categories.

2.2.3.1. Form

Children with DLD present with deficits in grammar, in particular deficits of morphosyntax (e.g. I *walk* to school yesterday) (Rice, 2000) and also do not always use the correct auxiliary verb (saying 'I going' instead of 'I am going'). Crucially these errors are errors of omission rather than commission (Bishop, 1994a). In addition children with DLD also display difficulties with grammatical judgements and understanding complex syntax (Rice, Hoffman, & Wexler, 2009). Children with DLD show inconsistencies in their grammatical errors, indicating there is not a complete lack of grammatical knowledge (Bishop, 1994a). In addition, children often present with word finding difficulties. These difficulties are demonstrated by children's increased use of lexical fillers and use of non-specific alternatives such as 'thing' for words they cannot recall (Leonard, 2014; Schwartz & Solot, 1980). It has been proposed that these word finding difficulties are due to phonological impairments that restrict children's abilities to retrieve the correct phonological form of a word (Constable, Stackhouse, & Wells, 1997).

Children's difficulties with word finding and grammatical sentence structure may manifest in their gestural communication. For example, if gestures were used to compensate for language deficits, the prediction would be that children with DLD would be more likely to replace words they cannot recall with gestures (resulting in more extending gestures, or gesture-speech mismatches) or gesture more frequently to facilitate word finding.

2.2.3.2. Content

Children with DLD often display weaknesses in vocabulary knowledge (Beitchman et al., 2008). Word learning studies indicate that vocabulary is learnt at a slower rate and that word learning requires more exposures, in comparison to TD peers (Alt, Plante, & Creusere, 2004). In addition, word knowledge is often inflexible, for example not understanding that a word can have two meanings. These impairments may be underpinned by underdeveloped semantic knowledge (McGregor, Newman, Reilly, & Capone, 2002). Weak semantic knowledge may impact children's use of gesture, as in order to produce accurate representational gestures, children first need to have a semantic representation of that word in order to express it through gesture. Thus differences in gesture *quality* may be evident, even if children with DLD gesture more frequently to compensate for language weaknesses.

2.2.3.3. Use

Conversational discourse can be a relative strength for children with DLD (Bishop, 2000), as children are able to learn the rules of conversation and have a typical drive to communicate. However, children with DLD may have difficulties with pragmatics, or social use of language (Adams, 2008). For example, some children may provide too little or too much information during speech. While children with DLD display difficulties in social communication, it is acknowledged that they display immature social pragmatic abilities, in contrast to children with ASD whose impaired social understanding is much more severe (Norbury, Nash, Baird, & Bishop, 2004). In addition, discourse weaknesses may be identified through tasks of narrative recall, in which children with DLD provide fewer information units and shorter, less complex sentences (Reed, Patchell, Coggins, & Hand, 2007).

In general, language trajectories parallel TD peers (Rice, 2012), with little evidence of catch up over the school years (Tomblin, Zhang, Buckwalter, & O'Brien, 2003). As such, children with DLD remain, on average, two years behind peers on most language measures (Rice, 2012). However, the difficulties children with DLD exhibit may not be specific to language and may extend to difficulties with attention (Tallal, Dukette, & Curtiss, 1989), procedural memory (Ullman & Pierpont, 2005), working memory (Marton & Schwartz, 2003), perception impairments (Tallal, Miller, & Fitch, 1993), motor skill (Hill, 1998; Johnston, Stark, Mellits, & Tallal, 1981; Powell & Bishop, 1992) and non-verbal cognitive development (Stothard, Snowling, Bishop, Chipchase, & Kaplan, 1998).

2.2.4. What is known about causes and consequences of DLD?

Genetic, cognitive and environmental factors are all likely to be involved in risk for language disorder.

2.2.4.1. Genetic Influence

Evidence for a genetic influence on risk for language disorder comes from a number of sources. In behavioural genetics, twin studies provide crucial insight into the influence of both genetics and children's environment. Both monozygotic (MZ) and dizygotic (DZ) twins share the same environment, but MZ twins are also genetically identical, whereas DZ twins only share 50% of segregating alleles. If genes are important, the extent to which both twins meet criteria for DLD (concordance rates) should be greater for MZ twins. Indeed, a number of twin studies have demonstrated that concordance rates of DLD are much higher for MZ twins in comparison to DZ twins (Bishop, North, & Donlan, 1995; Lewis & Thompson, 1992; Tomblin & Buckwalter, 1998).

One exception to this pattern is Hayiou-Thomas, Oliver and Plomin (2005) who examined a population study of four-year-old twins classified as DLD using standardised measures of assessments. In this study there was no increase in concordance rates for MZ twins. A critical difference between this study and previous investigations was the use of an epidemiological cohort diagnosed using research criteria on psychometric assessment, instead of a convenience sample of twins in which one had been clinically diagnosed with language disorder. Re-analysis of this population using referral to speech-language therapy (SLT) as an indication of language disorder led to a significant increase in heritability estimates (Bishop & Hayiou-Thomas, 2008), indicating that ascertainment bias and specific diagnostic criteria may affect concordance rates (Bishop, 2002).

To address this Bishop suggests that diagnostic categories should not be used to identify genetic influences on DLD. Instead Bishop (2006) investigated genetic influence on tasks that tap underlying cognitive traits associated with DLD, and may be characteristic of language disorder in other diagnostic conditions. Children's non-word repetition and morphosyntactic abilities were taken as indication of language disorder, which indicated high heritability for both measures. However, non-word repetition and morphosyntactic abilities were weakly correlated, suggesting independent genetic influences (Bishop, Adams, & Norbury, 2006).

Molecular genetic studies have identified five candidate genes associated with DLD; these include FOXP2, CNTNAP2 (Vernes et al., 2008), ATP2C2 and CMIP (Newbury et al., 2009) and KIAA0319 (Newbury et al., 2011). For example ATP2C2 and CMIP are both associated with non-word repetition ability (Newbury et al., 2009). However, genes that have been associated with DLD have also been associated with other developmental disorders such as ADHD (Lesch et al., 2008), Dyslexia (Newbury et al., 2011) and ASD (Arking et al., 2008). The genes that relate to DLD are likely to be involved in early neurobiological development (Rice, 2012). However, genetic abnormalities do not necessarily result in DLD, but rather indicate increased risk of developing DLD. As such this suggests that genetic risk does not mean that environmental inputs such as intervention are unimportant. In addition, it is likely that not everyone with DLD has all of the genetic vulnerabilities identified, but more likely that DLD arises from the complex interaction between several genes and environmental risk factors (Bishop, 2006; Newbury & Monaco, 2010).

2.2.4.2. Environmental Influences

There is little evidence that environmental influences are the sole cause of language disorder; however, links between language deficit and environmental disadvantage have long been established. Hoff (2013) suggested that this relationship is influenced by maternal education and the quality and quantity of parent-child interactions. In a longitudinal study (Reilly et al., 2010) reported that low maternal education and socio-economic status were both significant predictors of low language outcomes and helped to explain variation in language ability in four year old children, a finding that is consistent with Letts, Edwards, Sinka, Schaefer and Gibbons (2013). However, Reilly et al. (2010) highlight that these factors could not reliably predict whether a child was categorised as having low language (language scores of more than 1.25 below the mean) or specific language disorder (language scores of more than 1.25 below the mean and non-verbal abilities within the normal range).

Interesting findings of environmental influences on language highlight that the full range of language abilities are seen at all levels of social economic status (Goldfeld, O'Connor, Mithen, Sayers, & Brinkman, 2013; Reilly, Tomblin, et al., 2014). Reilly et al. (2014) compare data from the Millennium cohort, and Growing up in Scotland, in addition to showing that high and low language scores are evident across the whole spectrum of social advantage, they report that median language scores increase with social advantage, with a narrowing distribution of language scores as social advantage increase.

However, there is also an argument that genetic factors could explain the relationship between socio-economic status and language outcomes. For example, a parent's low socioeconomic status or education may be a result of their own language difficulties (Oliver, Dale, & Plomin, 2005). As such, environmental disadvantage may be a marker of genetic vulnerability to language disorder.

2.2.4.3. Linguistic theories of DLD

Linguistic frameworks propose that DLD is a result of deficits in linguistic knowledge, in particular children's ability to develop grammatical rules. These theories assume that language is modular and as such is independent of other cognitive functions (Fodor, 1983). Many linguistic theories suggest that children with DLD have deficits at the level of linguistic representation. However, they vary in their accounts of the cause of DLD and the extent to which their explanations have a developmental account.

2.2.4.3.1. Extended optional infinitive account (Rice, Wexler, & Cleave, 1995)

The extended optional infinitive account (EOI) of DLD suggests that typically developing children pass through an optional infinitive stage, during which both inflected and un-inflected stems are recognised as acceptable within the child's grammatical system and result in children making grammatical errors, such as omitting tense markers (Wexler, 1994). This view proposes that children with DLD remain at this stage for longer than TD children, indicating an <u>extended</u> optional infinitive stage (Rice et al., 1995). Rice et al. (1995) assessed 21 DLD children's use of language in comparison to age-matched TD peers and younger TD children matched for mean length of utterance (MLU). Rice et al. (1995) reported that the correct past tense was used in 92% of age-matched TD children's utterances, 50% of MLU matched children's utterances and 27% of DLD children's utterances. These findings indicate that children with DLD had difficulties with morphosyntax that are not explained by immature vocabulary. Longitudinal studies provided further support for the idea that children with DLD use immature grammar for longer than TD children (Rice, 2012).

2.2.4.3.2. Computational grammatical complexity hypothesis (Van der Lely, 2005)

The computational grammatical complexity hypothesis (GCC; Van der Lely, 2005) is a development of the representational deficit for dependent relations theory (RDDR: Van der Lely, 1996, 1997, 1998; Van der Lely & Stollwerck, 1997). This theory posits that rather than children with DLD having difficulties learning morphological paradigms, they have difficulties relating these paradigms correctly (Van der Lely & Stollwerck, 1997), a skill which is required for WH-questions and subject-verb agreement marking. The CGC extends the RDDR's view of a syntactic deficit, by proposing that independent deficits in syntax, morphology and phonology explain grammatical difficulties in DLD (Marshall & Van Der Lely, 2007; Van der Lely, 2005). Support for this theory comes from Marshall and Van der Lely (2007), who manipulated the phonological complexity of inflected verb endings during a past tense elicitation task with children with 'grammatical' DLD (G-DLD). They reported that verb-ending phonological complexity impacted on G-DLD, but not typically developing children's ability to correctly use the past tense suffix.

2.2.4.3.3. Implications and limitations of linguistic theories of DLD

The linguistic theories outlined account for many of the grammatical deficits observed in children with DLD. However, these theories are limited in the extent to which they fully explain DLD. For example, grammatical deficits in DLD are not "all of nothing" but rather children with DLD display inconsistent use of grammatical rules, indicating there is not a complete lack of grammatical knowledge (Bishop, 1994a). Furthermore, linguistic models of DLD do not account for the full range of linguistic deficits, such as word finding difficulties (Leonard, 2014), nor non-linguistic deficits also associated with DLD. As such, it is difficult to ascertain what predications these theories would make in regard to the relationship between language and gesture in children with DLD. Whilst the linguistic theories outlined do not make explicit predictions regarding gesture use in children with DLD, they do not deny the possibility of a co-morbidity of motor deficits in DLD (Van der Lely, 2005), but rather suggest that comorbid deficits are not causally related to linguistic (specifically grammatical) deficits. As these theories assume that language is modular, this may lead the prediction that gesture is unimpaired and may even be a strength in DLD.

2.2.4.4. Cognitive theories of DLD.

Cognitive models allow consideration of why language is often disproportionately impaired in relation to other areas of development. Morton and Frith (1995) propose a framework that has multiple levels of explanation including biological, environmental and cognitive components. They stipulate that although biological and environmental components explain some of the behavioural features of DLD, cognitive models mediate the behavioural and biological levels as there is no direct link between brain and behaviour. In order for causal models of DLD to inform intervention, an understanding of the cognitive difficulties associated with DLD is needed, regardless of whether the origin of the disorder is environmental or genetic. Thus, these cognitive models serve to bridge the neurobiological and behavioural level.

2.2.4.4.1. Auditory processing theory

The Auditory Processing theory suggests that children with DLD have difficulties perceiving and processing rapid sounds, and as a result have difficulties processing phonemic contrasts (Tallal, Miller, & Fitch, 1993; Tallal, 1980, 2000). This can impact on children's grammatical processing as often grammatical contrasts are evident from unstressed phonemes which are often rapid and brief. As such deficits in phonological processing may result in difficulties with grammatical processing.

However, it has been established that not all children with DLD display auditory processing deficits and that some TD children also present with auditory processing deficits (McArthur, Ellis, Atkinson, & Coltheart, 2008). In addition, intervention studies aimed at improving auditory processing do not appear to lead to improved language skills (Strong, Torgerson, Torgerson, & Hulme, 2011). For example, McArthur, Ellis, Atkinson, & Coltheart (2008) conducted a six week intervention aimed at improving auditory processing in children with DLD. Although children's auditory processing abilities improved following training, training had no impact on language or literacy outcomes. This highlights that although auditory processing difficulties may be a symptom of DLD, it is unlikely to be the cause.

2.2.4.4.2. Limited processing capacity

Another theory is that DLD is caused by a limited processing capacity, which is evident by deficits in working memory (Leonard, 2014). Thus, children with DLD have limited capacity to store information whilst processing complex information. Indeed when asking a child with DLD to make judgements about whether a sentence is true or false (processing) and then asking them to recall the last word in that sentence (capacity), children have greater difficulty with sentence processing as sentences become longer and more complex. This theory suggests that if children with DLD have limited processing capacity then their ability to complete the task as it becomes more complex will diminish, as cognitive resources will only be able to either process the sentence or remember the last word (Montgomery & Evans, 2009).

It is unclear whether such deficits are limited to verbal material or whether they also include visual spatial working memory. If this is the case, then limited processing capacity may also impact on children's ability to express information through gesture. However, if visual spatial working memory is unimpaired then expressing information through gesture may relieve some of the cognitive pressures, as seen in TD children (Goldin-Meadow et al., 2001). Thus for children with DLD with capacity limitation gesture could be a useful strategy to relieve these processing pressures.

2.2.4.4.3. Procedural deficit

A more recent and highly influential theory is that children with DLD have difficulties with procedural memory and the neural systems that underpin procedural learning, whilst declarative memory systems are relatively intact (Ullman & Pierpont, 2005). Ullman and Pierpont (2005) reported that brain regions linked to the procedural memory system are also linked to grammar, lexical retrieval, dynamic mental imagery, working memory, rapid temporal processing, motor and cognitive skills. As such, they propose that the procedural deficit hypothesis can explain both linguistic and non-linguistic deficits in DLD.

The procedural memory system is involved in the learning of new skills and also the control of already acquired cognitive and motor skills (Squire & Knowlton, 2000). It is this system that underpins rule learning (Knowlton, Mangels, & Squire,

1996) and sequence learning and production (Aldridge & Berridge, 1998). As such, the procedural system is involved in rule governed behaviours such as grammar. This includes the use of phrases, sentences and morphology, all of which enable the production and comprehension of complex language. The procedural memory system is thought of as implicit as these rules are learnt and used unconsciously. Declarative memory on the other hand involves semantic and episodic knowledge and is linked to vocabulary learning.

The Procedural Deficit Hypothesis (Ullman & Pierpont, 2005) proposes that children with DLD exhibit brain abnormalities that are involved in the procedural memory system and predicts that if language disorder is due to deficits in the procedural memory system, then functions that rely on the same brain regions will also be impaired (e.g. motor skill). Indeed studies report procedural memory deficits in children with DLD (Lum, Conti-Ramsden, Morgan, & Ullman, 2014; Lum, Conti-Ramsden, Page, & Ullman, 2012; Lum, Gelgic, & Conti-Ramsden, 2010), which may explain why children with DLD present with impairments in grammar (Rice, 2000) and often co-occurring deficits such as motor sequence production (Bishop, 2002; Owen & McKinlay, 1997; Powell & Bishop, 1992).

One of the positives of this theory is that it has potential to explain co-occurring non-linguistic difficulties that are also associated with DLD, such as motor control. This has implications for gesture use in DLD, as the brain regions related to motor skill and mental imagery are also related to procedural memory (Ullman & Pierpont, 2005). In addition, difficulties with motor sequencing may lead to difficulties with gesture production. Thus if children with DLD have deficits in procedural memory system then it is likely that this will be evident in co-occurring difficulties with gesture.

2.2.5. Developmental course of DLD

DLD can impact not only on a child's language development but also on their academic attainment as children with DLD obtain lower grades and fewer academic qualifications than their TD peers (Conti-Ramsden & Durkin, 2012; Snowling, John, Bishop, Adams, & Stothard, 2001). In addition, adults with a history of DLD are less likely to be in education or employment aged 19 (Conti-Ramsden & Durkin, 2012) and have poorer communication, academic attainment and occupational status than peers at 25 years old (Johnson, Beitchman, & Brownlie, 2010). Longitudinal studies of adults with a history of DLD also indicate increased risk of difficulties with social relationships and independent living (Howlin, Mawhood, & Rutter, 2000). However, Johnson et al. (2010) reported that adults with a history of DLD did not rate their quality of life as any poorer than either adults with no history of DLD or adults with a history of speech-impairments. These findings are supported by Whitehouse, Watt, Line and Bishop (2009) who found that although language deficits persisted and affected employment and independent living, severe difficulties with social relationships, were not a characteristic of adults with DLD. For example, Whitehouse et al. (2009) reported that adults with DLD did not differ from TD adults in relation to the quality of their friendships; all of the adults with DLD reported to have at least one friend, with 80% of these friendships classified as ‘close’ (Whitehouse et al., 2009).

2.2.6. Summary and implications for gesture use

In sum, children with DLD are thought to have a typical drive to communicate (Bishop, 2000) and it is generally assumed that children with DLD use non-verbal communication strategies to compensate for their oral language weaknesses. However, gesture is a complex skill and it is unclear how children’s language disorder impacts on their ability to understand and produce gestures during communication. It is of particular interest to explore whether children with DLD use gestural communication in a similar way to their TD peers, or if, like in other areas of verbal communication, they display subtle differences in their gestural communication.

2.3. Gesture and Language Disorder

2.3.1. Child gesture

As outlined, in addition to language deficits, children with DLD experience other developmental challenges that are not specific to language and give rise to the prediction that child gesture in DLD may be atypical. For example, co-occurring motor deficits and/or impoverished semantic representation may yield less accurate gesture forms, in which case gesture may not serve to compensate so successfully. In addition, differences in SES or family history of DLD may result in differences in exposure to gesture within the home (Rowe & Goldin-Meadow, 2009a). The following section will explore whether children with DLD use gesture as a tool to compensate for verbal limitations, resulting in high gesture rates and the use of gesture to extend verbal utterances. The extent to which children with DLD can utilise gestural cues to support their comprehension of speech and to facilitate word learning is then considered.

2.3.1.1. Gesture comprehension

If gesture helps with language development, or potentially helps children to compensate for their language weaknesses, then children need first of all to understand non-verbal communication. Botting, Riches, Gaynor and Morgan (2010) measured gesture comprehension during a gesture-speech integration task in school-aged children with DLD in comparison to TD peers. Children were presented with a spoken sentence of which the last word had been replaced with a gesture; for example 'swimming in the sea, I saw a [*fish gesture*]'. Following this they were asked to identify the missing word from a choice of four pictures. The four pictures presented included the target picture (e.g. Fish), a gesture distractor (which fitted the gesture context but not the semantic context, e.g. Snake), a semantic distractor (which fitted the semantic context but not the gesture context, e.g. Boat) and an unrelated distractor (e.g. Sponge). Children with DLD achieved significantly lower scores than TD peers. In addition, when children failed to integrate gestural and spoken information in an utterance, group differences were observed. The TD group were more likely to select the semantic distracter, indicating that they were relying on spoken information to complete the task. In contrast, children with DLD were more likely to select the gesture distractor, indicating that they were more likely to rely on gesture cues to complete the task. This suggests that children with DLD were able to utilise information from the gesture cue, but difficulties integrating the gesture meaning with the semantic context led to children incorrectly choosing the gesture distractor. This finding was replicated by Wray, Norbury and Alcock (Wray, Norbury, & Alcock, 2015) who employed the same task on a slightly older group of children with DLD.

However, Botting et al's (2010) measure of gesture comprehension required children to integrate verbal and non-verbal information in order to successfully complete the task. Thus, this task was not a direct measure of gesture comprehension as it also required a level of language comprehension. A poor score on this task could therefore equally be attributed to difficulties in either language or gesture comprehension, or both.

These studies highlight that children may have difficulties integrating gesture and speech when gestures are used to replace words. However, crucially when there is a breakdown in language comprehension, children with DLD show a preference for gestural communication. These findings imply that although children with DLD rely on gestural cues to help with language comprehension, their ability to integrate this information with speech may limit the extent to which gestures support language comprehension for this group of children. As such, gestures that complement the spoken utterance, may be more beneficial than replacing words with gestures for children with DLD.

2.3.2. What might influence children's ability to produce accurate gestures?

As outlined above, children with DLD present with motor deficits, poor semantic representations, but relatively good social skills. The Interface Hypothesis (Kita & Özyürek, 2003), highlights that these are all factors that feed into both the action generator and message generator, thus raising questions about the impact of these deficits on gesture production and raises questions about the extent to which children with DLD are able to use gesture to support verbal language and how beneficial gesture is to successful communication.

2.3.2.1. Motor skill

There is substantial evidence that children with DLD have motor difficulties (Iverson & Braddock, 2011; Powell & Bishop, 1992; Webster et al., 2006; Webster, Majnemer, Platt, & Shevell, 2005), which may make gesture production more difficult. Previous studies have indicated that children with DLD perform less well than TD children on both gross motor tasks (Powell & Bishop, 1992) and fine motor tasks (Johnston, Stark, Mellits, & Tallal, 1981). In addition, their motor abilities are similar to those children with Developmental Co-ordination Disorder (DCD) (Hill, 1998). For example, in a sample of 65 children with DLD, 33% also met criteria for DCD (Flapper & Schoemaker, 2013). More crucially to gesture use, children with DLD also display motor imitation difficulties. Vukovic, Vukovic and Stojanovik (2010) assessed children's ability to imitate simple movements (hands and arms) and more complex movements (fingers and hands). They reported that children with DLD scored significantly lower on measure of co-ordination and imitation than age matched TD peers. Poor motor abilities may therefore limit the extent to which children with DLD are able to utilise gesture as a communicative tool.

2.3.2.2. Procedural memory

As outlined earlier in the chapter, children with DLD are thought to have difficulties with procedural memory (Ullman & Pierpont, 2005); deficits in the procedural memory system may be linked to difficulties with language learning and also motor tasks. This may be related to sequencing deficits exhibited in children with DLD. For example, children with DLD take longer to learn sequences during serial reaction time tasks than typically developing children (Gabriel et al., 2013; Hsu & Bishop, 2014) and also take longer to complete motor sequence tasks, such as peg moving (Bishop 2002). In addition, the difficulties children have with serial reaction time tasks reduce as the number of exposures increase (Lum et al., 2014). In terms of gesture production, the Procedural Deficit Hypothesis may suggest that if features such as motor skill and imagery are all related to areas of the brain included in procedural memory then children with DLD may have difficulties using gesture to compensate for their language difficulties, as they may have difficulties producing the motor sequences required for gesture production.

2.3.2.3. Semantic knowledge

In addition, other factors may also influence how children use gesture. Children with DLD are likely to have underdeveloped semantic representations (McGregor et al., 2002) which may impact on their ability to represent words through speech or gesture. Indeed Capone (2007) observed gesture use during a word learning experiment and reported that children's gesture-speech combinations changed in line with their semantic development. Children transferred from using gesture-speech mismatches to gesture-speech matches as words were learnt. In addition, they found that children revealed semantic information through gesture but not speech, until the child had built a strong enough semantic representation to express the word verbally. They demonstrated that young children's difficulties with object naming were not due to missing semantic representations, but rather that these representations were weak. However, Capone (2007) did not measure what other impact weak semantic knowledge was having on gesture production. For example, semantic knowledge may impact on the quality of gestures children are able to produce. If children with DLD have weak semantic representations then this too could influence the quality of gestures produced during communication.

2.3.3. Spontaneous gesture production

2.3.3.1. Do children with DLD gesture more frequently than their TD peers?

Whilst it is commonly assumed children with DLD gesture frequently to compensate for their language difficulties, the literature contains many conflicting findings. On the one hand, studies employing narrative tasks report that children with DLD gesture significantly more frequently than their TD peers (Iverson & Braddock, 2011; Lavelli, Barachetti, & Florit, 2015; Lavelli & Majorano, 2016; Mainela-Arnold, Alibali, Hostetter, & Evans, 2014). For example, Iverson and Braddock (2011) asked children aged 2 to 6 to tell stories from cartoon sequences (task taken from the Autism Diagnostic Observation Schedule) and a wordless picture book ('frog where are you?'). Iverson and Braddock (2011) demonstrated that children with DLD produced fewer utterances per minute, fewer different words and shorter mean length of utterance than TD children. Despite this, those with DLD gestured at a higher rate, producing a greater number of gestures per utterance. In addition, they reported a significant *negative* relationship between gesture production and language composite scores, indicating that those children with more severe language deficits were gesturing more frequently than children with more advanced language skills. Consistent with this, Lavelli et al. (2015) reported that children with DLD gestured significantly more frequently than TD peers, but at similar rates to younger language-matched controls, during shared book reading. This finding indicates that gesture frequency may be linked to language proficiency, as children with DLD appear to resemble younger TD children with similar levels of language competence.

On the other hand, studies have found that children with DLD do not gesture any more frequently than TD children (Blake, Myszczyszyn, Jokel, & Bebiroglu, 2008; Evans, Alibali, & McNeil, 2001; Mainela-Arnold, Evans, & Alibali, 2006) . Blake et al. (2008) asked children with DLD, age-matched TD peers and a younger TD group matched for verbal ability, to complete two spontaneous communication tasks, a narrative recall task, and a classroom description task. Blake et al. found no differences between children with DLD and either age-matched or language-matched comparison groups in the frequency with which they gestured. Similarly, Evans et al. (2001) reported that during a Piagetian conservation task, children with DLD gestured at similar rates to their TD peers.

Differences in diagnostic criteria may contribute to conflicting findings. For example, studies which show differences in gesture frequency (Iverson & Braddock, 2011; Lavelli et al., 2015; Mainela-Arnold et al., 2014) identify DLD as scoring 1 or 1.2 SD below the mean on standardised measures of language, whereas studies which indicate no group difference have classified DLD as more than 11 months below chronological age (Blake et al., 2008), or reported that children met criteria for severe expressive language on the Clinical Evaluation of Language Functions (CELF-R; Evans et al., 2001). Evans et al. (2001) do not stipulate what cut off was used but children in the DLD group had expressive language standard scores ranging 50-70, which suggests children were -2 to -3 SD below the normative mean. Severity of language disorder may impact on the extent to which children use gesture to compensate for language weaknesses. Future research needs to consider more systematically whether severity of language disorder is related to frequency of gesture use, which would indicate either a compensation or disorder in verbal communication.

Table 2.1. Summary table of studies investigating spontaneous gesture in children DLD

Reference	DLD Age	DLD (n)	Control (n)	Task	Gesture Frequency Measurement	Gesture Frequency	Extending gestures
Evans et al. (2001)	7;0-9;4	7	JM-TD (7)	Piagetian conservation	Per 10 words	DLD=JM-TD	DLD>JM-TD
Mainela-Arnold et al. (2006)	7-10;5	12	AM-TD (17) JM-TD (10)	Piagetian conservation	Per 100 words	DLD=AM-TD DLD= JM-TD	DLD= AM-TD DLD= JM-TD
Blake et al. (2008)	5;1-9;8	15	AM-TD (15) LM-TD (15)	Narrative, directions, classroom description.	Raw numbers	DLD=AM-TD DLD=LM-TD	DLD>AM-TD DLD>LM-TD
Iverson & Braddock(2011)	2;8-6;1	11	AM-TD (16)	Storytelling and picture book narration	Per utterance	DLD>AM-TD	DLD>AM-TD
Mainela-Arnold et al (2014)	6;2-9;5	15	AM-TD (18)	Cartoon Narrative	Per 100 words	DLD>AM-TD	DLD=AM-TD
Lavelli et al. (2015)	3;5-5;6	15	AM-TD (15) LM-TD (15)	Shared book reading	Per minute	DLD>AM-TD DLD=LM-TD	DLD>AM-TD DLD=LM-TD
Lavelli et al. (2016)	3;5-5;6	15	AM-TD (15) LM-TD (15)	Picture naming task	Raw counts controlling for number of answers.	DLD >AM-TD DLD=LM-TD	DLD=AM-TD DLD= LM-TD

Note. *DLD: developmental language disorder, AM-TD: Age matched typically developing control group, LM-TD: Language matched typically developing control; JM-TD: Judgement matched typically developing control group.*

2.3.3.2. Are there qualitative differences in the gestures produced by children with DLD, relative to TD peers?

While it is unclear whether children with DLD use gesture more frequently or at the same rate as TD children, there is no direct evidence that children with DLD use gesture less frequently than peers. This suggests that any gesture impairment in children with DLD likely reflects qualitative differences in gesture accuracy rather than quantitative differences in gesture rate. It may be that while children with DLD have difficulties with the execution of gestures, this does not hinder their attempts or motivation to use gesture to communicate. To further explore how children with DLD use gesture as a compensatory mechanism, measures of gesture frequency should be complemented by measures of qualitative differences in the ways in which gesture is used. For example, studying the function of gestures children use will help elucidate whether children with DLD produce gestures to extend the spoken message, or whether underlying cognitive or linguistic difficulties impact on gesture production.

Church and Goldin-Meadow (1986) demonstrated that TD children often express information in gesture that they cannot verbalise and that this is an indication that they may be on the cusp of learning a new concept. They argue that these gestures indicate that children have partially developed the correct concepts, but these are not fully formed enough to be able to express them verbally. However, it is possible that for children with DLD the concepts are not developed at all, in which case they may not be able to express certain ideas in gesture or in speech.

Once again, studies investigating the function of gesture use in children with DLD yield mixed findings (Table 2.1). Mainela-Arnold et al. (2014) reported that children with DLD do not differ from TD peers in the frequency of production of either extending or redundant gestures during narrative recall, a finding that is consistent with studies of extending gestures produced during a Piagetian conservation task (Mainela-Arnold et al., 2006) and a picture naming task (Manuela Lavelli & Majorano, 2016).

Others, however, have reported that children with DLD are more likely to use gestures alone, or replace words with gestures (Blake et al., 2008; Evans et al., 2001; Iverson & Braddock, 2011; Lavelli et al., 2015). For example, Evans et al. (2001) reported that during a Piagetian conservation task, children with DLD were more likely to produce extending gestures to express information they were unable to verbalise, whereas TD children were more likely to reinforce the spoken message by producing redundant gestures. This is consistent with the findings of Blake et al. (2008) and Iverson and Braddock (2011), who reported that children with DLD produce significantly more extending gestures than their TD peers during cartoon narrative re-telling. Interestingly, Lavelli et al. (2015) reported that children with DLD produced more extending gestures than age-matched TD peers but similar numbers to younger language-matched children. This supports the idea that children's reliance on gesture as a communication strategy may depend on the child's language abilities, as children with DLD resemble younger, TD children.

One explanation for the difference between studies may be the choice of task; Mainela-Arnold et al. (2014) asked children to narrate a wordless cartoon, while Evans et al. (2001) employed a Piagetian conservation task, which is arguably conceptually more difficult. Although Blake et al. (2008) also employed a narrative task, a critical difference between studies was that Mainela-Arnold et al. (2014) stimuli was wordless and lasted only 90 seconds, with two viewings. Blake et al. (2008) on the other hand showed a longer cartoon that included verbal dialogue and was only shown once, increasing cognitive demands of the task. The narrative task employed by Mainela-Arnold et al. (2014) was perhaps less cognitively demanding for children to complete than a conservation task as they had pictures available to scaffold their language. It is possible that qualitative differences in the function of gestures used by children with DLD may only arise when the cognitive and linguistic demands of the task are challenging.

A further explanation for the disparity between studies may be the age of participants. In the Evans et al. (2001) study children were aged 7 to 9 years, and Iverson and Braddock's (2011) study examined children aged 2 to 6 years. Given that gesture use develops and changes throughout childhood (Capirci et al., 1996, Masur, 1982), it is likely that gesture use varies throughout childhood, dependent on the child's age and developmental stage. This is particularly important in relation to young participants; some of the participants in Iverson and Braddock's (2011) study were only 2 years old, and therefore may have been displaying a language delay, rather than a persistent language disorder. Children with early language delays that later resolve may differ from children with more persistent language problems in terms of gesture use. For example, Thal and Tobias (1992) measured spontaneous gesture in 18-24-month-old late talkers, and found that initially, the late-talkers gestured more frequently than TD peers. However, at follow-up one year later only four of the late-talkers still presented with language delay, whereas the remaining six had caught up. After re-analysing their data with this in mind, they found that children with persistent language disorder did not differ from their TD peers in the number, type or function of gestures they produced. However, children whose language delay had resolved used more communicative gestures than their TD peers. This suggests that children with transitory language delays were able to utilise gesture more readily as a compensatory mechanism than those children with persistent language difficulties. It may be that children with language delay had the semantic representations for referents and so were able to utilise this information to express information more often in gesture, when unable to verbalise a word. Children with persistent DLD on the other hand, may have more limited semantic knowledge and may be less able to utilise gesture as a compensation strategy. Small sample size challenges interpretation of these findings and replication is required to determine whether gesture does distinguish children with language delay from those with persistent DLD.

2.3.4. Elicited gesture production

Hill (1998) and Hill, Bishop and Nimmo-Smith (1998) explored the relationship between motor deficits in DLD and gesture production. Hill (1998) measured gesture production by asking children to either imitate a gesture or were given a verbal command to produce a gesture (e.g. asked to gesture “brushing their teeth”). They reported that children with DLD produced less accurate gestures than age-matched TD peers. In addition, children with DLD made errors that were similar to those made by children with Developmental Co-ordination Disorder (DCD) and a younger TD comparison group (Hill et al., 1998). This was observed even for children with DLD who had motor abilities within the normal range, indicating that their difficulties were not solely due to a motor impairment.

Botting et al. (2010) explored gesture production in school-aged children (4-7 years old) with DLD. During this task, children were presented with pictures of actions, objects and concepts, and asked to tell the researcher what the picture was by only using their hands. Botting et al. (2010) rated gesture accuracy according to how closely related the gesture was to the target picture; gesture production scores of the DLD group did not differ significantly from a comparison group of age-matched TD peers. Wray et al. (2015) attempted to replicate Botting et al. (2010) with slightly older children and reported contradictory results. In this study, children with DLD produced significantly fewer accurate gestures in comparison to TD peers. Wray et al. (2015) also reported significant positive relationships between both expressive and receptive vocabulary and gesture production, thus indicting that children with poorer vocabulary scores produced the least accurate gestures.

The disparity between studies may again be due to differences in the age of participants. The children with DLD in Botting's study (4 to 7 years) were younger than those in Wray et al (4; 4 to 8; 9) and Hill's study had a much wider age range (5 to 13 years). In addition, Wray et al. (2015) controlled for non-verbal cognition. NVIQ is associated with more pervasive developmental deficits, including motor skill, which may affect gesture production. As such, controlling for NVIQ isolated the impact of low language on gesture, which may explain the differing results with Botting et al. (2010).

Table 2.2. Summary table of studies investigating elicited gesture production, gesture imitation and comprehension in children DLD.

Reference	DLD Age	DLD (n)	Control groups (n)	Task	Gesture production	Gesture imitation	Gesture Comprehension
Hill, (1998)	5-13	19	DCD (11) AM-TD (25) Y-TD (17)	-Produce transitive & intransitive gestures -Imitate unfamiliar hand postures/sequences	DLD<TD DLD=DCD DLD= Y-TD	DLD=TD DLD=DCD DLD=Y-TD	-
Hill et al. 1998	7-13	19	DCD (11) AM-TD (25) Y-TD (17)	-Produce transitive gestures intransitive	***Error types*** DLD similar DCD & Y-TD ***Number of errors:*** DLD=DCD & Y-TD DLD>AM-TD	-	-
Marton (2009)	5-7	40	AM-TD (40)	-Imitation of body positions. -Imitation of bilateral motor coordination	-	DLD<TD DLD<TD	-
Botting et al. (2010)	4;3-7;4	20	AM-TD (19)	-Elicited Gesture production from pictures -Gesture comprehension: Gesture-speech integration	DLD=TD	-	DLD<TD
Dohmen et al. (2013)	2-3;5	LD (45)	AM-TD (60)	***Social acts.*** Imitate: facial expression, manual postures, object and conventional gestures. **Pretend acts:** Imitate: 'brush teeth' ***Instrumental acts.*** Imitate: Familiar/unfamiliar actions	-	***Social & pretend*** DLD<TD ***Instrumental:*** DLD=TD	-
Wray et al. 2015	4;4-8;9	15	AMTD (14)	-Elicited Gesture production from pictures -Imitate static hand positions -Gesture comprehension: Gesture-speech integration	DLD<TD	DLD=TD	DLD<TD

Note. *DLD: developmental language disorder, AM-TD: Age matched typically developing control group, LM-TD: Language matched typically developing control; DCD: Developmental co-ordination disorder. Y-TD: Younger TD control*

2.3.5. Gesture imitation

As discussed earlier, gesture production may be affected by motor, semantic, or procedural memory limitations associated with DLD. If these skills underpin gesture imitation, then the extent to which children with DLD are able to imitate gestures accurately may be limited.

Research exploring gesture imitation in children with DLD also produces conflicting findings, depending on the type of imitation task employed. On the one hand, it has been reported that children with DLD have weaknesses in body posture imitation and bilateral hand imitation (tapping and clapping movements), in relation to TD peers (Marton, 2009). Consistent with this, a study of young language delayed children (2-3;5 years) also indicated gesture imitation deficits on imitating social acts such as facial expression, manual postures (e.g. tapping top of head) and conventional gestures (e.g. waving), and also pretend acts (e.g. brushing teeth) in comparison to TD peers (Dohmen, Chiat, & Roy, 2013). However, in the same study, children with language delay were able to imitate instrumental acts (e.g. playing a xylophone) as accurately as their peers (Dohmen et al., 2013). These findings indicate that imitating actions that are more closely tied to social function may be more challenging for children with language and communication deficits. However, Dohmen et al. (2013) also reported that younger LD children (2; 0-2; 11) refused to produce over 50% of items for both the imitation of manual postures and gestures, which was much higher than TD children. As such, this suggests that the observed group differences may have been due to task refusal, rather than difficulties with accurate imitation.

On the other hand, Wray et al. (2015) reported that children with DLD did not differ from peers on an accuracy measure of gesture imitation (static arm and hand movements), a finding consistent with Hill (1998). Wray et al. (2015) also reported that accuracy of gesture imitation was not associated with vocabulary. One explanation for the disparity between studies may be that the task used by Wray et al. (2015) and Hill (1998) were neither semantically nor motorically challenging enough to tap deficits in DLD. For example, Wray et al. (2015) asked children to only imitate static hand positions, and thus it may be that meaningless sequences imitation (as used by Marton, 2009) is more closely related to language as they may be more motorically demanding, place more demands on memory, and more closely resemble communicative gestures. Although Hill (1998) used both static and multiple posture imitation tasks, they reported that children were nearly at ceiling on both tasks, which again may indicate that the task was too simplistic to tap deficits associated with DLD that may impact gesture imitation.

Elicited gesture and imitative gesture tasks may yield different results to studies investigating spontaneous use of gesture. Whilst gesture frequency measures children's ability to utilise dual modalities during communication, gesture production tasks enable us to closely measure how accurate these gestures are. Gesture frequency and gesture accuracy may reveal different information about how children use gesture when language is impaired. It is possible that children with DLD may in fact use gesture more frequently during communication even if the manual production of their gestures is less accurate than TD peers.

2.3.6. Gesture Intervention Studies

Kirk, Pine and Ryder (2011) suggest that adults producing gestures alongside speech may be beneficial to children's pragmatic understanding. Children with DLD were presented with ten verbal scenarios, each comprising two sentences and followed by a question, for instance, "Freddie helped his dad paint the bedroom. Freddie had to put on his old clothes", followed by the question, "why did Freddie have to put on his old clothes?" (Kirk et al., 2011). Five sentences were presented with speech only and five were accompanied by a contextually appropriate gesture (e.g. Painting).

Overall, children with DLD answered fewer items correctly during the speech only condition than age matched TD peers. However, no group differences were observed for the gesture and speech condition. The DLD group also answered more scenarios correctly for the speech and gesture condition than speech alone, a finding that was not evident for the TD group. However, it is notable that the TD group were at ceiling on the speech only condition, so the extent to which additional gesture cues could improve performance was limited. Further research with a more complex task that did not yield ceiling effects for the TD group would better illustrate whether gesture is as beneficial to TD and DLD children's understanding of language.

Whilst this study highlights that children with DLD may be able to utilise gesture to help them comprehend complex sentences, it still raises the questions of whether gesture helps children with DLD learn language. Given that children with DLD appear to understand and utilise gestural information during language comprehension, a reasonable hypothesis is that gesture would facilitate language learning. However, as discussed earlier in the chapter, difficulties with gesture-speech integration may render these attempts less successful. The following section therefore considers the extent to which children with DLD are able to utilise non-verbal cues to support word learning.

2.3.6.1. Do gestures facilitate word learning?

Gesture training studies indicate that gesture may be beneficial to children with DLD, though this advantage may be limited. Weismer and Hesketh (1993) taught 5-7 year old children with DLD (n=8) and TD children (n=8) nine novel words across three training conditions (*stress, rate* and *gesture*). Three words were taught during each condition: For the *stress* condition target words were produced either with or without emphasis. For the *rate* condition words were presented at either a slow, normal or fast rate. For the *gesture* condition, novel words were either presented verbally ("Sam is *wug* the box") or were also accompanied with a pointing gesture. As a measure of word comprehension, children had to move Sam to the correct location (e.g. "put Sam *wug* the box"). Children's production of each novel word was also measured e.g. "where is Sam?". Weismer and Hesketh (1993) reported that children learnt more words when words were trained with gesture than no gesture, for both DLD and TD groups. However, this was only significant for word comprehension and not production of new words. In addition, *rate* of presentation also positively impacted on children's word learning, but *stress* did not. However, Weismer and Hesketh (1993) did not compare across conditions, so it is not clear whether *gesture* cues are more beneficial than the other cues. Whilst this study does suggest a potential gesture advantage for word comprehension, the small sample size and fact that children only learnt three words in each condition limits the findings of this study. In addition, children were taught novel words for words that children already knew (e.g. under, on); such learning may have affected children's ability to learn the new word due to conflicting representations, and increased cognitive load of inhibiting an already known word.

Gesture did not enhance production of novel words, similar to intervention studies of bilingual children with low language (Rowe et al., 2013). This may be due to word retrieval requiring a more advanced semantic representation of the word, something which may not have had time to develop during fast mapping tasks. As children with DLD often have weak semantic knowledge (McGregor et al., 2002), in this instance gesture cues may only facilitate learning during a less semantically demanding comprehension task. However, word retrieval may require a more in depth semantic knowledge, which was not facilitated by gesture in the limited number of exposures in this instance.

In a recent study, Lüke and Ritterfeld (2014) also considered gesture and word learning in children with DLD. They conducted a three week intervention study with a follow-up one week later. At each intervention session, children played different games and were introduced to novel character names. Children were randomly allocated to either an iconic gesture or no gesture condition (10 children in each group). In the iconic gesture condition, a gesture accompanied each exposure which represented a feature of the character (e.g. a "glasses" gesture if the character had glasses). Children's word production was assessed using a picture naming and a word comprehension task via a picture selection task. There were no group differences in picture naming after the first intervention session. However, after the third intervention session the gesture group remembered more correct labels than the no gesture group, an advantage that was still evident one week after intervention. However, at no time was there a gesture advantage reported for the comprehension task. This study suggests that children with DLD benefit from gesture during word learning, but perhaps most advantageous for the slow mapping of new words. The study conclusions are limited by the small sample size of 10 participants per condition and a brief follow-up period of only one week after intervention. As with TD children, it is difficult to determine whether gesture has long term benefits to children's word learning.

These findings seem at odds to Weismer and Hesketh (1993) who reported a gesture advantage for gesture comprehension but not gesture production. However, differences in methodologies may elucidate these differences. For example, Lüke and Ritterfeld's intervention spanned multiple sessions, whereas Weismer and Hesketh's study had only one session. Given that Lüke and Ritterfeld only reported a gesture advantage for word production after the third training session, this supports the idea that gesture may only benefit word production once children have established semantic knowledge for the word, which may take multiple exposures to the word. In addition, the types of gestures used during the training studies also differed (pointing vs. iconic). As discussed in Chapter One, different types of gestures may facilitate language learning in different ways. Differences in the type of target word may also impact findings; as such the learning of nouns, such as character names, may be a different process to the acquisition of words such as ‘under’. For example, it has been established that noun concepts are more concrete than those of verbs and maybe easier to imagine and thus learn (McDonough, Song, Hirsh-Pasek, Golinkoff, & Lannon, 2011).

2.3.7. Parent gesture in DLD

Variability of language and gesture within DLD leads us to consider whether parent gesture influences children’s gesture and language development in similar ways to what we have seen in typical language development. As previously discussed, in typical development parent gesture is positively related to child gesture use and may directly and/or indirectly influence children’s later language abilities (Iverson & Goldin-Meadow, 2005; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). Based on this research, similar patterns in parents of children with DLD are expected. However, child language and behaviour may also influence parent behaviour, in which case a negative relationship between parent gesture and language may be observed, whereby parents utilise gesture to compensate for their child’s language difficulties. A handful of studies have considered this issue in DLD, as reviewed below.

Lasky and Klopp (1982) observed parent-child interaction with seven children with DLD (27-45 months) and 10 TD children (12-39 months) during storybook telling, a cognitive problem solving task, and free play. Parents of children with DLD who used more non-verbal behaviours (facial expression, body posture, action, demonstration, gesture and imitation) had children with more severe language difficulties. In addition, parents of children with DLD produced significantly more actions, deixis (pointing or glancing), and gestures than parents of TD children. However, this study included a wide range of non-verbal behaviours and it is difficult to determine whether parents were using all of these behaviours equally or whether one behaviour was driving this significant relationship; thus we cannot isolate the impact of gesture on interaction. In addition, this study explored gesture use across three different tasks. The authors stated that parents could choose which tasks they used and how long they used them for, during the 30 minute observation. Although all children did play with all three tasks, the length with which they interacted within them varied. To counteract this, the authors only coded five minutes of each task for each child. However, children did not always stay on task for a full five minute period, thus impacting on opportunities to produce non-verbal behaviour. In addition, the authors did not compare non-verbal behaviour across the different tasks. It may be that free play or storybook telling elicit more non-verbal parent behaviours than a more complex, goal-orientated cognitive task, something which requires further consideration.

Lavelli, Barachetti, and Florit (2015) reported that parents of children with DLD produced more combined gesture-speech utterances than an age-matched TD group during shared book reading. Interestingly, parents of children with DLD performed similarly to parents of younger TD children, suggesting that parents may use non-verbal communication in accordance with the language abilities of their child, regardless of age. Lavelli et al. (2015) also observed a trend for parents of DLD and younger TD children to gesture more frequently than parents of age-matched TD peers, however this difference was not significant. In addition, they found that parent gesture actually helped children engage in the task more readily. For example, when a parent produced a gesture-speech utterance, this was more likely to be followed by a child initiation than parent utterances that were speech alone. However, it is unclear what mechanism is influencing child language, whether the gesture is simply making the task more engaging, or whether gesture is aiding children’s comprehension of the verbal message. Whilst their findings do suggest that parents modify their communication in line with the language abilities of their child, this study only explored gesture use during shared book reading and as a result, the majority of gestures produced were pointing gestures. It is therefore difficult to know whether these findings would generalise to different parent-child interaction scenarios or whether parents’ use of representational gestures also support language. Furthermore, it is unclear whether parents of children with DLD use gesture in different ways, not only dependent on the language ability of their child, but also according to task demands.

Grimminger, Rohlfing, and Stenneken (2010) considered whether gesture use varied according to task demands when parents were interacting with late-talking toddlers. Parents of late talking (LT) 22-24 month-old toddlers instructed their child to arrange objects that had either a canonical ("put the girl on the chair") or a more complex non-canonical ("put the girl under the chair") spatial relationship. Grimminger et al. (2010) reported that parents of LT toddlers produced significantly more gestures and were more likely to hold a gesture throughout an utterance relative to parents of toddlers without language delay. Parents also produced significantly more gestures during the more complex non-canonical task than the canonical, a pattern seen for parents of both DLD and TD toddlers. These findings support the idea that parents modify their gestures in accordance not only to the language abilities of their child, but also in relation to task demands, whereby a more complex task elicits more non-verbal communication to support understanding. However, the extent to which parent/other gestures are a useful support for language development in the same way as observed in TD infants is uncertain. Parents may compensate by gesturing more, but this might not help with acquisition of new information.

2.3.8. Limitations of current knowledge and questions for this thesis

Although the studies presented begin to paint a picture of how and when children with DLD use gesture during communication, there are still too few studies and existing studies produce conflicting findings. In addition, no studies have explored both gesture frequency and gesture accuracy within the same cohort of children with DLD. It is therefore difficult to draw firm conclusions given differences between studies in task demands, ages of participants, diagnostic criteria, measures of language, and measurement of gesture (Tables 2.1 and 2.2). As outlined earlier, if studies employ tasks with different cognitive and linguistic task demands, this could hugely influence subsequent gesture use. In addition, the disparity between participant age and diagnostic criteria also raises questions about the severity of language disorder, and issues of whether young children have a persistent language disorder or transient language delay. There is considerable disparity between studies as to whether gesture frequency is measured by number of gestures per 100 words (Mainela-Arnold et al., 2014), number of gestures per 10 words (Evans et al., 2001), number of gestures per utterance (Iverson & Braddock, 2011), number of gestures per minute (Lavelli et al., 2015) or raw counts controlling for number of answers (Lavelli & Majorano, 2016). Raw counts do not take into account the number of words, or time spent communicating; as this is likely to differ between participants, especially those with differing language abilities, this metric may not be as informative. For example, if parents/children say less then they potentially have fewer opportunities to produce gestures, something for which raw scores do not take into account.

Whilst studies using both gestures per 100 words and gestures per minute demonstrate that these measures yield similar findings (Hostetter et al., 2007), it does make comparisons across studies more challenging when different dependent variables are used.

2.4. Conclusions

This chapter has provided an overview of gesture development in both typical and atypical populations as well as the influence of both parent and teacher gesture on children's language production and comprehension. Overall, the literature on typically developing children supports the hypothesis that gesture and speech form one integrated communication system, as demonstrated by the positive relationships between gesture and speech in early development and the evidence that gesture continues to support children's communication in later childhood. However, the literature regarding children with atypical language development is less clear cut, and in particular, research to date does not provide a coherent message regarding gesture in children with DLD. The main reason for this is that the literature is fraught with limitations in sample size and our ability to compare studies is compromised due to differing diagnostic criteria, wide age ranges, and different methods of assessing and measuring gesture frequency, function and accuracy.

The studies reported in this thesis assess gesture production (frequency, function and accuracy) in the same cohort of children with DLD and their parents across a graded set of gesture production tasks. These include (a) accuracy of gesture imitation and elicited single gestures, (b) frequency of spontaneous gestures in narrative and interactive problem-solving tasks and (c) functional use of those spontaneous gestures across narrative and problem-solving tasks.

Children with DLD are compared to typically developing children (TD) and children with low language (LL) and educational concerns. The LL group represent an intermediate group who were identified at school entry as having language and communication concerns, but who did not meet criteria for DLD one year later. Thus, including this group ensures that this thesis explores gesture use in relation to language across the whole spectrum of language abilities.

The first experimental chapter will explore children's gesture across all gesture tasks. If language and gesture form an integrated system then we may expect children with DLD to produce less accurate gestures and their ability to use gesture to compensate for their language weaknesses should be limited, resulting in the production of fewer accurate gestures and fewer extending gestures. In contrast, if gesture and language form separate systems then we would expect children with DLD to utilise gesture to compensate for oral language weaknesses, by gesturing more frequently and producing more extending gestures than their TD peers. However, the extent to which this is evident may depend on task demands. In relation to the LL group, based on previous investigations of children with resolved early language delay, we expect that they may gesture more frequently than both DLD and TD children. However, this group may also elucidate residual communication deficits.

Chapter Five includes assessment of parent gesture across measures of spontaneous gesture production (narrative recall and interactive problem solving task). It was predicted that parents of children with DLD would use gesture more frequently than other parents to facilitate communication with their child. Chapter Six examines gesture use during parent child interaction more closely by examining parent responses following a child's extending gesture. This chapter aimed to explore one potential mechanism by which parent gesture may promote child language; that child gesture elicits a verbal response from interlocutors that provides the missing linguistic information. It was predicted that parents of children with severe language difficulties would produce more gesture translations, reflecting parent's use of verbal strategies to facilitate communication. The final chapter investigated the influence of gesture training on word learning. Crucially the study asked whether gesture exposure was sufficient to facilitate new word learning or whether there was added benefit in encouraging children to produce target gestures. It was predicted that both gesture production and gesture exposure would lead to greater word recall in comparison to the no gesture condition, but that children in the gesture production group would show greater learning than those children merely exposed to gesture.

Theories of communication vary in the extent to which spoken language and gesture are viewed as complementary or integrated systems. In typical development, there is considerable evidence that they are integrated systems, intimately related and mutually supporting development of the other. Investigation of atypical development is therefore crucial as such tight relationships may become unravelled. This thesis will help to inform language interventions by establishing the impact of DLD on child and parent gesture use and the impact of gesture on language learning.

Chapter 3: Methods Chapter

3.1. Overview

This thesis investigates gesture use in children with developmental language disorder (DLD) in comparison to TD peers and peers with low language and educational concerns. This chapter will outline the recruitment, selection and assessments used at each stage of this project.

3.2. Surrey Communication and Language in Education Study (SCALES)

Children who took part in the studies were recruited as part of the Surrey Communication and Language in Education Study (SCALES), a population study of language disorder at school entry (Norbury et al., 2016). The SCALES project aimed to identify the number of children starting school with language and communication problems, the percentage of these children who continued to display persistent language disorder and explore any additional developmental concerns that may co-occur with DLD.

The SCALES project comprised two stages, stage 1; the screen, and stage 2: an in-depth assessment of language and communication abilities.

3.3. SCALES Stage 1

3.3.1. Recruitment

All state maintained schools in Surrey were invited to take part in the first stage of SCALES (n=263). Participating schools (n=161) were asked to complete a screening questionnaire for all of the children in their reception classes. Screening data were obtained for 7,267 children aged between 4;9 and 5;10 years old. Participating schools (n = 161) did not differ from those that opted out (n = 102) on measures of socio-economic disadvantage (percentage of children receiving free school meals), $t(261) = 1.38$, $p = .17$; children in receipt of a statement of special educational need, $t(261) = 0.19$, $p = .85$; or children speaking English as an additional language, $t(232) = 1.05$, $p = .29$.

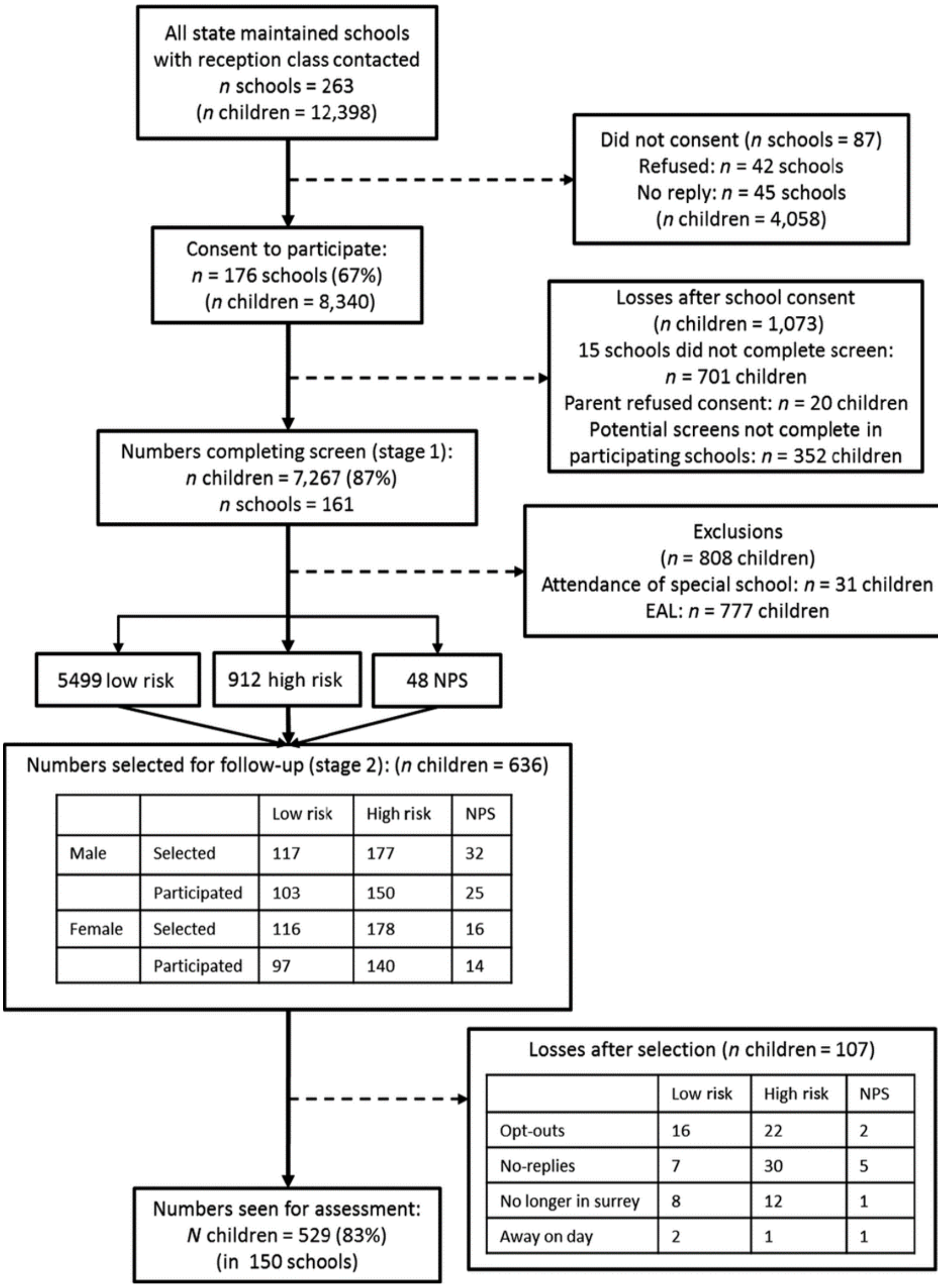


Figure 3.1. Recruitment flow chart (Norbury et al. 2016)

3.3.2. The screen

3.3.2.1. Children's Communication Checklist-Short (CCC-S)

Teachers completed the CCC-S, a short version of the CCC-2 (Bishop, 2003). This comprised 13 items chosen to discriminate children with DLD from typically developing children. Teachers were asked to rate the frequency with which behaviours occurred using a four point scale. Total scores ranged from 0-39, with higher scores indicating greater communication difficulties. Children who had no phrase speech (NPS; i.e. they were not yet combining words into sentences) at the time of screening received the maximum score of 39. A score of more than 1SD above the mean was classified as indicating significant language and communication concerns.

3.3.2.2. Teacher Strengths and Difficulties Questionnaire (Goodman, 1997)

Teachers completed the strengths and difficulties questionnaire for an assessment of children's social, emotional and behavioural strengths and weaknesses. The total difficulties subscale comprised 20 items on a three point scale, whereby higher scores indicated more severe difficulties. A score of 16 or above suggests clinically significant social, emotional and behaviour problem (Goodman, 1997).

3.3.2.3. Early years foundation stage profile (Standards and Testing Agency, 2012)

This is an assessment of academic attainment at the end of first year of schooling. Teachers rated children's progress as either emerging, expected or exceeding across 17 attainment targets. In order to achieve 'Good Level of Development' children had to obtain 'expected' or 'exceeded' targets on 12 core curriculum targets.

3.4. SCALES Stage 2

3.4.1. Selection

Children in special educational schools were excluded from further selection, as it was deemed by teachers that children with such severe difficulties would struggle to complete the assessment items. Children learning English as an additional language were also excluded, however, 60 children were invited to participate as part of a separate pilot project (Whiteside, Gooch, & Norbury, 2016) .

Stage 2 used cut-off scores on the CCC-S for each of the three age-groups (autumn, spring, and summer born) to identify sex-specific strata of boys (13.9%) and girls

(14.8%) with teacher ratings of poorer language relative to children of similar age and sex. In total, 636 monolingual children were invited to participate, with a higher sampling fraction for high-risk children (40.5% of high-risk boys, 37.5% high-risk girls) versus low-risk children (4.3% for boys, 4.2% for girls). In year one, 529 children (83% of invited cohort) participated in an in-depth assessment of language, non-verbal cognition and motor skills (ages 5-6 years; 329 HR and 200 LR children, see Norbury et al., 2016, for details).

3.4.2. Stage 2 Assessments

Children were assessed at school by a trained member of the SCALES team when they were in Year 1 (age 5-6 years). Each assessment lasted approximately two hours across the school day. Regular breaks were given to ensure that the child did not become over tired.

3.4.2.1. Language Assessments

Six language measures were administered, tapping both expressive and receptive language abilities, including vocabulary, grammar and narrative. These measures were selected to echo the language assessments used by Tomblin et al. (1997) and because these measures reflect current DSM5 criteria (American Psychological Association, 2013).

3.4.2.1.1. Receptive One word Picture Vocabulary Test (ROWPVT; Martin & Brownell, 2000)

Children heard a word and were asked to select the corresponding picture out of a choice of four. Testing was discontinued when children scored 6 out of 8 items incorrectly (maximum score = 190). Test-retest reliability was good with coefficients of .97 (raw scores) and .91 (standard scores).

3.4.2.1.2. Expressive One Word Picture Vocabulary Test (EOWPVT; Martin & Brownell, 2000)

Children were presented with a picture and were asked to name the picture. Testing was discontinued when children failed to correctly name six consecutive pictures (Maximum score =190). Test-retest reliability was good for this measure with coefficients of .98 (raw scores) and 0.97 (standard scores). As both receptive and expressive vocabulary raw scores were highly correlated in the current sample, $r(60)=.69$, $p<.001$, they were combined to make a vocabulary composite.

3.4.2.1.3. Test of Reception of Grammar – Short Form (TROG-S) (Bishop, 2003a)

Children heard a sentence such as "the ball that is red is on the pencil" and were asked to select the corresponding picture out of a choice of four. The maximum number of sentences a child could hear was 40, however if six consecutive items were answered incorrectly the test was discontinued. Pilot testing demonstrated excellent agreement between short and long forms of the TROG, r (17) = 0.88.

3.4.2.1.4. School-aged sentence imitation test- E32 (Marinis, Armon-Lotem, Piper, & Roy, 2011)

Children were asked to repeat 32 sentences out loud. All sentences were pre-recorded and played over headphones to the child one at a time, with a break for the child to repeat the sentence. Each repetition was audio-recorded, a mark was given if the child correctly repeated the whole sentence (Maximum score =32). The child was given two practice trials to ensure that they understood the task.

3.4.2.1.5. Assessment of Comprehension and Expression 6-11 (Adams, Cooke, Hesketh, & Reeves, 2011)

Narrative Recall. Children were asked to listen to a story about a monkey in a forest. The story was pre-recorded and played over headphones with accompanying colour cartoon pictures displayed on a laptop computer. After listening to the story the child was asked to tell the story in their own words. The child was given a mark for each part of the story they correctly re-told, giving a maximum score of 35.

Narrative Comprehension. Following the Narrative Recall task, the child was asked to answer 12 comprehension questions (6 literal and 6 inference questions) about the story they had just heard (maximum score =24). Each answer was scored as either correct, partially correct or incorrect. For each question a list of acceptable partially correct answers was created, answers that did not distinctly fit the predefined criteria were discussed in lab meetings to ensure consistency.

3.4.2.2. Non-verbal IQ

3.4.2.2.1. Wechsler Preschool and Primary Scale of Intelligence: Block Design (WPPSI-III; Wechsler, 2003)

Using a combination of white and red blocks the experimenter modelled a pattern with the blocks and then asked the child to create the same pattern with their blocks. Following this, the child was given a picture of a pattern and asked to create the picture with the blocks. Patterns became progressively more difficult, by including more blocks and a more complex pattern. Testing was discontinued after the child failed to replicate three consecutive items. SCALES employs a more inclusive non-verbal IQ cut-off than previous epidemiological studies; children were including in the DLD diagnosis as long as they did not meet criteria for intellectual disability (-2SD below population mean; Norbury et al. 2016). The children in this thesis meet the same criteria, with the exception of one child in the DLD group who scored more than 2SD below the mean on the non-verbal IQ composite. This child was included in the study, however, as this child was part of the NPS group, and including children with the most severe language difficulties was essential to answering the key questions posed by this thesis.

3.4.2.3. Motor Skills

3.3.2.3.1. Movement Assessment Battery for Children-2 (Henderson, Sugden, & Barnett, 2007)

Children completed two subtests of the Movement ABC:

Posting Coins. Children were asked to post 12 coins into a money box, first with their preferred hand and then with their non-preferred hand. Children were instructed to only pick up one coin at a time and to only use one hand to pick up the coins. The time it took each child to post all twelve coins in the box was recorded.

Bead Threading. Children were asked to thread six beads onto a piece of string one at a time. The time it took each child to thread all six beads onto the piece of string was recorded.

A motor composite score was derived from combining times of posting coins and bead threading, whereby a faster time indicated better motor skill.

3.4.2.4. Social Economic Status

Social economic status was estimated using the Income Deprivation Affecting Children Index rank scores (IDACI). This measure assessed SES using children's home post codes. Scores in England range from 1 (most deprived) to 32,844 (most affluent), with a mean of 16,352 (data from 2010). Despite SCALES taking place in a county that is relatively affluent in comparison to other counties in the UK, SCALES assessed children from a vast array of backgrounds and across the social strata. Data from the T1 screen indicated IDACI rank mean scores of 21,592 (SD=7830), with scores ranging from 731 (most deprived) to 32,474 (most affluent).

3.5. Current Study

Data for this thesis were obtained at two time points. Data for Chapters Four, Five and Six were collected at the first time point: observation at home. Data for chapter Seven was collected at the second time point: gesture training study.

3.5.1. Ethics

Participants had consented to be contacted for future studies as part of the SCALES consent procedures. Parents provided informed, written consent for participation in the study, including a home visit by myself and video recording of all gesture tasks. The study protocol was approved by the Royal Holloway Research Ethics Committee.

3.5.2. Recruitment

For the current thesis I aimed to visit approximately 10% of the total in-depth SCALES cohort, over-sampling high-risk children at a ratio of 2:1. One hundred and thirty families were contacted by letter and phone, inviting them to take part in the study. Fifty families did not consent to take part in the study and a further eleven families initially consented, however suitable arrangements could not be made for the home visit. Sixty-three monolingual parent-child dyads (61 mother-child) consented and were observed for stage one: observation at home. Analysis comparing opt-in families and opt-out families indicated no statistically significant difference, on measures of social economic status, $t(111) = .08$, $p=.937$, $d=.02$, speech and language concerns, $\chi^2=1.06$, $p=.304$, or high risk status, $\chi^2=1.58$, $p=.209$ (Opt-in: 41 high-risk; Opt-out: 38 high risk).

For the second stage: gesture training, all sixty three families were invited to take part. From the original cohort, one family opted out of the main SCALES project, and two families initially agreed, however it was not possible to arrange the home visit. Nine additional children were recruited from the main SCALES cohort to participate in this stage. This resulted in a sample of 69 children who took part in stage two.

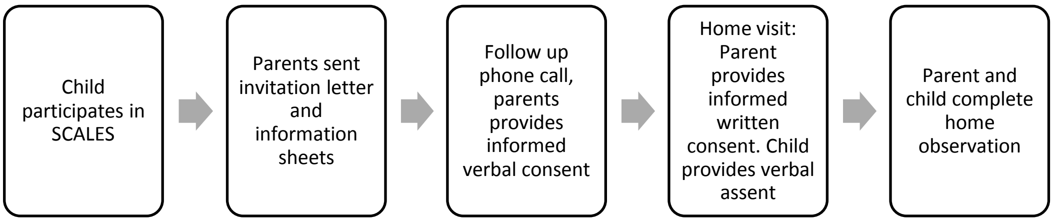


Figure 3.2. Recruitment flow chart for the gesture project.

3.5.3. Defining Groups

From the SCALES background data a total language composite score was derived from tests of expressive and receptive vocabulary (Brownell, 2010); receptive and expressive grammar (Bishop, 2003; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011); narrative retelling and comprehension (Adams et al., 2001). The core language battery consisted of tests that did not have current UK standardisations, either because they were standardised in North America, or were recently developed. Raw scores were therefore adjusted for child age using the full weighted SCALES sample (see Norbury et al. 2016 for details of this procedure). Co-standardising measures also allows for direct comparison across measures.

Children were categorised as having DLD (n = 21, 15 male) if their total language composite z-score was 1SD below the SCALES population mean. Typically developing (TD) children (n = 18, 8 males) were low-risk at screen and scored within the normal range on the total language composite. Twenty-one children were high-risk at screen, indicating communication skills 1SD below the normative mean at school entry, but scored within the normal range on the total language composite a year later. These children obtained intermediate total language composite scores that were significantly lower than TD peers, and significantly higher than children with DLD (Table 3.1). Eight of these children are receiving special education support at school and six had previously been seen for speech and language therapy. In addition, 85.71% of children in the LL group failed to achieve a good level of development on the Early Years Foundation Stage Profile. Due to their history of language and communication concerns and ongoing special educational needs, they were not combined with the TD group, but instead formed an intermediate group of children with low language (LL) and educational concerns (n=21, 9 male). Including this intermediate group ensured that I could explore gesture use in relation to language across the whole spectrum of language abilities. In addition, three children within the sample had a known diagnosis of autism spectrum disorder (2 Male, 1 Female); these children were excluded from further analysis in this thesis.

As outlined in Chapter Two there is much variation in how DLD is diagnosed within the literature and what cut off scores are used. For example, Norbury et al (2016) used a cut off of -1.5, whereas Tomblin et al. (1997) used a cut off of -1.25, below the normative mean. For the current thesis, a cut off of -1SD below the total language composite mean was chosen as there is evidence that even children 1SD below the mean experience functional language deficits (Reilly, Tomblin, et al., 2014). A different cut-off to SCALES was used to maximise the number of children with language deficits that involve functional impact. As demonstrated by Table 3.1, nearly all of the DLD children were rated by teachers as not achieving a good level of development on the Early Years Foundation Stage Profile.

3.5.4 Observation at home

The final sample of 60 comprised 18 TD (10 Female, 8 Male), 21 LL (12 Female; 9 Male) and 21 DLD (6 Female; 15 Male) parent-child dyads. All children were in the same school year and were aged between 6-8 years at the time of the home visit.

Table 3.1.

Means (SD) of background measures for children in each language group.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η_p^2
Age (months)	87.50 (5.53)	89.00 (5.11)	89.19 (5.54)	.56	.575	.02
Non-verbal ability	29.00[a] (4.86)	26.48[a,b] (3.57)	24.19[b] (3.68)	6.88	.002	.51
Language composite	.61[a] (.81)	-.40[b] (.45)	-1.67[c] (.62)	61.49	<.001	.68
Vocabulary composite	174.11[a] (20.07)	154.05[b] (10.64)	129.71[c] (14.81)	40.76	<.001	.59
SES	24721.28 [a] (4966.74)	23278.33 [a] (6346.25)	19357.91[b] (8302.65)	3.36	.042	.11
Nº not achieving GLD	5 (27.77%)	18 (85.71%)	19 (90.48%)	χ^2=21.94	<.001	
Nº abnormal on SDQ	2 (11.11%)	5 (23.81%)	6 (28.57%)	χ^2=3.72	.450	

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All means are raw scores other than the language composite which is reported as a z-score and GLD and SDQ which are number of children (and percentages). Different superscripts within the same row indicate differences between group means that are significant at p < .05.

3.5.5. Gesture Training Study

The final sample for stage two comprised 65 children aged 7-9 years old. This sample included 21 TD, 20 LL and 24 DLD children.

3.5.6. Procedure

For the first stage, observation at home, measures of gesture imitation, elicited single gesture production and spontaneous gesture production were completed in the child's home. Each home visit lasted approximately 90 minutes, with frequent breaks. Children completed all measures with the exception of three children who did not complete the gesture imitation task and one child whose elicited single gesture task data could not be used due to technical video error.

Approximately one year after the initial visit children were visited at home for the gesture training study. All children completed the task, however one child's data could not be used as it was not possible to video record the session.

3.6. Observation at home Gesture Tasks

3.6.1. Gesture imitation task.

The motor sequence task from the NEPSY (Korkman, Kirk, & Kemp, 2007) was used to assess children's ability to produce the motor movements required for gesture production. This test includes 12 gesture sequences which become progressively more difficult. Gesture sequences included a combination of bimanual and unimanual sequences, moving the hands simultaneously, alternating between hands, and also included a combination of different hand position (e.g. in sequence: hand in a fist, palm down, palm to the side, clap,). The task started with a simple gesture sequences, such as moving both hands up and down simultaneously in a fist action. Following this the sequences became progressively more complex and longer, such as sequences that required the child to alternate their hands whilst producing different actions (e.g. Right hand fist, left hand palm down, right hand palm to the side, left hand fist).

The researcher demonstrated a motor sequence three times. The child was then asked to copy the sequence and repeat it five times. The child received a score of one each time they repeated the whole sequence correctly, giving a maximum score of five for each item and 60 for the whole test. The assessment was discontinued if the child scored zero on four consecutive items.

3.6.2. Elicited single gesture task

This elicited gesture task was an experimental task designed to examine how accurately children are able to produce meaningful gestures. This task was adapted from the gesture production task used by Botting et al. (2010), however the stimuli differed and the scoring criteria were developed specifically for this study. For this task, children were asked to act out eight different items without speaking (train, guitar, sleep walking, sad, climbing a ladder, monkey, painting, and sword fight).

These words were chosen to provide a range of items that the child would already be familiar with. Items were presented to the child verbally, one at a time and parents were asked to guess what their child was acting out. There were no time constraints on this task, so children had opportunities to modify their gesture if the parent did not guess correctly first time. However, only the child's first attempt was coded, regardless of whether or not it was correctly identified by the parent.

As representational gestures are categorised as gestures that portray information about action, relative location and shape (McNeill, 1992), I coded children's ability to produce these elements accurately for all eight items (see appendix D for coding manual). The way that children portrayed items often differed, and as these alternative actions still accurately portrayed the intended item the coding scheme was continuously adapted to take into account the variety of actions children produced. For example, for the item 'painting' some children's gestures depicted 'holding' a paint brush, whereas other children used their finger as a paint brush, both variations on shape were accepted as correct. In addition for 'sleep walking' any action that depicted sleeping was accepted, this included lying down, closing eyes and head to the side, and putting hands to the side of their head.

During initial coding I noticed that children frequently produced two part gestures for certain items. For example, for climbing a ladder they gestured climbing, followed by ladder. To account for this, five items were classed as two part gestures (climbing a ladder, monkey, train, sword fighting, sleep walking), whereby both actions were coded and three items classed as single part gestures (sad, painting, guitar). In addition, for the action 'climbing a ladder' an additional point was given if the child used both arms and legs, as this was deemed to demonstrate a clearer message than just using hands alone. Two part items had a maximum score of six (seven for climbing a ladder) whereas one part items had a maximum score of three. Thus, the overall maximum score for the whole task was 40.

All children completed the task, however, three children did not complete all items. As not all children completed all items and some items had higher scoring, I calculated a proportion accuracy score (accuracy score across items completed /maximum score on items completed*100). 10% of participant videos were double coded by a second rater, blind to the child's diagnostic group. Disagreements were resolved through discussion. The inter-rater reliability was 83% agreement, Kappa = .81 which indicates very good reliability (Landis & Koch, 1977).

3.6.3. Narrative Recall.

The Narrative recall task aimed to capture gesture frequency and function during spontaneous communication. Previous studies of gesture use in DLD have utilised similar tasks (Blake et al., 2008; Mainela-Arnold et al., 2014).

Each child watched four wordless cartoons (Die Sendung mit derMaus www.wdrmaus.de/lachgeschichten/spots.php5) that depicted a mouse and an elephant in different scenarios but did not include any verbal dialogue. The first cartoon was presented on a laptop screen, after watching the video the child was asked to re-tell the story to their parent, who had not seen the video (McNeill, 1992). This procedure was repeated for subsequent videos. Videos lasted between 30 and 60 seconds, were shown once and no specific instructions regarding story re-telling or using gesture were given. Videos elicited different numbers of gestures (see appendix A), however gesture rate combined gestures across all four videos, and as such differences in gesture use across videos did not impact on the results. In addition, the order of presentation was counterbalanced across participants.

10% of participant narrative recall videos were double coded by a second rater, blind to the child's diagnostic group. The inter-rater reliability for child gestures was 80% agreement, kappa = .72 and for parent gestures was 83% agreement, kappa = .74, which indicates good reliability (Landis & Koch, 1977).

3.6.4. Referential Communication Task.

In this task, the parent and child sat opposite each other, and both had a board in front of them which the other could not see, though they could see each other (Figure 3.3). This task comprised four trials, the order of which was counterbalanced. Children and parents were assigned to either the describer or listener role. The child always started in the describing role and this alternated thereafter. The describer was given a board with eight animal pictures (cats, dogs, mice or rabbits) displayed in a specific order on a 4x2 grid. The listener was given a blank board and 12 cards which included the eight target cards and four distractor cards. All drawings were in black and white and were designed to be visually similar (Appendix B). The describer was instructed to describe each of their cards and the order they appeared so that the listener could locate the correct card and place it in the correct position. Parents and children were free to communicate naturally throughout the task. Time taken to complete the task differed across stimuli which led to differences in the number of words and number of gestures produced in each trial (see Appendix C), however counterbalancing stimuli and using a gesture rate that accounted for number of words eliminated this issue.

Ten percent of participant referential communication videos were double coded by a student research assistant, blind to the child's diagnostic group. Disagreements were resolved through discussion. The inter-reliability for children's gestures was 73% agreement, Kappa = .70, and for parents was 72%. Kappa=.69, which indicates good reliability (Landis & Koch, 1977).

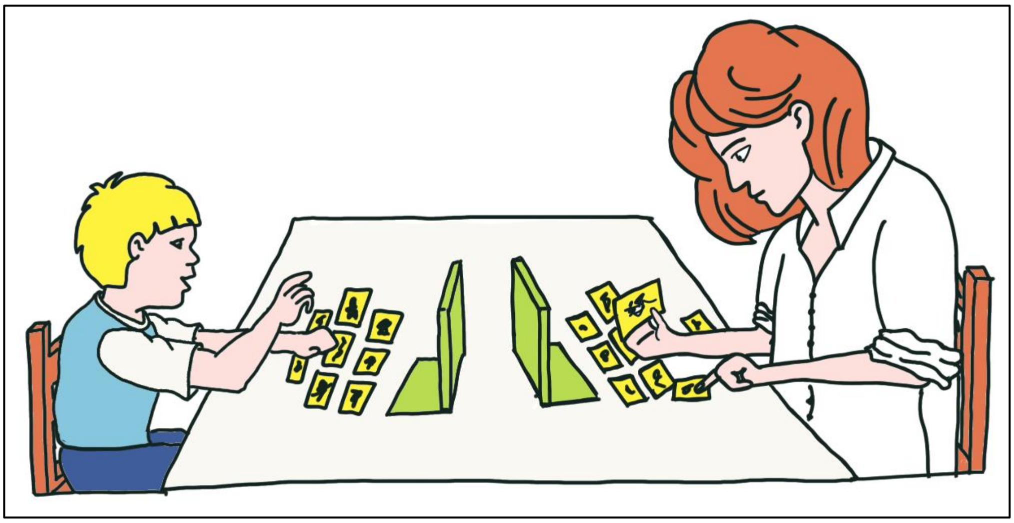


Figure 3.3. Referential communication task example stimuli.

3.6.6. Verbal transcripts and gesture coding for the narrative and referential communication task.

Verbal dialogue in both tasks was transcribed using SALT (Miller & Iglesias, 2012). SALT was used to count the total number of words in each task. For both the narrative and referential communication task, videos were coded using The Observer XT software (Grieco, Loijens, Zimmermann, & Spink, 2013). The number of different gesture types produced by children during each of these tasks was coded. Gesture types included: *Deictic gestures*, which are pointing gestures used to draw attention to a particular object, person or location in the environment; *Representational gestures*, which combine both iconic and metaphoric gestures.

These are gestures which show a close relationship to the object, action, idea or concept that they refer to (e.g. making a circular shape with hand to represent a ball). For consistency the term *representational* will be used throughout this thesis to refer to both iconic and metaphoric gestures. *Conventional gestures* which are culturally specific and convey meaning without the need for speech (e.g. nodding to symbolise yes); and *Beat gestures*, rhythmic movements which emphasises aspects of speech (McNeill, 1992).

The total number of gestures (combining all gesture types) formed a raw gesture score. As language groups did not differ on the amount of time taken to complete each task, but did differ on the number of words spoken (see Chapter 4), gesture rate was calculated as the number of gestures per 100 words (number of gestures/ number of words*100). This provided a gesture rate that accounted for the number of words children used during each task which was particularly important within this sample of children with varying language abilities; for example if parents or children say less, then this provides fewer opportunities to produce gestures. In addition, this is a metric which has been used in previous studies of gesture production in children with DLD (Mainela-Arnold et al., 2014; Mainela-Arnold et al., 2006).

Gesture function was also coded as either *extending* or *redundant*. *Extending* gestures included gestures that were produced with speech but which added extra information (e.g. "the cat had a tail like that", whilst simultaneously producing a curly tail gesture) and also gestures produced in isolation, in the absence of the verbal equivalent. *Redundant* gestures included gestures that reinforced the spoken message; although these gestures may highlight important aspects of an utterance, they do not add extra information to the utterance (e.g. "the cat had a curly tail", whilst simultaneously producing a curly tail gesture). (See appendix E for coding manual).

In addition, parental responses to extending gestures were coded. These responses were firstly categorised into verbal, nonverbal or combined responses. Following this the percentage of verbal, nonverbal and combined responses was calculated (number of verbal responses/total number of responses). *Verbal responses* were classified as either: Translation, positive feedback, request for clarification, prompt for verbal equivalence, verbatim, other response. *Non-verbal responses* were classified as either: Extending Gesture, Copy child's gesture or nod (see appendix F for example responses). From these categories the percentage of responses including each verbal and non-verbal category was calculated (number of translations/total number of verbal responses). For this metric, combined responses were included in both verbal and non-verbal categories. Following this, children's responses to parent translations or requests for clarification were coded. Translation responses were coded as either: repetition of the translated word, yes or no response, continue with the task (no verbal response), or correction of the translated word. Request for clarification responses were coded as either: 'yes or no', add information, unrelated response, or no response (see appendix G for examples).

3.7. Gesture Training study

3.7.1. Procedure

All children were seen at home and taught six new science words (Troposphere, Breccia, Smolt, Crawdad, Gadfly, Photon) and three familiar words (Fire, Lion, Sun) in one of three conditions: word alone, gesture exposure or gesture production. Children were exposed to each word six times across four learning trials presented on the computer. Following this, receptive learning, picture naming and gesture recall (for the gesture exposure and gesture production only) were assessed. Each home visit lasted for approximately 30 minutes. All sessions were video recorded for later scoring and coding. Chapter Seven outlines details of stimuli and coding of this task.

3.8. Experimental Chapters

The following experimental chapters are presented as manuscripts ready for submission to peer reviewed journals; as a result, methods sections are very similar and the selection and recruitments of participants is the same. However, the chapters differ with regard to the specific aspect of the referential communication task that was analysed. Chapters Four and Six consider only trials in which the child was in the describer role. Chapter Five considers group analysis when parents are in the describer role, to measure child directed gesture use. However, this is followed by exploration of language and gesture across the whole task.

Chapter 4: Gesture production in language impairment: It's quality not quantity that matters.

4.1. Abstract

It is generally assumed that children with developmental language disorder (DLD) can use gesture to compensate. However, gesture is a complex task integrating social, cognitive and motor skills. Thus, the ability to use gesture effectively in populations in which these precursor skills may be compromised is uncertain. In addition, the literature provides conflicting arguments regarding gesture use in this population and differing age ranges, language diagnostics and measures of gesture make comparison across studies difficult. The aim of this study was to determine whether children with DLD use gesture to compensate for their language difficulties. The present study investigated gesture accuracy and frequency in children with DLD (n = 21) across gesture imitation, gesture elicitation, spontaneous narrative and interactive problem solving tasks, relative to typically developing (TD) peers (n = 18) and peers with low language (LL) and educational concerns (n=21). Children with DLD showed weaknesses in gesture accuracy (imitation and gesture elicitation) in comparison to TD peers, but no differences in gesture rate. Children with LL only showed weaknesses in gesture imitation and used significantly more gestures than TD peers during parent-child interaction. Across the whole sample, motor abilities were significantly related to gesture accuracy but not gesture rate. In addition, children with DLD produced proportionately more extending gestures, suggesting that they may use gesture to replace words that they are unable to articulate verbally. The results support the notion that gesture and language form a tightly linked communication system in which gesture deficits are seen alongside difficulties with spoken communication. Furthermore, it is the quality, not quantity of gestures that distinguish children with DLD from typical peers.

4.2. Introduction

Gesture commonly accompanies spoken communication at all ages of development. In typically developing (TD) children there is strong evidence that gesture and language are tightly linked, as early gesture use significantly predicts the onset of two word combinations (Iverson & Goldin-Meadow, 2005), children's ability to produce complex sentences, and later vocabulary competence (Rowe & Goldin-Meadow, 2009a). Rowe and Goldin-Meadow (2009) reported that individual differences in children's vocabulary level at 52 months could be explained by child gesture vocabulary at 14 months. This finding was replicated by Rowe, Özçalışkan, and Goldin-Meadow (2008) who found that child gesture at 14 months was a significant predictor of vocabulary at 42 months, even when child and parent language at 14 months was taken into account. They also found a significant, positive relationship between parent and child gesture at 14 months; however, there was no direct link between parent gesture and children's later vocabulary size. This implies that children's early gesture is important for later language development, while parental gesture may facilitate child gesture in the first instance.

In school aged children, gesture aids learning and problem solving abilities (Alibali & DiRusso, 1999; Goldin-Meadow et al., 2001). For example, Goldin-Meadow et al. (2001) asked participants to solve a maths problem whilst also remembering letters and found that children who were allowed to gesture remembered more of the letters than those who were prohibited from gesturing. This suggests that the act of gesturing may lighten the cognitive load, creating more available space in working memory for complex problem solving tasks. In addition, Goldin-Meadow, Cook, and Mitchell (2009) demonstrated that the accuracy of gesture production influenced task performance; children who were taught to produce an accurate gesture correctly solved more problems than children who were taught only partially correct gestures, or no gestures at all. In addition, those who were taught only partially correct gestures outperformed children who produced no gestures at all. This not only supports the idea that gesture helps children learn new concepts and ideas but also indicates that the more accurately children gesture, the more benefit gesture has for task performance.

Much less is known about the relationship between language and gesture in atypical populations, in particular, populations who display difficulties acquiring spoken language. Developmental language disorder (DLD) is generally defined as a language difficulty that occurs in the absence of other developmental concerns, sensory impairments or global developmental delays, and affects 7.58% of children at school entry (Norbury, Gooch,et al., 2016). It is generally assumed that children with DLD use non-verbal communication strategies to compensate for their oral language weaknesses. However, gesture is a complex task that requires integrating social, cognitive and motor skills; thus the ability to use gesture effectively in populations in which these precursor skills may be compromised is uncertain. Children with DLD have difficulties that extend beyond language and include deficits in attention (Lum, Conti-Ramsden, & Lindell, 2007; Tallal, Dukette, & Curtiss, 1989), procedural memory (Ullman & Pierpont, 2005), working memory (Lum et al., 2012; Marton & Schwartz, 2003), perception, (Tallal et al., 1993), and motor abilities (Iverson & Braddock, 2011; Powell & Bishop, 1992; Webster et al., 2006, 2005). All of these skills may be influential in the development of both oral language and gesture development.

Exploring gesture abilities in children with DLD may further elucidate the relationship between language and gesture to determine whether they form one integrated communication system (McNeill, 1992), or two distinct communication modalities, whereby the function of gesture is to facilitate spoken communication (Hadar et al., 1998). For example, if language and gesture form an integrated communication system, children with spoken language deficits may also display difficulties with gesture production. However, if gesture and speech form two separate communication systems, it may be possible that gesture remains intact and children with DLD recruit gesture to compensate for their language deficits. The literature concerning gesture use in DLD has provided conflicting findings and there is some debate as to how frequently, for what purpose, and how accurately children with DLD produce gestures.

4.2.1. Do children with DLD gesture more frequently than TD peers?

Children with DLD are thought to have a typical drive to communicate (Bishop, 2000), suggesting they may in fact use gesture more frequently than TD peers to enhance communication. Iverson and Braddock (2011) reported that children with DLD gestured at a higher rate than TD peers, despite saying fewer utterances per minute, producing fewer different words and having a shorter mean length of utterance. They concluded that children with DLD use gesture to compensate for language deficits. Similarly, Mainela-Arnold, Alibali, Hostetter and Evans (2014) found that during a story re-telling task, children with DLD gestured more frequently than TD peers. Consistent with this, Lavelli, Barachetti, and Florit (2015) reported that children with DLD gesture more frequently than age matched TD peers, but at a similar rate to language matched children. However, a handful of studies have reported that children with DLD do not gesture any more frequently than TD children (Blake et al., 2008; Evans et al., 2001). Blake et al. (2008) asked children with DLD, age-matched TD peers and a language-ability matched younger TD comparison group, to complete a narrative recall task and a classroom description task. No differences were observed between children with DLD and either the age-matched or language-matched comparison groups with regard to gesture rate, raising questions about the ability of children with DLD to use gesture to compensate for language deficits. However, differences in diagnostic criteria may contribute to these conflicting findings. Nevertheless, while it is unclear whether children with DLD use gesture more frequently or at a similar rate to TD peers, there is no direct evidence that children with DLD use gesture less frequently. It is therefore prudent to ask whether gesture enhances their communicative efforts.

4.2.2. Are there qualitative differences in the gestures produced by children with DLD, relative to TD peers?

Children with DLD may use gesture to enhance their communication in at least two ways. First, they may use gesture to reinforce a verbal message that is unclear. In this case, we might expect to see more ‘redundant’ gestures, in which gestures match, and reinforce, the linguistic content of the verbal utterance. Second, gestures may serve to ‘extend’ utterance length by realising concepts the child cannot articulate (Rowe, 2012b). A critical question is whether children with DLD use a higher proportion of ‘extending’ gestures, or whether their language deficits limit production in any modality. Again there are conflicting findings within the literature regarding how children with DLD integrate gesture and speech.

On the one hand, Mainela-Arnold et al. (2014) found no differences between children with DLD and TD children in the number of redundant or extending gestures they produced during narrative monologue. This suggests children with DLD were predominantly using gesture to reinforce the spoken utterance rather than to express additional information. On the other hand, Evans et al. (2001) found that children with DLD were more likely to express unique information through gesture, whereas TD children were more likely to use redundant gestures to express the same concepts in both speech and gesture. A critical difference between studies was the choice of task; Mainela-Arnold et al. (2014) asked children to narrate a wordless cartoon, while Evans et al. (2001) employed a Piagetian conservation task. The narrative task employed by Mainela-Arnold et al. (2014) is arguably conceptually easier for children to complete than the conservation task, as they have pictures available to scaffold their language. As such, the narrative task may not have placed sufficiently high cognitive demands on the children, reducing their need to use gesture to aid their communication. However, other studies of gesture have used similar narrative tasks and have reported that children with DLD produce more extending gestures than their TD peers (Blake et al., 2008; Iverson & Braddock, 2011). Mainela-Arnold et al. (2014) and Blake et al. (2008) both used narrative recall tasks, but the Mainela-Arnold et al. (2014) stimuli were non-verbal, only lasted for 90 seconds and children watched the cartoon twice. In contrast, Blake et al. (2008), used a longer cartoon which had a verbal element and was only shown once, increasing working memory demands. Therefore, it is possible that qualitative differences in gesture use by children with DLD may only arise when the cognitive and linguistic demands of the task are challenging.

Elicited gesture tasks may again yield different results to studies investigating spontaneous use of gesture. Botting, Riches, Gaynor and Morgan (2010) reported that gesture accuracy is robust in the face of language impairment, at least in school-aged children with DLD. In this study, children were presented with pictures of actions, objects, and concepts and asked to tell the researcher what the picture was by only using their hands. Botting et al. (2010) rated gesture accuracy on a scale of 1-5 according to how closely related it was to the target picture and found that the DLD group did not differ significantly from a group of age-matched TD peers. In contrast, Hill (1998) reported that children with DLD produced less accurate gestures than age-matched TD peers, when asked to either imitate a gesture or produce a gesture in response to a verbal command (e.g. “show me brushing your teeth”). Hill reported that children with DLD made errors similar to children with developmental co-ordination disorder (DCD) and a younger TD comparison group. This was true even for children with DLD who had motor abilities within the normal range, indicating that their difficulties were not solely due to co-occurring motor impairment. The disparity between these studies could be due to word stimuli, children in Hill (1998) were asked to produce everyday actions, whereas in Botting et al. (2010), they varied from actions such as playing tennis, to more abstract words such as wind. However, Wray, Norbury and Alcock (2015) used the same task as Botting et al. (2010) and found that children with DLD demonstrated poorer performance during an elicited gesture production task relative to age-matched peers, despite the fact that these same children did not differ from peers on a meaningless gesture imitation task. This suggests that children with DLD have difficulties generating gestures even when their motor abilities are sufficient.

One explanation for the disparity between studies may be the age of participants. Hill’s (1998) study had a large age range of 5 to 13 years, while children in the Evans et al. (2001) study were aged 7 to 9 years, and Iverson and Braddock’s (2011) study examined pre-school children aged 2 to 6 years. As gesture use develops and changes throughout childhood (Capirci et al., 1996, Masur, 1982), it stands to reason that children with DLD of different ages and different developmental stages may use gesture in different ways. In addition, some of the children in Iverson and Braddock’s (2011) study were so young, many of those children may have been have been displaying a language delay, rather than a persistent DLD. Children with milder language difficulties may use gesture in different ways to those who have persistent language deficits. For example, Thal and Tobias (1992), found that children with persistent language impairment did not differ from their TD peers in the number, type or function of gestures they produced; however, children with resolved early language delays used more communicative gestures than their TD peers. This suggests that children with transient and milder language difficulties were able to utilise gesture more readily as a compensatory mechanism than those children with persistent language impairment. Examining gesture use across the entire spectrum of language ability is important as it will help to ascertain whether differences in gestural abilities differentiate children with persistent language impairment from those with transient delays.

To overcome the limitations of previous research and address the conflicting findings in the field, the current study examined motor skill and gesture use within the same cohort of children with clinically significant DLD, relative to typically developing children and children with low language and educational concerns.

The current study has a number of advantages over previous investigations: my participants were drawn from a population cohort, were all attending the same school year (thus reducing the age range within groups considerably), and motor, language and cognitive measures were available for all children. In addition, a graded set of gesture production variables were available for all participants, including (a) accuracy of gesture imitation and elicited single gestures, (b) frequency of spontaneous gestures in narrative and interactive problem-solving tasks and (c) functional use of those spontaneous gestures across narrative and problem-solving tasks. Thus the current study is uniquely placed to answer two key questions of theoretical and practical import: First, do children with DLD have deficits in accuracy, frequency or function of gestures relative to age-matched peers, or peers with low language? Second, are measures of oral language and motor ability associated with gesture accuracy and/or gesture frequency?

If language and gesture are an integrated communicative system, we might expect children with DLD to produce fewer accurate gestures and fewer extending gestures relative to TD peers and peers with low language. In contrast, if gesture can be used to compensate for oral language weaknesses, children with DLD are expected to gesture more frequently, and to use more extending gestures than their TD peers, though gesture use might depend on task demands. Motor accuracy was predicted to be more closely related to gesture accuracy than gesture rate. Finally, if language and gesture are an integrated system, positive relationships between gesture and measures of oral language ability were anticipated in children with DLD, as is the case in typical development. However, if gesture serves a primarily compensatory purpose in DLD, a negative relationship might be evident, in which those with more severe linguistic deficits gesture more to enhance communication.

My predictions regarding the low language group are more guarded; they represent an intermediate group who do not meet strict criteria for DLD, but for whom milder language deficits are affecting classroom performance and teacher ratings of communicative competence. Thus I include them to ensure the full range of language ability is represented in my sample. I anticipate that both accuracy and frequency of gesture use may be greater relative to DLD and TD peers, based on previous investigations of children with resolved early language delay. However, this group may also elucidate residual communication deficits.

4.3. Method

4.3.1. Recruitment

Children were recruited as part of the Surrey Communication and Language in Education Study (SCALES), a population study of DLD at school entry (Norbury et al., 2016). Reception class teachers completed the Children's Communication Checklist-S, (CCC-S, a short-form of the CCC-2, Bishop, 2003) for 7,267 children aged 4-5 years old in state-maintained schools in Surrey, a county in South East England (Stage 1). From this screen, the bottom 14% (stratified by season of birth and gender) of children were classified as high-risk (HR) for DLD, whilst children scoring above this threshold were classified as low-risk (LR) of DLD. Selection for Stage 2 used cut-off scores on the CCC-S for each of the three age-groups (autumn, spring, and summer born) to identify sex-specific strata of boys (13.9%) and girls (14.8%) with teacher ratings of poorer language relative to children of similar age and sex. In total, 636 monolingual children were invited to participate, with a higher sampling fraction for high-risk children (40.5% of high-risk boys, 37.5% high-risk girls) versus low-risk children (4.3% for boys, 4.2% for girls). In year 1, 529 children (83% of invited cohort) participated in an in-depth assessment of language, non-verbal cognition and motor skills (ages 5-6 years; 329 HR and 200 LR children, see Norbury et al., 2016, for details).

For the current gesture study, I aimed to visit approximately 10% of the total in-depth cohort, over-sampling high-risk children at a ratio of 2:1, HR: LR. One hundred and thirty families were invited to take part in the study, of which 50 families did not consent to take part, a further eleven families initially consented, however suitable arrangements could not be made for the home visit. Sixty-three monolingual parent-child dyads (61 mother-child) consented and were observed for this study. There were no statistically significant difference between those families who opted in and those that opted out, on measures of social economic status, $t(111) = .08$, $p=.937$, $d=.02$, speech and language concerns, $\chi^2=1.06$, $p=.304$, or high risk status, $\chi^2=1.58$, $p=.209$ (Opt-in: 41 high-risk; Opt-out: 38 high risk).

4.3.2. Defining Groups

Prior to the home visits for the current study, children completed an in-depth test of language and cognitive function at their school with a trained member of the SCALES research team. A total language composite score was derived from tests of expressive and receptive vocabulary (Brownell, 2010); receptive and expressive grammar (Bishop, 2003; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011); narrative retelling and comprehension (Adams, Cooke, Crutchley, Hesketh, & Reeves, 2001). The core language battery consisted of tests that did not have current UK standardisations, either because they were standardised in North America, or were recently developed. Furthermore, co-standardising measures allows for direct comparison across measures. Therefore raw scores were adjusted for child age using the full weighted SCALES sample (see Norbury et al. 2016 for details of this procedure). Children were categorised as DLD (n = 21, 15 males) if their total language composite z-score was 1SD below the SCALES population mean. Typically developing (TD) children (n = 18, 8 males) were LR at screen and scored within the normal range on the total language composite. Twenty-one children were HR at screen, indicating communication skills ~1SD below the normative mean at school entry, but scored within the normal range on the total language composite two years later. These children obtained intermediate total language composite scores that were significantly lower than TD peers, and significantly higher than children with DLD (Table 4.1). In addition, eight of these children are receiving special education support at school and six had previously been seen for speech and language therapy. Due to their history of language and communication concerns and ongoing special educational needs, they were not combined with the TD group, but instead formed an intermediate group of children with low language (LL) and educational concerns (n=21, 9 male). Including this intermediate group ensured that I could explore gesture use in relation to language across the whole spectrum of language abilities.

4.3.3. Participants

Sixty-three monolingual children aged 6-8 years participated in the current study. Three children with a known diagnosis of ASD were excluded from further analysis. The final sample of 60 comprised 18 TD (10 female, 8 male), 21 LL (12 Female; 9 Male) and 21 DLD (6 female; 15 male) children (see Table 4.1 for group characteristics). Participants had consented to be contacted for future studies as part of the SCALES consent procedures. Families were contacted by post and parents provided informed, written consent for participation in the study, including a home visit and video recording of all gesture tasks. The study protocol was approved by the Royal Holloway University of London Research Ethics Committee.

Table 4.1.

Means (SD) of background measures for children in each language group.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η^2
Age (months)	87.50 (5.53)	89.00 (5.11)	89.19 (5.54)	.56	.575	.02
Non-verbal ability	29.00[a] (4.86)	26.48[a,b] (3.57)	24.19[b] (3.68)	6.88	.002	.51
Language composite	.61[a] (.81)	-.40[b] (.45)	-1.67[c] (.62)	61.49	<.001	.68
Vocabulary composite	174.11[a] (20.07)	154.05[b] (10.64)	129.71[c] (14.81)	40.76	<.001	.59
Number of words (Referential task)	654.28[a] (335.76)	576.67[a,b] (186.95)	455.10[b] (158.81)	3.62	.033	.11
Time taken in seconds (Referential task)	569.66 (249.80)	562.98 (224.23)	556.62 (182.69)	.017	.983	.001
Number of words (Narrative Task)	412.00[a] (106.41)	375.24[a,b] (65.61)	317.05[b] (123.44)	4.40	.017	.13
Time taken in seconds (Narrative Task)	191.30 (55.50)	188.99 (54.24)	203.17 (98.61)	.224	.800	.01

Note. All means are raw scores other than the language composite which is reported as a z-score. Different superscripts within the same row indicate differences between group means that are significant at $p < .05$. TD: typically developing, LL: low language, DLD: developmental language disorder.

4.3.4. Procedure

Measures of oral language, non-verbal reasoning and motor skill were obtained as part of the larger SCALES battery. Children were seen at school by a trained member of the SCALES team when they were in Year 1 (age 5-6 years). Subsequently, gesture imitation and all gesture tasks were completed in the child's home. Each home visited lasted for approximately 90 minutes, with frequent breaks. Children completed all measures with the exception of three children who did not complete the gesture imitation task and one child whose elicited single gesture task data could not be used due to technical video error.

4.3.5. Background Measures

As previous research has focused on the link between vocabulary and gesture use (Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008), the current paper used a composite of the *Receptive One word Picture Vocabulary Test* (ROWPVT; Brownell, 2000b) and *Expressive One Word Picture Vocabulary Test* (EOWPVT; Brownell, 2000a), to index vocabulary. In addition, non-verbal IQ was assessed using the WISC *Block Design* (Wechsler, 2003).

4.3.6. Motor Skill

Children completed two subtests from the *Movement Assessment Battery for Children-2* (Henderson et al., 2007), posting coins and bead threading. The *Posting Coins* task require the child to post 12 coins into a money box as quickly as possible, first with their dominant hand and then with their non-dominant hand. Children were instructed to only pick up one coin at a time and to only use one hand to pick up the coins. The time it took each child to post all twelve coins in the box was recorded. The *Bead Threading* task required the child to thread six beads onto a piece of string as quickly as possible. The time taken to thread all six beads onto the string was recorded. A motor composite score was created combining time taken to complete both of these tasks. These tasks were measured in seconds whereby a lower (faster) time indicates more advanced motor ability.

4.3.7. Gesture Tasks

4.3.7.1. Gesture imitation task

The motor sequence task from the NEPSY (Korkman et al., 2007) was used to assess children's ability to produce the motor movements required for gesture production. This test includes 12 gesture sequences which become progressively more difficult. Gesture sequences included a combination of bimanual and unimanual sequences, moving the hands simultaneously, alternating between hands, and also included a combination of different hand position (e.g. in sequence: hand in a fist, palm down, palm to the side, clap). The task started with a simple gesture sequences, such as moving both hands up and down simultaneously in a fist action. Following this, the sequences became progressively more complex and longer, such as sequences that required the child to alternate their hands whilst producing different actions (e.g. right hand fist, left hand palm down, right hand palm to the side, left hand fist).

The researcher demonstrated a motor sequence three times. The child was then asked to copy the sequence and repeat it five times. The child received a score of one each time they repeated the whole sequence correctly, giving a maximum score of 5 for each item and 60 for the whole test. The assessment was discontinued if the child scored zero on four consecutive items.

4.3.7.1. Elicited single gesture task

This elicited gesture task was an experimental task designed to examine how accurately children are able to produce meaningful gestures. This task was adapted from the gesture production task used by Botting et al. (2010), however the scoring criteria were developed specifically for this study. For this task, children were asked to describe eight different items without speaking (train, guitar, sleep walking, sad, climbing a ladder, monkey, painting, and sword fight). These words were chosen to provide a range of items that the child would already be familiar with. This task was designed to elicit bimanual representational gestures. As representational gestures are categorised as gestures that portray information about action, relative location and shape (McNeill, 1992) I coded children's ability to produce these elements correctly for all eight items. During initial coding it was noticed that children frequently produced two part gestures for certain items. For example, for climbing a ladder they gestured climbing, followed by ladder. To account for this, five items were classed as two part gestures (climbing a ladder, monkey, train, sword fighting, sleep walking), whereby both actions were coded and three items classed as single part gestures (sad, painting, guitar). In addition, for the action 'climbing a ladder' an additional point was given if the child used both arms and legs, as this was deemed to demonstrate a clearer message than just using hands alone. Two part items had a maximum score of six (seven for climbing a ladder) whereas one part items had a maximum score of three. Thus, the overall maximum score for the whole task was 40.

All children completed the task, however, three children did not complete all items. As not all children completed all items and some items had higher scoring, I calculated a proportion accuracy score (accuracy score across items completed /maximum score on items completed*100). Ten percent of participant videos were double coded by a second rater, blind to the child's diagnostic group. Disagreements were resolved through discussion. The inter-rater reliability was 83% agreement, Kappa = .81 which indicates very good reliability (Landis & Koch, 1977).

4.3.7.1. Narrative Recall

Each child watched four wordless cartoons (Die Sendung mit derMaus www.wdrmaus.de/lachgeschichten/spots.php5) that depicted a mouse and an elephant in different scenarios but did not include any verbal dialogue. The first cartoon was presented on a laptop screen, after watching the video the child was asked to re-tell the story to their parent, who had not seen the video (McNeill, 1992). This procedure was repeated for subsequent videos. Videos lasted between 30 and 60 seconds, were shown once and no specific instructions regarding story re-telling or using gesture were given. The order of presentation was counterbalanced across participants. Ten percent of participant videos were double coded by a second rater, blind to the child's diagnostic group. The inter-rater reliability for the narrative task was 80% agreement, kappa = .72 which indicates good reliability (Landis & Koch, 1977).

4.3.7.1. Referential Communication Task

In this task, the parent and child sat opposite each other and both had a board in front of them which the other could not see, though they could see each other. This task comprised four trials, the order of which was counterbalanced. Children and parents were assigned to either the describer or listener role. The child always started in the describing role and this alternated thereafter. The describer was given a board with eight different pictures of one animal (cats, dogs, mice or rabbits) displayed in a specific order on a 4x2 grid (see appendix B). The listener was given a blank board and 12 cards which included the eight target cards and four distractor cards. All drawings were in black and white and were designed to be visually similar. The describer was instructed to describe each of their cards and the order they appeared so that the listener could locate the correct card and place it in the correct position. Parents and children were free to communicate naturally throughout the task.

For the current analyses, only data obtained when the child was in the describing role was included. Ten percent of participant videos were double coded by two trained undergraduate research assistants, blind to the child's diagnostic group. Disagreements were resolved through discussion. The inter-reliability for the referential task was 73% agreement, Kappa = .70, which indicates good reliability (Landis & Koch, 1977).

4.3.8. Verbal transcripts and gesture coding for the narrative and referential communication task

Verbal dialogue in both tasks was transcribed using SALT (Miller & Iglesias, 2012). This was used to count the total number of words in each task. For both the narrative and referential communication task, videos were coded by myself and a trained research assistant using The Observer XT software (Grieco et al., 2013). The number of different gesture types produced by children during each of these tasks were coded. Gesture types included: Deictic gestures, which are pointing gestures used to draw attention to a particular object, person or location in the environment; Representational gestures, which show a close relationship to the object, action, idea or concept that they refer to (e.g. making a circular shape with hand to represent a ball); Conventional gestures which are culturally specific and convey meaning without the need for speech (e.g. nodding to symbolise yes); and Beat gestures, rhythmic movements which emphasises aspects of speech (McNeill, 1992). The total number of gestures (combining all gesture types) formed a raw gesture score. As language groups did not differ on the amount of time taken to complete each task, but did differ on the number of words spoken (see Table 4.1), the gesture rate calculated the number of gestures per 100 words (number of gestures/ number of words*100) to provide a gesture rate that accounted for the number of words children used during each task.

Gesture function was also coded as either extending or redundant. Extending gestures included gestures that were produced with speech but which added extra information (e.g. “the cat had a tail like that”, whilst simultaneously producing a *curly tail gesture*) and also gestures produced in isolation, in the absence of the verbal equivalent. Redundant gestures included gestures that reinforced the spoken message; although these gestures may highlight important aspects of an utterance, they do not add extra information to the utterance (e.g. “the cat had a curly tail”, whilst simultaneously producing a *curly tail gesture*).

4.4. Results

4.4.1. Data analysis plan

The following analyses explores differences in child gesture rate and gesture function in relation to child language ability. A series of ANOVAs was conducted to explore group differences in gesture frequency and gesture function across tasks. Cohen’s d effect sizes are reported and interpreted as an effect size of .2 being a small effect, .5 a medium effect and .8 a large effect (Cohen, 1988). Group and task comparisons of the referential communication task focused on trials in which the child was in the describing role. Extreme outliers (more than three times the interquartile range) on the gesture and motor tasks were excluded from analysis. This included one child’s referential communication data and one child’s motor skill data.

4.4.2. Gesture types

Table 4.2 demonstrates that children produced predominantly representational gestures during both narrative recall and referential communication.

Table 4.2.

Mean proportion (SD) of gesture types produced during each task.

Gesture Type	Representational	Deictic	Conventional	Beat
Narrative Task	90.79 (15.14)	3.23 (7.17)	3.73 (5.39)	.34 (1.59)
Referential Task	65.73 (19.43)	19.92 (14.59)	12.12 (16.29)	.48 (1.14)

Table 4.3.

Means (SD) for motor skill and gesture skill in all three language groups.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η^2
Motor skill (seconds)	80.19[a] (20.55)	80.04[a] (12.72)	93.32[b] (17.13)	4.18	.020	.13
Gesture imitation	46.12[a] (9.03)	36.00[b] (10.53)	36.85[b] (10.21)	6.22	.004	.18
Elicited single gesture	62.47[a] (6.60)	56.13[a,b] (10.65)	49.13[b] (.13.19)	7.61	.001	.21
Narrative gesture rate	6.95 (3.11)	8.81 (4.47)	7.96 (5.00)	.89	.415	.03
Referential gesture rate	5.48[a] (2.10)	8.71[b] (2.19)	8.05[a,b] (5.11)	4.42	.016	.14

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All data is raw data other than gesture rate which is number of gestures per 100 words. Motor skill was measured in seconds, whereby a lower (faster) time indicates more advanced motor ability. Different superscripts within the same row indicate differences between group means that are significant at $p < .05$.

4.4.3. Do children with DLD have deficits in accuracy, frequency or function of gestures relative to age-matched peers, or peers with low language and educational concerns?

Time taken to complete the motor tasks, mean accuracy scores for gesture imitation and elicited single-word gesture task, and gesture rates in the narrative and problem-solving tasks are reported in Table 4.3. There was a significant main effect of language group on motor skill, F (2, 56) =8.08, p=.001, η_p^2 =.22. Post-hoc comparisons revealed that the TD and LL groups performed more similarly to one another and completed the motor task more quickly, indicating more advanced motor ability, than children in the DLD group (TD vs. DLD: p=.001, d=1.20; LL vs. DLD: p=.010, d=.88). Thus as a group, children with DLD have more demonstrable motor deficits relative to peers. I next considered qualitative differences in gesture production during gesture imitation and elicited, single-word gesture tasks. There was a significant main effect of language group on gesture imitation scores, *F* (2, 55) =6.22, *p*=.004, η_p^2 =.18. However, in contrast to the motor skill test, the LL group performed more similarly to the DLD group, with both the LL and DLD groups providing less accurate gesture sequences relative to TD peers, (LL vs. TD: *p*=.006, *d*=1.19, DLD vs. TD: *p*=.015, *d*=1.03, DLD vs. LL: *p*=.989, *d*=.09). There was also a main effect of group in ratings of gesture quality during the elicited single gesture task, *F* (2, 56) =7.61, *p*=.001, η_p^2 =.21. As predicted, the gestures of children in the DLD group were rated as significantly less accurate than the TD group (*p*=.001, *d*=1.28). No significant differences were found between children with LL and either of the other two groups.

I next considered gesture rate in more naturalistic tasks of story-telling and interactive problem-solving. As illustrated in Figure 4.1, there was considerable within group variation in both tasks. In the narrative task, there were no significant group differences in the rate at which children produced gestures, *F* (2, 57) =.89, *p*=.415, η_p^2 =.03. In contrast, during the referential communication task there was a significant main effect of language group, *F* (2, 57) =4.42, *p*=.016, η_p^2 =.14. These data violated assumptions of homogeneity (*F* (2, 56) =6.36, *p*=.003), therefore the Games-Howell correction was applied in post-hoc analysis. Here it was clear that the LL group gestured significantly more frequently than the TD group (*p*<.001, *d*=1.50), but there was no significant difference between the DLD and TD groups (*p*=.108, *d*=.07).

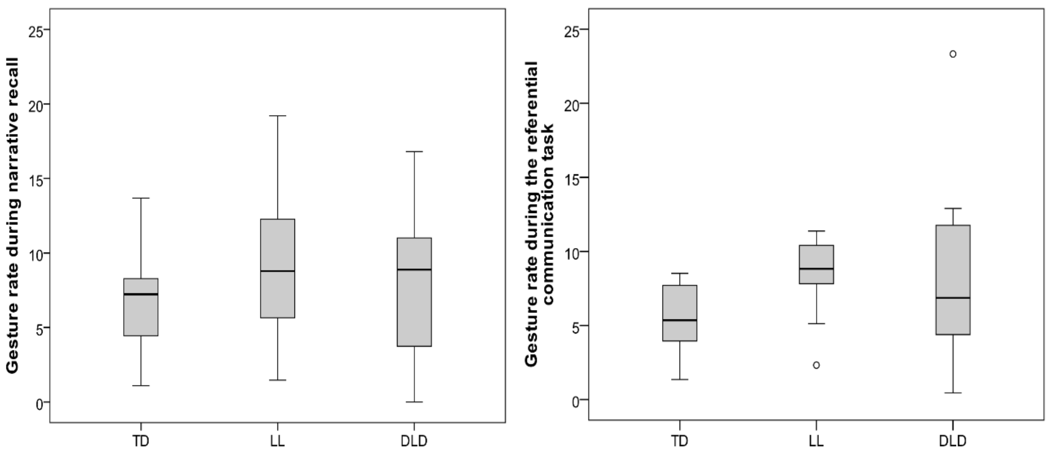


Figure 4.1. Number of gestures per 100 words produced by children during the narrative task and referential communication task.

Figure 4.2 illustrates that in general, all children use gesture to reinforce their spoken message, as indicated by the large proportion of redundant gestures. This is particularly true in the narrative task, and children with DLD did not differ from their peers in terms of the function of gestures (e.g. extending or redundant) they produced during the narrative task. However, there was a main effect of group on gesture function during the interactive problem-solving task, $F(2, 56) = 8.40$, $p < .001$, $\eta_p^2 = .23$. As expected, children with DLD produced significantly more extending gestures than either the TD (p=.030, d= .84) or LL (p=.002, d= 1.15) groups. Thus, during an interactive and cognitively demanding task, children with DLD use gesture to convey more complex messages than are realised verbally.

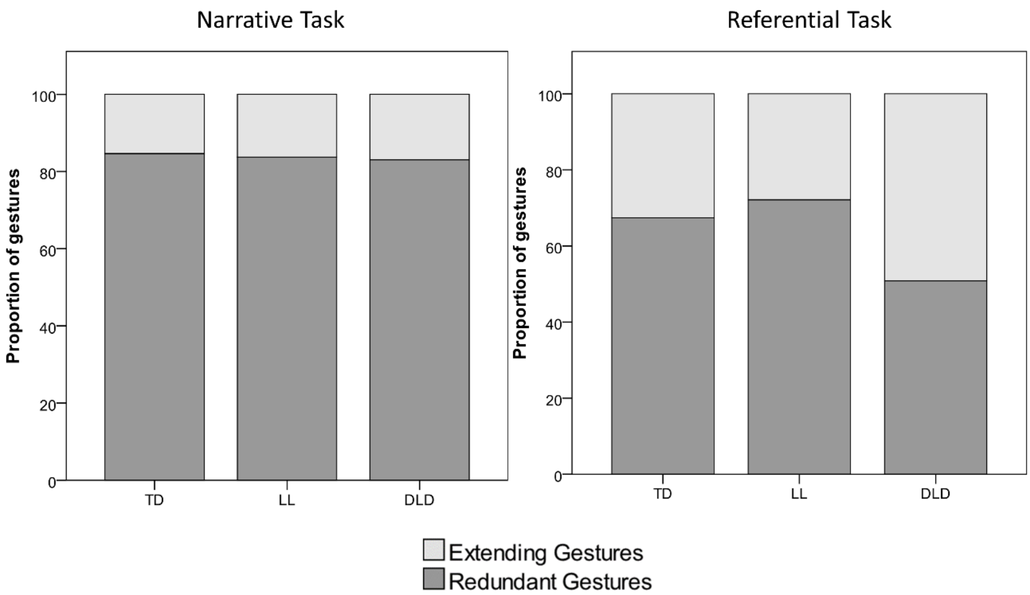


Figure 4.2. The proportions of extending and redundant gestures produced by children during the narrative and referential communication tasks.

4.4.4. Secondary Analysis

It may be that the inclusion of the intermediate LL group may have resulted in a more able TD group, and thus exaggerated the differences between the TD and DLD groups. To explore this, I re-analysed the data, combining the TD and LL group. Children who had a history of speech and language therapy or had special educational support at school were excluded from analysis (n=15). The following analysis indicates that the DLD group still scored significantly lower than their TD peers on measures of language and non-verbal reasoning (see Table 4.4). Children with DLD also displayed significantly more motor difficulties than TD peers, $F(1,42)$

=13.74, *p*<.001, *d*=. 1.10, and produced significantly less accurate gesture sequences during gesture imitation, *F* (1,41) =6.62, *p*=.014, *d*=.79. In addition, the gestures of children with DLD were rated as significantly less accurate than TD peers during the elicited gesture task, *F* (1,43) =12.02, *p*=.001, *d*=. 1.02.

Next I re-analysed data from spontaneous communication during naturalistic tasks of story-telling and referential communication. In the narrative task, there were no significant group differences in the rate at which children produced gestures, *F* (1,42) =.07, *p*=.790, *d*= .08. Similarly, during the referential communication task there was no significant difference between the DLD and TD group, *F* (1,42) =.78, *p*=.381, *d*= .26.

Finally, the analysis indicated that DLD children did not differ from their TD peers in terms of the function of gestures (e.g. extending or redundant) they produced during the narrative task, F(1,41)=1.28, *p*=.83, *d*=.09. However, there was a main effect of language group on gesture function during the interactive problem-solving task, children with DLD (Mean: 49%) produced a significantly higher proportion of extending gestures than the TD (Mean: 31%) group, *F*(1,42) = 9.92, *p*=.003, *d*= .94.

Table 4.4.

Means (SD) for background measures, motor skill and gesture skill.

Measure	TD (n=24)	DLD(n=21)	Range	F	*p*	*d*
NV-Reasoning	28.25 (3.97)	24.19 (3.68)	16-38	15.23	<.001	1.06
Language composite	.25 (.86)	-1.67 (.62)	-3.11-1.86	55.18	<.001	1.89
Vocabulary composite	167.21 (20.02)	129.71 (14.81)	81-207	78.81	<.001	2.13
Gesture imitation	43.87 (8.93)	36.85 (8.93)	20-58	6.62	.014	.79
Elicited single gesture	60.30 (8.12)	49.13 (13.19)	15-70	12.02	.001	1.02
Narrative gesture rate	7.60 (3.96)	7.96 (5.00)	0-19.2	.07	.790	.08
Referential gesture rate	7.61 (3.67)	8.05 (5.11)	0.45-23.33	.78	381	.26

Note. TD: typically developing, DLD: developmental language disorder.

Table 4.5

Correlation matrix demonstrating relationship between language, motor skill and gesture skill across the whole sample.

	Vocabulary	NV-IQ	Motor skill	Gesture imitation	Elicited single gesture	Gesture rate (narrative)	Gesture rate (referential)
NV-IQ	.554**	.					
Motor skill	-.465**	-.573**	-				
Gesture imitation	.503**	.451**	-.345**	-			
Elicited single gesture	.552**	.292*	-.566**	.417*	-		
Gesture rate (Narrative)	-.039	-.079	-.174	-.075	.198	-	
Gesture Rate (Referential)	-.320*	-.146	.053	-232	-.177	.477**	-
Proportion of extending gestures (referential)	-.390**	-.152	-.356**	-.226	-.512**	-.214	.059

*p<.05, **p<.001

Note. All data is raw data other than gesture rate which is number of gestures per 100 words. Motor skill was measured in seconds, whereby a lower (faster) time indicates more advanced motor ability.

4.4.5. Are measures of language and motor ability associated with gesture accuracy and/or gesture frequency?

For the following analysis children in all three language groups were analysed as a whole. Significant negative correlations were found between motor skill and gesture accuracy in both gesture imitation ($r(57) = -.345$, $p = .009$) and elicited single-word gesture tasks ($r(58) = -.566$, $p < .001$). This demonstrates that children with greater motor skill produce more accurate gestures. However, there was no significant relationship between motor skill and gesture rate for either the narrative task ($r(59) = -.174$, $p = .188$) or the referential task ($r(58) = .053$, $p = .694$).

There was a significant positive correlation between vocabulary and gesture accuracy in the gesture imitation task ($r(60) = .503$, $p < .001$) and elicited single gesture task ($r(59) = .552$, $p < .001$; Table 4.5); this relationship was similar across all three language groups (Figure 4.3a and b). This indicates that, overall, children with more advanced vocabulary produced more accurate gestures than those with poorer vocabularies. Somewhat surprisingly, gesture rate (both narrative task and referential communication task) and gesture accuracy were not significantly correlated (Table 4.5). Although gesture rate during narrative recall was not significantly correlated with vocabulary ($r(60) = -.039$, $p = .766$), gesture rate during referential communication was significantly negatively correlated with vocabulary level ($r(59) = -.320$, $p = .014$). This suggests that during the interactive task, those children with more severe vocabulary deficits gestured more frequently than those with more advanced vocabulary. In addition, Figure 4.3c illustrates the negative relationship between vocabulary and gesture rate during narrative recall for both the LL and DLD groups, as well as the expected positive relationship within the TD group. However, due to the small sample size these relationships are not significant at the group level.

The significant negative relationship between vocabulary and gesture rate during referential communication was attenuated when the outlier observed in Figure 4.3d was removed ($r(58) = -.127$, $p = .341$). It should be noted that this child had the most severe expressive language deficits, and relied heavily on gesture to communicate. However, this child also scored poorly on measures of gesture imitation and gesture elicitation. The extreme scores are not spurious and reflect the child's true language profile and thus give some insight into the use of gesture when verbal expression is severely limited. In addition, vocabulary was also significantly negatively correlated with the proportion of extending gestures produced during referential communication ($r(59) = -.390$, $p = .002$), again indicating that those children with more severe language difficulties were using proportionately more extending gestures than children with more advanced language abilities.

As vocabulary, motor skill and non-verbal IQ were significantly related to gesture accuracy during elicited gesture production I further explored these relationships with a regression analysis; elicited gesture production accuracy was entered as the outcome variable and vocabulary, motor skill and NVIQ as the predictor variables. Overall the model was significant, $F(3,54)=14.85$, $p<.001$, and explained 42% of the variance in gesture accuracy scores. Vocabulary was a significant predictor of gesture accuracy during elicited gesture production ($\beta = .23$, $t = 3.60$, $p = .001$), as was motor skill ($\beta = -.36$, $t = -3.84$, $p < .001$). The motor skill co-efficient was negative as motor skill was measured in seconds, whereby a lower (faster) time indicates more advanced motor ability. Non-verbal IQ however did not predict gesture accuracy when vocabulary and motor skills were included in the model ($\beta = -.60$, $t = -1.64$, $p = .107$).

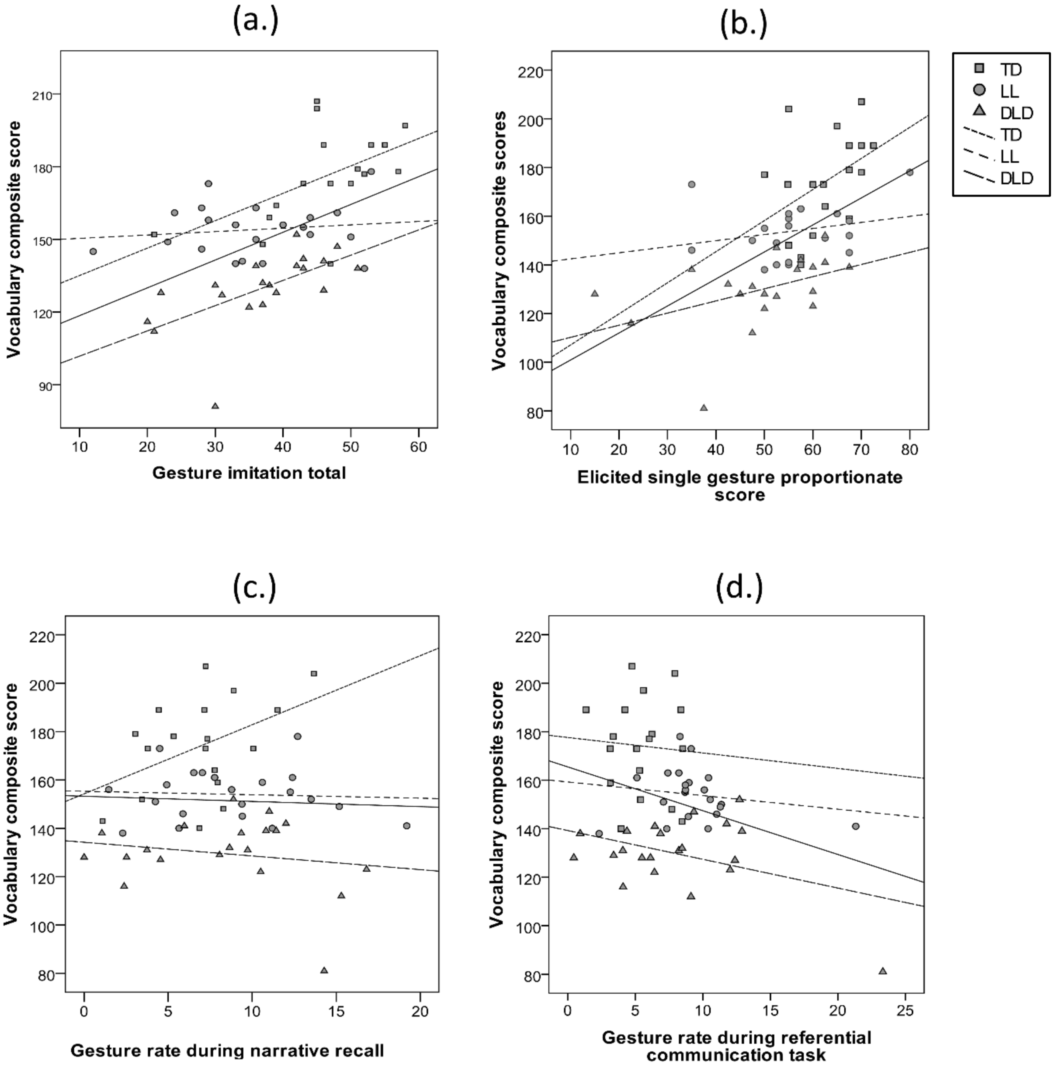


Figure 4.3. Scatterplots showing the relationships between vocabulary and (a) gesture imitation, (b) elicited gesture production, (c) gesture rate during narrative recall and (d) gesture rate during referential communication.

4.5. Discussion

This study explored gesture accuracy and gesture frequency in children with DLD on measures of meaningless gesture sequence imitation, meaningful elicited gesture production and spontaneous gesture production, using both narrative monologue and interactive problem-solving tasks. In addition, I considered whether gesture accuracy and/or frequency were related to child vocabulary, and whether gesture was related to underlying motor competence. The key findings were that children with DLD gestured as frequently as peers, and in complex tasks produced more extending gestures to convey information they could not verbalise. Nevertheless, the gestures they produced in imitation and elicitation tasks were not as accurate as those of their peers. Gesture accuracy was moderately correlated with both vocabulary knowledge and underlying motor skill. Importantly, both vocabulary and motor skill, but not NVIQ, were significant predictors of elicited gesture production accuracy. I consider the implications of these findings in relation to the initial hypotheses below.

The present study confirmed that many children with DLD have co-occurring motor deficits (cf. Johnston, Stark, Mellits, & Tallal, 1981; Powell & Bishop, 1992). In addition, children with DLD also have difficulties imitating meaningless gesture sequences, in comparison to TD peers. At first glance, these findings appear to contradict Wray et al. (2015), who found no differences between children with DLD and age-matched peers on a gesture imitation task. Crucially, however, Wray et al. (2015) only required children to imitate hand positions and not hand sequences. Taken together, these findings indicate that children with DLD have difficulties with producing gesture sequences which are arguably more closely related to naturalistic gesture than imitating hand position only. Interestingly, children with LL exhibited gesture imitation abilities that more closely resembled the DLD group than the TD group. This suggests that children with mild language difficulties may have subtle deficits in motor movements that are in keeping with their oral language abilities.

During meaningful elicited single-word gesture production, children with DLD demonstrated relative weaknesses in their ability to produce accurate gestures in comparison to TD peers, consistent with previous investigations (Hill, 1998; Wray et al., 2015). Notably, Botting et al. (2010) did not find less accurate gesture production in children with DLD. However, participants in Botting et al. were younger than those in the current study, raising the possibility that differences in gestural skill become more apparent over the course of development. Additionally, some of the younger children in the Botting et al. study may have been exhibiting early language delay, rather than persistent DLD, consistent with the LL group findings. In contrast, the LL group did not demonstrate accuracy weaknesses during elicited single word gesture production despite showing impairments in gesture imitation. This task required children to have well-developed semantic representations for each word in order to produce an accurate gesture; thus these results may reflect more limited semantic knowledge in the DLD group, relative to the LL group (cf. Capone, 2007). In addition, pragmatic language abilities may also have influenced the ability of children with DLD to understand the linguistic context and tap into their pre-existing knowledge and experience of target words, or their ability to express concepts succinctly. For example, they often provided either too little or too much detail in their gestures, making it difficult for the observer to clearly understand the intended word.

In addition, this task also required children to have the motor skills to produce accurate gestures, as such co-occurring motor deficits may also explain the elicited gesture production difficulties within the DLD group. The finding that motor skill and vocabulary were both significant predictors of gesture accuracy provides support for the idea that motor and language abilities are intimately related to gesture accuracy. It is likely this combination of risk factors reflects atypical brain development that impacts on both language and gesture. Future research assessing the gesture production accuracy of words for which children have already demonstrated they have a good semantic representation (McGregor et al., 2002), may elucidate whether children with DLD can produce accurate gestures when linguistic demands are low, and thus whether motor deficits are the primary factor influencing gesture production accuracy in DLD. In addition, as vocabulary, motor skill and NVIQ in combination only accounted for 42% of the variance in gesture accuracy scores, future research will need to identify other factors which may impact gesture accuracy, for example the development of symbolic function (c.f. Capone & McGregor, 2004).

In the current study, children with DLD did not gesture more frequently than their peers during either the narrative or the interactive problem-solving task, in contrast to previous reports (Iverson & Braddock, 2011; Mainela-Arnold et al., 2014). Instead, children with DLD gestured at the same rate as their peers, suggesting that even though their gestures are less accurate, they remain motivated to use gesture during communication. Children with LL, on the other hand, gestured more frequently than their TD peers, again highlighting differences between children with low language and those with persistent DLD. Given that children within the LL group were identified as having language and communication difficulties during their first year of school, but did not meet criteria for DLD two years later, some of these children may have had language difficulties that have now resolved. If so, then these findings are consistent with Thal and Tobias (1992) who reported that children with resolved language delay gesture more frequently than their TD peers. Gesture rate may therefore be an important prognostic indicator of persistent DLD in children with early language deficits.

Children with DLD did use a greater proportion of gestures that extended utterances, rather than just reinforcing the verbal message, particularly in the interactive problem-solving task. This highlights an important function of gesture for children with DLD; they may not use gesture more <u>frequently</u> than their peers, but they may be using gesture to convey ideas that they are unable to express verbally by using gesture to replace those words. This is consistent with Blake et al. (2008) and Evans et al. (2008; 2001), who also found no differences in gesture rate, but evidence that a greater proportion of gestures used by children with DLD were extending gestures. The fact that this compensation was more evident during an interactive problem-solving task suggests that children with DLD may only use gesture to compensate when the cognitive demands of the task are high. Nevertheless, the fact that the gestures they produce are less accurate suggests that these attempts to compensate may not be consistently successful.

It could be argued that these differences have been exaggerated because the TD group did not include children rated as ‘high-risk’ on the teacher screen, who may in fact be false positives. If so, the TD group does not represent the full range of language abilities and is therefore a ‘super’ ability TD group. However, the results remained unchanged when I combined the TD group with those children with LL who were not receiving specialist support for their communication challenges. In addition, the correlational analyses take account of the entire sample, ensuring that the findings are not limited to those at the extremes of the distribution.

In addition, disparities in NVIQ between DLD and TD group may also have influenced the findings. I did not control for NVIQ in the group comparison analysis as it is not unusual to find that children with DLD have significantly lower NVIQ relative to TD children, even if they are selected to have NVIQ within the normal range (NVIQ > 70; Norbury et al., 2016). In addition it is not appropriate to use ANCOVA when the co-variate is non-randomly associated with group membership, as NVIQ is in this case (Dennis et al., 2009; Miller & Chapman, 2001). Finally, whilst both language and non-verbal ability were associated with the imitation and elicitation measures, the direction of causal influence cannot be determined from this study alone. Language, motor and NVIQ are all highly correlated within this population and likely reflect atypical brain development, but may not be causally related to one another.

The significant negative correlation between gesture rate during interactive problem solving and vocabulary across the whole sample, again suggests that increased gesture rate is associated with lower levels of language competence. The fact that this relationship was only seen during complex parent-child interaction and not narrative recall, along with increased use of extending gestures, suggests that children are more likely to use gesture to compensate when task demands are high. In addition, the significance of this relationship was partially driven by an outlier with extremely limited expressive language abilities. If the sample included more children with such extreme verbal language limitations, the negative relationship would likely have been stronger.

It is notable that within all three language groups there was wide variation in gesture rates that is not fully accounted for by the child variables measured here. Previous research with young, typically developing children has identified parent gesture use and socio-economic status as important factors in explaining individual differences in gesture use in young children (Rowe et al., 2008). Investigation of these parental and environmental factors in different language groups could be enlightening, and is something I am currently investigating. Longitudinal data is also necessary to begin to elucidate the causal relationships between these variables, for example, whether gesture is predictive of later language in this population or whether diminished semantic representations adversely impacts gesture production. Intervention paradigms that employ gesture to enhance oral language may provide further insight into the causal relationships between language, gesture and motor skill.

Theories of communication vary in the extent to which spoken language and gesture are viewed as complementary or integrated systems. In typical development, there is considerable evidence that they are integrated systems, intimately related and mutually supporting development of the other. Investigation of atypical development is therefore crucial as such tight relationships may become unravelled. The data, however, provide some mixed evidence. To some extent these systems are complementary; children with DLD gesture as much (though not more) than TD peers, and can use gesture to express ideas that are not realised in spoken output. However, these compensatory uses of gesture are most evident when task demands are high and/or when verbal output is severely limited and gesture is the only way to communicate. Furthermore, children with DLD displayed difficulties with both meaningless and meaningful gesture production, indicating that when there is a language breakdown, difficulties with gesture production are also seen. This finding supports the hypothesis that gesture and language form an integrated communication system. Nevertheless, this does not hinder children's motivation to use gesture to communicate. Despite difficulties with both verbal and gestural communication children with DLD still have a typical drive to communicate both verbally (Bishop, 200) and non-verbally, thus providing them with the opportunity to use extending gestures to compensate for their language weaknesses. Unfortunately, the gestures they produce may not be as accurate or as informative as the gestures produced by TD children, and this may limit the ability of interlocutors to comprehend the gestures produced by children with DLD. The differences in gesture use between the DLD and LL group suggest that gesture may serve as a means to differentiate between children with low language and those that may have persistent language difficulties. The results also indicate that it is the quality, not quantity of gestures that differentiates the non-verbal communicative abilities of children with DLD from their peers.

Chapter 5: Parents modify gesture according to task demands and child language needs

5.1. Abstract

Parent-child interaction plays a crucial role in early child language acquisition. A specific role for gesture has been posited for young typically developing children, with both direct and indirect relationships between parent gesture, child gesture and child language observed. Far less is known about these relationships in atypical language development, and whether parents tailor their use of gesture to accommodate child language ability and task demands. The present study investigated parent gesture frequency and child gesture frequency and function in relation to child language ability in both narrative recall and an interactive referential communication task. Parent-child dyads were observed for children aged 6-8 with persistent developmental language disorder (DLD: n=21) relative to parents of typically developing peers (TD: n=18) and an intermediate group of children with low language (LL) and educational concerns (n=21). Parents of children with DLD gestured at a significantly higher rate than parents of TD children; however, this difference was only evident during a complex interactive problem solving task. Across the entire sample, parent gesture rate was positively correlated with child gesture rate, but negatively correlated with child vocabulary. Finally, children's use of extending gestures was positively associated with the number of words produced by parents, suggesting that child gesture may elicit verbal responses from parents that support communication. Parent gesture thus serves to compensate for children's oral language difficulties and maximise communication success. Parent gesture is therefore most evident when communication demands are high and parents receive direct feedback about their child's communication challenges.

5.2. Introduction

Parent-child interaction plays a crucial role in early child language acquisition; it is through these early interactions that children learn the semantic and linguistic structures and social cues required for language (Snyder-McLean & McLean, 1978). An important aspect of parent-child interaction is that parents are dynamic, constantly changing and adapting their communication to meet the demands of the situation and the needs of their child (Tamis-LeMonda et al., 2008). Child directed speech is a well-documented phenomenon that supports parent-child communication, but it is also common for parents to use co–speech gestures that are child directed to engage the child and enhance communication (Iverson et al., 1999). For example, parents are more likely to produce larger, less complex gestures when communicating with their infant, in comparison to communication with an adult (Brand et al., 2002; Iverson et al., 1999; Özçaliskan & Goldin-Meadow, 2005). Such observations prompt questions about whether these child directed gestures are a critical component of early language acquisition and/or language learning throughout childhood. A second question concerns how parent gesture affects language learning when child language follows an atypical developmental course, with potentially important implications for parent-based interventions aimed at using non-verbal communication to support language learning.

5.2.1. Parent gesture supports typical language and communication development

Across cultures, parents who gesture frequently also have children who gesture frequently (Goodwyn & Acredolo, 1993; Iverson et al., 1999; Liszkowski et al., 2012; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). This positive relationship may indicate that children observe parents' use of gesture and subsequently adopt this strategy to enhance their own communication. Parent gesture is also positively associated with young typically developing children's language ability (Iverson et al., 1999; Pan et al., 2005). For example, parental use of pointing gestures is positively related to children's vocabulary at 14 months (Pan et al., 2005) and 16 months (Iverson et al., 1999). However, Rowe, Özçalışkan, and Goldin-Meadow (2008) reported an indirect relationship between parent gesture and child language, in which parent gesture vocabulary predicted child gesture vocabulary, which in turn predicted child oral vocabulary. Methodological differences between studies challenge interpretation of causal relationships; both Iverson et al. (1999) and Pan et al. (2005) report a relationship with deictic (finger pointing) gestures, whereas Rowe et al. (2008) combined all gesture types. Thus, the mechanisms by which different gesture types facilitate language learning may vary. Deictic gestures may facilitate language growth by establishing joint attention of referents (McGregor, 2008) and accompanying parent labelling behaviours (Gogate, Bahrick, & Watson, 2000), helping those words to enter a child's verbal lexicon. Alternatively, representational gestures may reinforce the spoken message and provide more complex information about a referent's size, shape or motion (McNeill, 1992), which may lead to a greater depth of semantic understanding of the referent once the word has entered a child's verbal lexicon (Singleton, 2012).

Intervention studies further highlight the link between parent-child gestures and language development. Goodwyn, Acredolo, and Brown (2000) either encouraged parents of 11-month-old typical language development (TD) infants to either increase their labelling behaviours, use gesture alongside speech, or gave no specific instruction. Goodwyn et al. (2000) found that those children whose parents had been encouraged to use gesture showed the largest gesture repertoire and achieved significantly higher scores on measures of receptive and expressive language. However, the gesture advantage did not persist when children were re-assessed at 30 and 36 months, suggesting that gesture may only be influential in the earliest stages of language acquisition.

5.2.2. Child gesture use is positively associated with child language

Positive associations between early child gesture use and both later child vocabulary and sentence complexity have been consistently reported (Acredolo & Goodwyn, 1988; Rowe & Goldin-Meadow, 2009b; Rowe et al., 2008) at least in early childhood. Once again, the mechanism by which child gesture facilitates language learning is not well understood. One possibility is that early child gesture may not play a causal role in language learning per se, but may be a marker for language learning potential (Rowe & Goldin-Meadow, 2009b). For example, those children who find producing gesture-speech combinations easy may also subsequently learn complex sentences more readily. Another possibility is that gesture may play a more active role in language learning, as gesture provides children with the opportunity to practice more complex sentence structures before they can articulate such structures (Ozçalişkan & Goldin-Meadow, 2005). In addition, gesture may elicit verbal responses from parents, which further facilitates language learning (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). For example, if a child points to a bird and says "fly", and the parent responds "yes birds fly" The parent is providing the child with verbal translation of the gesture-word combination that both increases the likelihood of the word "bird" entering the child's verbal lexicon (Goldin-Meadow et al., 2007), and extends the child's length of utterance. Such findings signal reciprocal relationships whereby child language and gesture behaviour may influence parent language and gesture behaviour as much as parent behaviours drive child language and gesture development.

5.2.3. Parent gesture use in atypical populations

The positive associations among parent gesture, child gesture and child language suggest that gesture use in parents of children with language and communication disorders should be beneficial. However, surprisingly little is known about how parents of children with atypical language and cognitive development use gesture, and whether parent gesture has the same relationships with child language in these populations. In these populations, gesture is often regarded as a compensatory tool, rather than a driver of language acquisition. For example, parents of children with Down syndrome use simpler verbal language but gesture more frequently with their child during problem solving tasks, relative to parents of TD children (Iverson, Longobardi, Spampinato, & Caselli, 2006). In addition, negative relationships between parents' use of pointing gestures and child language have been reported for children with autism spectrum disorders, aged 7-18 years old (Medeiros & Winsler, (2014), in contrast to the relationship between parent gesture and child language reported for TD children (Iverson et al., 1999; Pan et al., 2005). While these differences may reflect compensation for child language deficits, it is also possible that methodological differences affect parent gesture behaviour. For example, Iverson et al. (1999) and Pan et al. (2005) measured gesture use during observations of free play in TD infants, whereas Medeiros and Winsler (2014) observed gesture during observations of parents and school-aged children completing a problem solving task. A more complex problem solving task may elicit higher gesture rates when the goal is to aid child understanding and successful task completion. Group differences may therefore be more evident in contexts that are more challenging for children with language deficits.

Developmental language disorder (DLD) is generally defined as difficulties acquiring one's native language, which occur in the absence of other developmental concerns, sensory impairments or global developmental delays. DLD affects 7.58% of children at school entry (Norbury, Gooch, et al., 2016). Exploring the impact of parent gesture on child language development within this disorder is of interest as children with DLD are thought to have a typical drive to communicate, but have deficient oral language skills relative to peers (Bishop, 2000).

In relation to children with DLD, the paucity of available research indicates that parents may modify their gesture in relation to their child's language ability. For example, Lasky and Klopp (1982) observed parent behaviour during shared book reading, a cognitive problem solving task, and free play. They found that parents who used more non-verbal behaviours (facial expression, body posture, action, demonstration, gesture and imitation) had children with more severe language skills. Lavelli, Barachetti, and Florit (2015) similarly reported that during shared book reading, parents of children with DLD behaved more similarly to parents of younger language-matched TD children, with both groups producing more combined gesture-speech utterances than parents of the age matched TD group. Although not significant, they also reported a trend for parents of the DLD children and language-matched TD children to gesture at a higher rate (defined by number of gestures per minute) than the age-matched TD group. However, due to the nature of shared book reading, the majority of gestures produced were pointing gestures. To fully understand how gesture relates to language learning in children with DLD, it is also necessary to know how their parents use representational gestures to support language, and how they use these gestures in tasks with different communicative goals.

Grimminger, Rohlfing, and Stenneken (2010) measured parent gesture during an interactive comprehension task with late-talking toddlers aged 22-24 months. Parents instructed their child to arrange objects that had either a canonical (“put the girl on the chair”) or a more complex non-canonical (“put the girl under the chair”) spatial relationship (Grimminger et al., 2010). Overall, mothers of late-talking children gestured more frequently and were more likely to hold a gesture throughout an utterance than parents of TD children. In addition, parents of both TD and late-talking children produced more gestures during the more demanding non-canonical setting, suggesting that whilst all parents increase gestures when task demands are high, this is more pronounced when a child’s language ability is low.

In summary, parents may adopt different gesture-communication strategies depending on the language needs of their child and the complexity of the interactive task. For children with DLD, gesture may be used primarily as a compensatory strategy, and may therefore be <u>negatively</u> correlated with the child’s language abilities, rather than positively associated, as seen in typical language development. However, to my knowledge, no studies of children with DLD have explored how parent gesture relates to child gesture, and how the child’s gesture may in turn affect language learning and communication. In these cases, parent gesture may signal an additional means to enhance communication when verbal skills are not developing as expected, and/or may prompt parents to reformulate the child’s gesture using verbal language.

The current study investigated parent gesture in three groups of children representing the full range of oral language abilities: those with typical language development, an intermediate group of children with low language and educational concerns and those with persistent DLD. This work extends previous research by examining gesture use in parents of school-aged children and by measuring gesture in two spontaneous gesture tasks, a narrative monologue and an interactive problem solving task. The study had three main aims; first I aimed to establish whether parents modify gesture use depending on their child’s language ability and/or task demands. Here I predicted that parents of children with DLD would generally gesture more frequently, but that an increased gesture rate might be especially evident in an interactive problem solving task relative to a narrative monologue task. My second aim was to establish whether there were positive relationships between parent gesture and (a) child gesture, and (b) child language in children with varying levels of language competence. I anticipated that parents who gestured more frequently would have children who also gestured more frequently in all three groups. However, in contrast to TD studies, I predicted that parents who gestured more frequently might in fact have children with more severe DLD, reflecting the need to use gesture to support communication. Finally, I asked whether child gestures were associated with the amount of verbal language that parents provided. If so, it would suggest a potential mechanism through which gesture could facilitate child language development.

5.3. Method

5.3.1. Participants

Children were recruited as part of the Surrey Communication and Language in Education Study (SCALES), a population study of DLD at school entry (Norbury et al., 2016). Reception class teachers completed the Children's Communication Checklist-S. (Bishop, 2003b, p. 2003) for 7,267 children aged 4-5 years old in state-maintained schools Surrey, a county in South East England (Stage 1). From this teacher-rated assessment, the bottom 14% (stratified by season of birth and gender) of children were classified as high-risk (HR) for DLD, whilst children scoring above this threshold were classified as low-risk (LR) of DLD. Selection for Stage 2 used cut-off scores on the CCC-S for each of the three age-groups (autumn, spring, and summer born) to identify sex-specific strata of boys (13.9%) and girls (14.8%) with teacher ratings of poorer language relative to children of similar age and sex. In total, 636 monolingual children were invited to participate, with a higher sampling fraction for high-risk children (40.5% of high-risk boys, 37.5% high-risk girls) versus low-risk children (4.3% for boys, 4.2% for girls). In Year 1, 529 children (83% of invited cohort) participated in an in-depth assessment of language, non-verbal cognition and motor skills (ages 5-6 years; 329 HR and 200 LR children, see Norbury et al., 2016, for details).

For the current gesture study, I initially aimed to visit 10% of the total in-depth cohort, over-sampling high-risk children at a ratio of 2:1. One hundred and thirty families were invited to take part in the study; 50 families did not consent to the home visit and/or video recording of the testing session. A further eleven families initially consented, however suitable arrangements could not be made for the home visit. Sixty-three monolingual parent-child dyads (61 mother-child) consented and were observed for this study. Three families of children reported diagnosis of ASD and were excluded from further analysis. There were no statistically significant differences between those families who opted in and those that opted out, on measures of socio-economic status, $t(111) = -.08$, $p=.937$, reported concerns about speech and language development, $\chi^2=1.06$, $p=.304$, or language risk status, $\chi^2=1.58$, $p=.209$ (Opt-in: 65% high-risk; Opt-out: 76% high-risk).

5.3.2. Group Classification

Prior to the home visit for the current study, children completed an in-depth test of language and cognitive function. A total language composite score was derived from tests of expressive and receptive vocabulary (Brownell, 2010); receptive and expressive grammar (Bishop, 2003; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011); narrative retelling and comprehension (Adams, Cooke, Crutchley, Hesketh, & Reeves, 2001). The core language battery consisted of tests that did not have current UK standardisations, either because they were standardised in North America, or were recently developed. Furthermore, co-standardising measures allows for direct comparison across measures. I therefore adjusted raw scores for child age using the full weighted SCALES sample (see Norbury et al. 2016 for details of this procedure). Children were assigned to one of three groups on the basis of their CCC-S and total language composite scores; there were no significant group differences in gender, $X^2 = 6.81$, $p =.08$. The DLD group (n = 21, 15 males) had both CCC-S raw scores and total language composite z-scores of -1SD or greater below the population mean. TD children (n = 18, 8 males) scored above the -1SD cut-off on both the CCC-S and the total language composite. Twenty-one children scored -1SD below the population mean CCC-S, indicating teacher ratings of significant communication deficits at school reception. However, these children scored above the 1SD cut-off on the total language composite in Year 1. As a group, they obtained intermediate total language composite scores that were significantly poorer than TD peers, and significantly higher than children with DLD (see Table 5.1). In addition, eight of these children were receiving special education support at school and six had been referred to speech-language therapy services. Due to their history of language and communication concerns and ongoing special educational needs, they were not combined with the TD group, but instead formed an intermediate group of children with low language and educational concerns (LL: n=21, 9 male). Including this intermediate group ensured that I could explore gesture use in relation to language across the whole spectrum of language abilities.

The study protocol was approved by the Royal Holloway Research Ethics Committee. All families had consented to be contacted for future studies; these families were contacted by post and parents provided informed, written consent for participation in the current study. Consent included a home visit by myself and video recording of all the gesture tasks. Each home visited lasted approximately 90 minutes.

Table 5.1.

Mean (SD) for background measures of age, neighbourhood deprivation, non-verbal reasoning, total language composite scores and expressive/receptive vocabulary composite for children in each language group.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η^2
Age (months)	87.50 (5.53)	89.00 (5.11)	89.19 (5.54)	.56	.575	.02
IDACI rank scores	24721.28 [a] (4966.74)	23278.33 [a,b] (6346.25)	19357.91 [b] (8302.65)	3.36	.042	.11
Non-verbal reasoning	29.00[a] (4.86)	26.48[a,b] (3.57)	24.19[b] (3.68)	6.88	.002	.51
Language composite	.61 [a] (.81)	-.40 [b] (.45)	-1.67 [c] (.62)	61.49	<.001	.68
Vocabulary composite	174.11 [a] (20.07)	154.05[b] (10.64)	129.71[c] (14.81)	40.76	<.001	.59

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All means are raw scores other than the language composite which is reported as a z-score. Different superscripts within the same row indicate differences between group means that are significant at $p < .05$.

5.3.3. Procedure

During the home visit, children and parents completed a number of structured and semi-structured tasks. Child gesture data are reported elsewhere (Chapter 4).

5.3.3.4. Narrative Recall

Parents watched two wordless cartoons (Die Sendung mit derMaus www.wdrmaus.de/lachgeschichten/spots.php5) of 30-60 seconds duration that depicted a mouse and an elephant in different scenarios. Cartoons were presented one at a time to parents on a laptop, and they were asked to re-tell the story to their child, who had not seen the video (McNeill, 1992). Videos were shown once and no specific instructions regarding story re-telling or using gesture were given. The order of presentation was counterbalanced across participants.

5.3.3.4. Referential Communication Task

In this task, parent and child sat opposite each other and both had a board in front of them which the other person could not see, though they could see each other. Children and parents performed both describer and listener roles across four trials, which was counterbalanced across participants. The child always started in the describing role and this alternated thereafter. The describer was given a board with eight pictures of one animal (cats, dogs, mice or rabbits) displayed in a specific order on a 4x2 grid (appendix B). All drawings were in black and white and were designed to be visually similar. The listener was given a blank board and 12 cards, which included the eight target cards and four distractor cards. The describer was instructed to describe each of their cards and the order that they appeared so that the listener could locate the correct card and place it in the correct position. Parents and children were free to communicate naturally throughout the task.

5.3.4. Verbal transcription and gesture coding of narrative and referential communication tasks

Verbal dialogue in both tasks was transcribed using Systematic Analysis of Language Transcripts software (Miller & Iglesias, 2012). The total number of words, number of different words and mean length of utterance were calculated for each task. Gestures were coded from the videos by the myself and a trained research assistant using Observer XT software (Grieco et al., 2013). The number of different gesture types produced by parents during each of these tasks were coded. Gesture types included: Deictic gestures, which are pointing gestures used to draw attention to a particular object, person or location in the environment; Representational gestures, which show a close relationship to the object, action, idea or concept that they refer to (e.g. making a circular shape with hand to represent a ball); Conventional gestures, which are culturally specific and convey meaning without the need for speech (e.g. nodding to symbolise yes); and Beat gestures, which are rhythmic movements that emphasise aspects of speech (McNeill, 1992). The total number of gestures (combining all gesture types) formed a raw gesture score. The number of gestures per 100 words was calculated (number of gestures/ number of words x 100) to provide a gesture rate that accounted for the number of words that the parents used during each task.

Gesture function was also coded as either extending or redundant. Extending gestures included gestures that were produced with speech but which added extra information (e.g. "the cat had a tail like that", whilst simultaneously producing a *curly tail* gesture) and also gestures produced in isolation, in the absence of the verbal equivalent. Redundant gestures included gestures that reinforced the spoken message; although these gestures may highlight important aspects of an utterance, they do not add extra information to the utterance (e.g. "the cat had a curly tail", whilst simultaneously producing a *curly tail* gesture).

5.3.5. Reliability

For both tasks, 10% of participants, parent gesture was double coded by a second rater, blind to the child's diagnostic group and study hypotheses. The inter-reliability for the referential task was 72% agreement (kappa = .69), while inter-reliability for the narrative task was 83% agreement, (kappa = .74), which indicates acceptable reliability for both tasks (Landis & Koch, 1977). Disagreements were resolved through discussion.

5.4. Results

5.4.1. Data analysis plan

Analyses focused on differences in parent gesture rate, gesture function and parent language in relation to child gesture rate and child language ability, a 2 (task: narrative, referential) x 3 (group) repeated measures ANOVA was conducted to explore group differences in gesture frequency and gesture function across tasks. Cohen's d effect sizes are reported and interpreted as an effect size of .2 is a small effect, .5 a medium effect and .8 a large effect (Cohen, 1988). Group and task comparisons of the referential communication task focused on trials in which the parent was in the describing role, as this enabled me to explore how parents used gesture during child directed speech. Later correlation analysis looked at the relationship between parent gesture, child language and child gesture across the whole task (taking into account when parents and children are in both roles) to examine the relationship between language and gesture across the entire interaction. As previous research has focused on the link between vocabulary and gesture use (Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008), the current paper used a composite expressive and receptive vocabulary.

5.4.2. Parent language

There were no significant group differences in the number of words produced during narrative recall, F(2,57) = 2.62, p = .082, η_p^2 =.08, or referential communication, F(2,57) =.38, p = .686, η_p^2 =.01, nor was there a significant difference in the MLU for either task (Narrative: F(2,57) = 2.49, p =.092, η_p^2 =.08; Referential: F(2,57) =.16, p = .849, η_p^2 =.01; see Table 5.2 and 5.3 for means). Thus the amount and complexity of the verbal information that parents provided was broadly similar across groups.

Table 5.2.

Means (SD) of verbal language and gestures produced by parents and child gesture rate during the narrative task.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η_p^2
Parent total words	290.22 (106.13)	233.29 (95.88)	221.81 (94.66)	2.62	.082	.08
Parent MLU	7.91 (.82)	7.35 (.87)	7.47 (.72)	2.49	.092	.08
Parent gesture rate	8.67 (2.95)	8.31 (4.20)	7.39 (4.19)	.582	.562	.02
Child gesture rate	6.95 (3.11)	8.81 (4.47)	7.96 (5.00)	.89	.415	.03

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All data is raw data other than gesture rate which is number of gestures per 100 words.

Table 5.3.

Means (SD) for parent and children for the referential communication task.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η_p^2
Parent total words	1386.39 (512.77)	1289.90 (461.58)	1251.00 (426.94)	.38	.686	.01
Parent MLU	5.02 (.91)	4.93 (.75)	5.07 (.66)	.16	.849	.01
Parent gesture rate	1.16 [a] (.82)	1.66[ab] (.68)	2.02 [b] (1.40)	3.21	.048	.10
Parent describer gesture rate	2.65 [a] (1.75)	4.10 [ab] (1.86)	4.73 [b] (2.33)	5.17	.009	.16
Child gesture rate	2.64[a] (.80)	3.88 [b] (1.24)	3.82 [a,b] (2.31)	3.51	.037	.11
Child describer gesture rate	5.48 [a] (2.10)	8.71 [b] (2.19)	8.24 [a,b] (3.71)	4.64	.014	.14
Child extending gestures (raw score)	22.82 (17.19)	18.71 (8.74)	25.19 (18.13)	.98	.381	.03

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All data is raw data other than gesture rate which is number of gestures per 100 words. Different superscripts within the same row indicate differences between group means that are significant at $p < .05$.

5.4.3. Gesture types

Table 5.4 demonstrates that parents produced predominantly representational gestures during both tasks. However, parents used proportionately more representational gestures during the narrative recall task than the referential task, $F(1,54) = 115.99$, $p = .001$, $d = 1.7$, in which parents used a more varied gesture repertoire.

Table 5.4.

Mean proportion (SD) of gesture types produced during each task.

Gesture Type	Representational	Deictic	Conventional	Beat
Narrative Task	94.00 (9.70)	1.18 (2.50)	3.42 (6.96)	1.06 (3.31)
Referential Task	60.90 (25.53)	16.31 (14.04)	20.54 (23.5)	1.91 (4.05)

5.4.4. Parent gesture use: Differences in task demands and children's language ability

Parents produced gesture at a higher rate during narrative recall (*M* = 8.02, *SD* = 3.83) than referential communication (*M* = 4.03, *SD* = 2.23), *F*(1,56) = 77.42, *p* = <.001 *d* = 1.27. As predicted, there was a significant interaction between group and task, *F*(2,56) = 3.42, *p*=.040, η_p^2 =.11. Planned comparisons indicated that there were no significant group differences in the rate at which parents produced gestures in the narrative task, *F*(2,57) =.58, *p* =.56, η_p^2 = .02, (Figure 5.1). In contrast, there were significant group differences in referential communication, *F*(2,56) = 5.17, *p* = .009, η_p^2 =.16. In this condition, parents of children in the TD group gestured less frequently than parents of children with DLD (*p* = .007, *d* = 1.01). The difference between parents of children in the TD group and parents of children with LL was not statistically significant, though the mean difference was of a large effect (*p* = .093, *d* = .90). There were no differences in gesture rate between parents of children with LL or DLD (*p* = .955, *d* = .14). The main effect of group was not significant, *F*(2,56)= .47, *p*=.629, η_p^2 =.02.

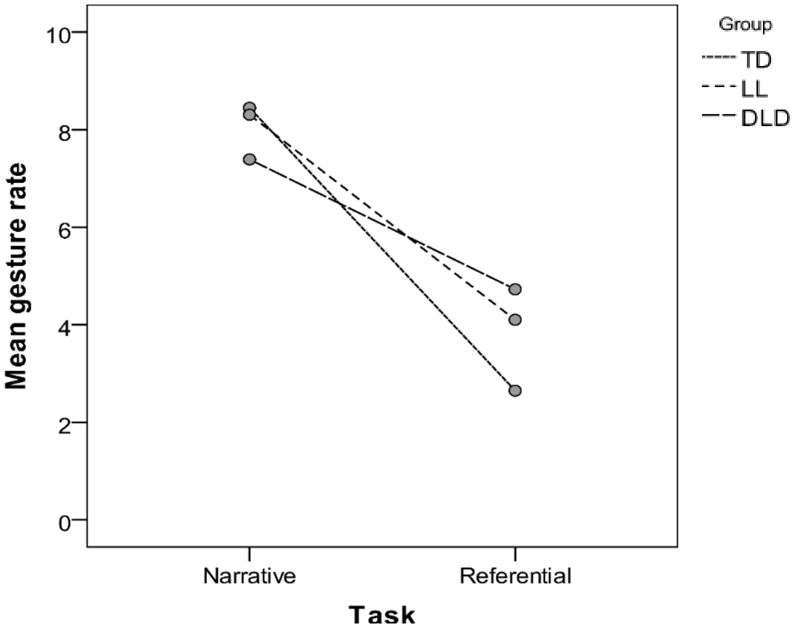


Figure 5.1. Interaction between gesture frequencies across both tasks, by language group.

5.4.5. Parent gesture use: gesture function

In general, all parents used gesture to reinforce their spoken message, as indicated by the large proportion of redundant gestures across both tasks (Table 5.5). Overall, there was a significant main effect of task, $F(1,54)=16.95$, $p<.001$, $\eta_p^2=.239$, as parents produced proportionately more extending gestures during referential communication than during narrative recall. There was no significant main effect of group, $F(2,54)=1.64$, $p=.204$, $\eta_p^2=.06$, nor a significant task x group interaction $F(2,54)=2.01$, $p=.144$, $\eta_p^2=.07$.

Table 5.5.

Mean (SD) Proportion of extending and redundant gestures used during each task.

Measure	Gesture Function	Whole Sample	TD (n=18)	LL (n=21)	DLD (n=21)
Narrative	Redundant	92.09 (9.68)	92.42 (11.06)	90.89 (7.99)	93.03 (10.29)
	Extending	7.91 (9.68)	7.58 (11.06)	9.11 (7.99)	6.97 (10.29)
Referential	Redundant	84.52 (12.82)	90.14 (8.19)	81.39 (12.41)	82.49 (15.45)
	Extending	15.48 (12.82)	9.86 (8.19)	18.61 (12.41)	17.51 (15.45)

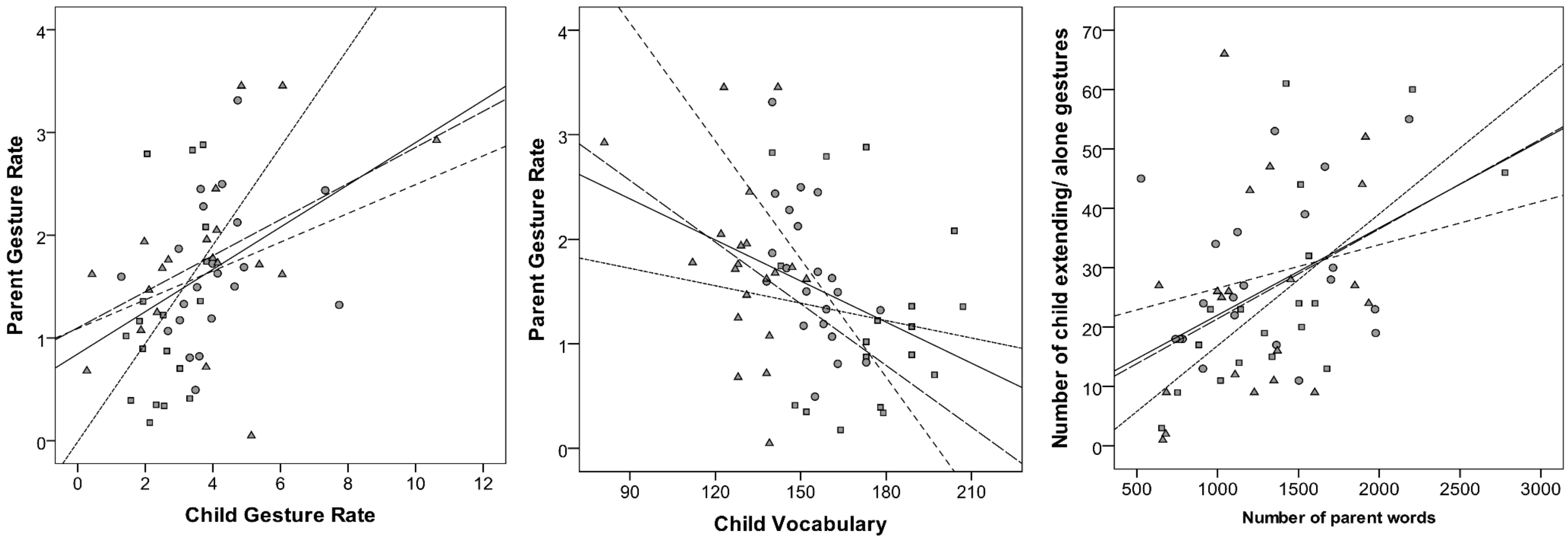
Note. TD: typically developing, LL: low language, DLD: developmental language disorder.

5.4.6. Relationships between parent gesture, child gesture and child language (vocabulary)

For this analysis, groups were analysed together and for the referential task across the whole task (total of describer and listener roles). As illustrated in Figure 5.2a, there was a small but significant positive relationship between parent gesture rate and child gesture rate during interaction, ($r(58) = .38$, $p = .003$), that was apparent in all three language groups. However, there was a significant negative correlation between child vocabulary and both child gesture rate ($r(58) = -.32$, $p = .015$) and parent gesture rate ($r(59) = -.42$, $p = .001$) during the referential communication task (Figure 5.2b). This indicates that parents of children with poorer vocabulary tended to gesture more frequently, but only during parent-child interaction.

5.4.7. Child gesture associations with parent language

As illustrated by Figure 5.2c, there was a significant, positive association between the number of extending gestures children produced and the number of words parents produced during the referential communication task, $r(59)=.38$, $p=.003$. This indicates that children who used gesture to convey information not realised in their verbal language elicited more verbal responses from their parents.



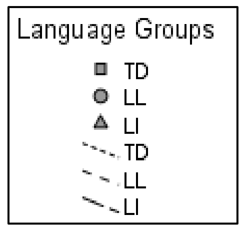


Figure 5.2. Scatterplots showing the relationships between (a) parent gesture child gesture, (b) parent gesture and child vocabulary and (c) children's extending gestures and parent language during the referential communication task.

5.5. Discussion

This paper investigated the frequency of parent gestures in both a narrative monologue task and an interactive problem solving task and considered the extent to which parents adapted their use of gesture to differing task demands and their child's language competence. The key findings are that parents of children with DLD gestured at a significantly higher rate than parents of TD children, but only during an interactive problem solving task. The function of parent gestures also differed across the two tasks; more redundant gestures were produced in the narrative task and more extending gestures were produced during the interactive task for parents across all three language groups. In addition, parent gesture rate during the referential communication task was positively correlated with child gesture rate, but negatively correlated with child vocabulary. Finally, children's use of extending gestures was positively associated with the number of words produced by parents during the referential task. I consider the implications of these findings in relation to each of the stated research aims below.

5.5.1. Do parents modify gesture use depending on their child's language ability and/or task demands?

Few studies have considered the role of parent gesture in atypical language development. The present study confirmed the initial hypothesis that parents of children with DLD would gesture more frequently than parents of TD peers. However, this difference was only significant in a task that involved interactive problem solving, where successful communication was key to accomplishing the task. A second novel finding is that whilst the LL children appeared to have intermediate language scores, on key gesture tasks their parents resembled parents of children with more significant language needs. It is likely that many children in the LL group have resolved early language delays; if so, the findings are consistent with Grimminger et al. (2010) who reported that parents of children with language delay gesture more frequently than parents of TD children during complex tasks.

At first glance, these findings appear to contradict Lavelli et al. (2015) who found no significant group differences in parental gesture rate, regardless of child language status. However, Lavelli et al. (2015) do report a trend for parents of children with DLD to gesture at a higher rate than parents of TD peers. Also, they reported that parents of children with DLD produced more utterances that combined gesture and speech than parents of TD children, suggesting that parents were using gesture as a means to support verbal communication. One explanation for the disparity in findings is how gesture was measured. Lavelli et al. (2015) measured gesture during shared book reading, whereas the current study used a more complex goal orientated task. The current study indicates that task demands may influence how frequently parents use gesture with their children, especially if their children have language and communication difficulties.

Consistent with previous studies of TD children and their parents, I found that parents of all three language groups produced gestures that predominantly reinforced the verbal message (Iverson et al., 1999; Özçaliskan & Goldin-Meadow, 2005). Such gestures are thought to support a child's understanding of their spoken utterance by representing information in dual modalities, highlighting salient information and focusing attention (Iverson et al., 1999). Taken together, these findings indicate that parents are sensitive to their child's language needs and adapt their behaviour accordingly, but that direct feedback from their child increases use of gesture in a compensatory way.

In the current study, parents used proportionately more redundant gestures during narrative recall relative to referential communication, during which more extending gestures were used. In addition, there was a trend for parents of LL and DLD children to produce proportionately more extending gestures during the referential communication task than parents of TD children (cf. Grimminger et al. (2010). This suggests that gesture may be employed for different purposes in each task. During narrative recall, gesture may serve to highlight salient information, reinforce the verbal message, and increase the child's attention and engagement by making the story more animated. Conversely, the referential task was a more complex, interactive task in which parents and children must successfully communicate to achieve their goal. In this situation, extending gestures could serve to "lighten the cognitive load" (Goldin-Meadow et al., 2001) by providing additional, non-verbal semantic cues to help solve the task.

5.5.2. Are the relationships between parent gesture and child gesture and child language similar across different language ability groups?

In the current study, parents who gestured more frequently tended to have children who gestured frequently, a pattern seen across all three language groups. This is consistent with a body of research documenting parent-child gesture relationships in much younger TD children (Iverson et al., 1999; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008; Tomasello & Farrar, 1986). My findings suggest that children with DLD are as able as TD peers to observe parents using gesture to communicate and to adopt that strategy themselves. Importantly, increased child gestures was also associated with more severe child language impairment. Thus, recognition that gesture is a useful communicative tool may go some way to facilitating communication, even when verbal skills are limited.

A different relationship, however, was observed between parent gesture and child language. During the interactive problem solving task, increased frequency of parent gesture was associated with more severe child language (vocabulary) impairment, partially supporting my initial predictions. My findings are in line with Lasky and Klopp (1982) who also reported a negative relationship between parental non-verbal communication (facial expression, body posture, action, demonstration, gesture and imitation) and child language ability. However, I did not observe a positive relationship between parent gesture and child vocabulary within the TD group, as expected based on extensive work with younger TD children (Iverson et al., 1999; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). There are at least two reasons for this apparent inconsistency; first, previous studies have focused on early parent-toddler gesture and relationship to language skills in the pre-school years. With regard to age, my study is in line with Goodwyn et al. (2000), who experimentally manipulated parent gesture and found that the early observed advantages of parent gesture on child language ability at age 11 months did not persist at 6 month and 12 month follow-up visits. Together, these findings suggest that the relationship between parent gesture and child language may be most evident in the earliest stages of child language development before spoken language is established. Furthermore, the findings of the current study suggest that in older children, gesture may be used as a strategy to support language production and comprehension. Over the course of development, the use of gesture in relation to language learning may change and take on a different role, especially when communication is difficult.

A second reason for discrepant findings may be that different indices of parent gesture are employed in different studies. For example, studies with infants have measured gesture by the total number of gestures, focused exclusively on deictic gestures, or gesture vocabulary (defined as number of different gestures) (Iverson et al., 1999; Rowe & Goldin-Meadow, 2009a; Rowe et al., 2008). Whereas, the current study and studies of older children (Lavelli et al., 2015) have typically used gesture frequency (number of gestures per 100 words or number of gestures per minute) as the dependent variable. It is possible that different gesture metrics relate to language in different ways. Due to the limited language of young children it would be difficult to measure gesture frequency with infants. However, future research could explore gesture vocabulary in school-aged children to determine whether this aspect of gesture is more closely linked to language development.

5.5.3. Are child gestures associated with the amount of verbal language parents provide?

Studies of TD children have indicated that the role of parent gesture on child language is indirect, exerting an influence on language development through its effects on child gesture (Rowe et al., 2008). A puzzle for researchers then has been to understand the mechanisms through which child gesture acts on child language development. An influential theory has been that child gesture matters because it elicits responses from parents that provide verbal labels for the concepts and structures that children are attempting to convey through gesture (Goldin- Meadow et al., 2007). In the current study, I asked whether increased use of child extending gestures, or gestures in isolation would elicit more verbal information from parents. Extending and isolated gestures involve gestures for which the verbal equivalent is not produced. Furthermore, extending gestures allow children to produce more syntactically complex utterances (Stefanini et al., 2007), something which might be particularly challenging for children with DLD. Indeed, I did observe significant positive correlations between the number of child extending gestures and the total number of words that parents provided. These findings suggest a reciprocal relationship in which parent gesture reflects the child's language learning needs, but child gestures signal to parents more specifically what those learning needs may be. Further investigation into this relationship could determine how semantically contingent parents' verbal responses are to their child's extending gestures, something that I am currently investigating. Nevertheless, the findings with children of varying language abilities echo earlier findings, which suggest that parent gesture signals to children that gesture is a useful communication strategy, and that the verbal responses of parents to child gesture fill in linguistic gaps and ultimately drive language development, particularly in the early stages of language growth and when language learning is more challenging.

5.5.4. Summary and conclusions

The findings indicate that at this age and with a diverse group of language learners, parent gesture is as much driven by the child's language needs as it is driving child language development. Similarly, the relationships we see indicate that all children, including those with DLD and LL, may use gesture to alter the verbal messages that their parents provide. It is worth highlighting that this study clearly shows that parents of children with DLD use gesture to the same extent (if not more) than TD parents, and are sensitive to their children's language learning needs. In this population, gestures serve to compensate for oral language weaknesses and maximise communication success. Thus, increased use of gesture is most evident when communicative demands are high and parents receive direct feedback about their child's communication challenges. When necessary, supporting parents to recognise a child's communicative attempts in gesture, and providing appropriate verbal labels to reinforce the gestures, may be a powerful tool in continuing to develop language skills in children with DLD.

Chapter 6: How do parents of school-aged children respond to their children's extending gestures?

6.1. Abstract

Gesture plays an important role in children's early language development and how parents respond to their children's gestures may play a role in facilitating language acquisition. In early childhood, parents are observed to translate the majority of children's pointing gestures into spoken words. Less is known about whether parental responses continue to facilitate language learning in later childhood and also whether parent verbal responses to gesture vary depending on the language ability of their child. The aim of the current study is to explore parental responses to extending gestures in a sample of school-aged children with developmental language disorder (DLD, n=21) in comparison to typically developing (TD) peers (n = 18) and peers with low language (LL) and educational concerns (n=21). Overall there were no group differences in the types of responses parents provided to extending gestures. In contrast to early childhood, I observed more varied responses to children's extending gestures. Parents predominantly responded with positive feedback, but also displayed moderate proportions of verbal translations and requests for clarification. Within the DLD group, the proportion of parent translations was negatively associated with language ability. Thus, parents produce proportionately more translations for children who have the most severe language disorders. Exploration of children's responses to parents' verbal translations indicated that children rarely repeat the translated word. The results suggest that there is more variation in how parents respond to their children's gestures later in childhood. In addition, the findings suggest that parent translations serve to check understanding and engage children in tasks, but there is limited evidence that they support language learning at this age.

6.2. Introduction

In typical development children express words through gesture approximately three months before the verbal equivalent emerges in speech (Iverson & Goldin-Meadow, 2005). Gestures not only predate but also predict verbal language abilities (Rowe & Goldin-Meadow, 2009a, 2009b). For example, Rowe and Goldin-Meadow (2009a) reported that children's gesture vocabulary at 14 months predicted children's oral vocabulary level at 52 months. More specifically, it has been reported that children's early deictic gestures are related to the development of nouns (Iverson & Goldin-Meadow, 2005). Studies of early language development focus on deictic gestures as these are the most prevalent at this age; however, other gesture types which emerge later and synchronise with speech may also play a role in language development. These findings prompt questions about the mechanisms by which these early gestures facilitate language learning, and also, whether the mechanisms that underpin gesture's role in language learning extend beyond deictic gestures.

6.2.1. Gesture development throughout childhood

Children's first gestures are deictic gestures which emerge between 10-12 months (Bates et al., 1979), followed by representational gestures around 12 months. Later in development children continue to show a preference for deictic gestures which begin to integrate with spoken language around 2-3 years of age (Iverson, Capirci, & Caselli, 1994; Tellier, 2009). Between the ages of 3-5 years, the frequency of representational gestures increases dramatically and becomes synchronised with speech (Tellier, 2009). As children's language becomes more complex, so does their use of gesture. For example, increasingly representational gestures are produced with adjectives and verbs rather than nouns, (Capone & McGregor, 2004).

Studies of school-aged children indicate that they continue to produce gestures alongside speech and these gestures often reveal information that is not present in speech (Breckinridge Church & Goldin-Meadow, 1986). In addition, six year old children produce fewer gestures during narrative re-telling than both 10 year olds and adults. This indicates that gesture use continues to change and develop throughout childhood and into adulthood (Colletta, Pellenq, & Guidetti, 2010). However, given that many studies of gesture use in later childhood focus on narrative or problem solving tasks, it is difficult to directly compare them with observational studies of infant gesture, raising the question of how different gesture types uniquely influence language.

It is possible that pointing and representational gestures facilitate language learning in different ways. For example, deictic gestures map closely to the intended referent, and are less cognitively demanding, as one gesture can be used to refer to multiple referents (Özçalışkan et al., 2016). Representational gestures on the other hand, use symbols to represent referents, and these gestures vary in form and function dependent on the referent, making them more complex to produce and comprehend. Özçalışkan et al. (2016) reported that pointing gestures were related to later vocabulary, but other types of gestures (conventional and 'give' gestures) were not. Unfortunately, due to participant age (18 months), the incidence of representational gestures was too low to explore the relationship between representational gestures and later language in this study. However, it has been proposed that representational gestures have a different relationship with language (Özçalışkan et al., 2014). Özçalışkan et al. (2014) demonstrated that rather than preceding the onset of early verbs, iconic gestures depicting actions develop six months after the emergence of verbs. At first glance this suggests that iconic gestures do not facilitate verb development. However, the production of verbs and iconic gestures increase in frequency between 22 and 26 months, and at this time iconic gestures begin to express information that is not in speech. For example, 42% of action meanings expressed in gesture were unique to gesture, thus helping children express action meanings that they could not express verbally with a verb. Taken together this indicates that representational gestures may help to facilitate vocabulary growth (in particular verbs), but only after children have acquired knowledge about verbs and are already producing them (Özçalışkan et al., 2014).

6.2.2. How may gesture facilitate early language acquisition?

One hypothesis is that early pointing gestures encourage joint attention and can be used by parents to draw children's attention to objects and vice versa (Trevarthen, 1998). As joint attention often elicits verbal labelling, gesture may indirectly facilitate word learning by encouraging joint attention (Tomasello & Todd, 1983). A second hypothesis is that gestures enable children to produce and practice complex linguistic structures that they are not yet able to verbalise through the use of 'extending gestures' (Ozçalişkan & Goldin-Meadow, 2005). For example, children can point to a ball and say 'dog' before they are able to say 'the dog's ball' in speech alone. Indeed children's early abilities to produce these gesture-speech combinations predicts the onset of two word combinations (Iverson & Goldin-Meadow, 2005) and also their ability to produce complex sentences (Rowe & Goldin-Meadow, 2009b). However, those children who find producing gesture-speech combinations easy may also subsequently learn two word combinations more readily. Thus early gestures may be a marker for language learning potential, rather than causally related to language learning.

Alternatively, gesture may facilitate word learning more directly by eliciting communication from adults (Goldin-Meadow et al., 2007). For example, if a child points to a bird and says "fly" and the parent says "yes, birds fly", the parent is not only providing a verbal label, but also a verbal model for how the sentence should be structured. In early childhood, it is common for parents to provide verbal labels in response to their child's pointing gestures (Olson & Masur, 2011). Parents not only translate the majority of their child's extending gestures, but these verbal responses are also realised in later vocabulary (Goldin-Meadow et al., 2007; Masur, 1982). Goldin-Meadow et al. (2007) observed parent-child dyads of ten TD infants from 10 months to 24 months. They reported that gestured items that were translated into words by parents were more likely to enter the child's spoken lexicon relative to words that were not translated. When considering gesture-word combinations, they also reported that extending gestures (point at cup and say 'drink') elicited longer responses than redundant gestures (point at cup and say 'cup'). One explanation for this is that extending gesture-speech combinations contain more information than redundant gesture-speech combinations. This suggests that parents incorporate information from both gesture and speech, when responding to their child (Goldin-Meadow et al., 2007). Thus children's extending gestures not only elicit verbal labelling, but may also elicit richer verbal responses. Indeed, children whose mothers produced a high proportion of translation responses were the first to produce two-word combinations (Goldin- Meadow et al., 2007).

It is probable that many factors contribute to the influence of gesture on language development and these theories may not be mutually exclusive. Indeed, Goldin-Meadow et al. (2007) concluded that gestures may indicate that a child is ready to learn a particular word; the gesture elicits a verbal response from a parent, which helps to facilitate language learning. Although Goldin-Meadow et al. (2007) demonstrated that gestures not translated are less likely to enter a child's vocabulary, it could be that without parental input this process simply takes longer. Thus parental responses may facilitate more rapid language growth.

Dimitrova, Özçalışkan and Adamson (2015) demonstrated a similar advantage of parental translations for young children (20-40 months) with developmental disorders. Dimitrova et al. (2015) observed parent-child dyads of typically developing children, children with Down syndrome (DS) and children with autistic spectrum disorder (ASD), all matched for expressive language. Dimitrova et al. (2015) reported that for all groups, parents predominantly responded to their child's gestures with verbal responses, and the majority of these verbal responses were translations (TD=74%, ASD=77%, DS=82%). Furthermore, items translated by parents were more likely to enter the child's vocabulary than items not translated, a pattern seen for all groups. Dimitrova et al. (2015) highlight both that parents' verbal translations can help facilitate word learning in children with developmental disorders and that parents of TD, ASD and DS children responded in similar ways to their children's gestures. Whilst Dimitrova et al. (2015) have examined parent responses in relation to two developmental disorders, their groups were matched on expressive language and so it is difficult to establish whether the language difficulties that are commonly associated with these disorders impact on parent responses. In addition, they do not report non-verbal abilities of their groups, so it is unclear whether the groups were also matched for mental age, or how varied the non-verbal abilities of the groups were. As NVIQ is associated with more pervasive developmental deficits, if groups were also matched for non-verbal abilities, this may limit the extent to which findings can be generalised to children across the whole spectrum of these disorders.

Given that children with language disorder express more unique information through extending gesture than their peers (Blake et al., 2008; Evans et al., 2001;

Iverson & Braddock, 2011; Wray, Saunders, McGuire, Cousins, & Norbury, 2017), it is an open question whether parent responses to gesture provide language learning opportunities for children with language deficits.

Previous investigations by Goldin-Meadow et al. (2007) and Dimitrova et al. (2015) only focused on very young children. This is limiting as the children observed were predominantly producing deictic and ‘give’ gesture. As a result, the extent to which other gesture types elicit responses from parents is unknown. In addition, we currently do not know how parents respond to their children’s gestures in later childhood. As gesture continues to develop throughout childhood, it is possible that the kinds of gestures older children engage in elicit responses from parents that may further language development.

One question that has not previously been addressed is how children subsequently respond to parent translations of their gestures. Children’s ability to imitate the verbal input they are exposed to relates to later vocabulary (Masur, 1995; Masur & Eichorst, 2002). For example, Masur and Eichorst (2002), observed parent child interaction at 13, 17 and 21 months. They reported that, children’s imitation of novel words at 13 months was significantly related to later vocabulary (17 and 21 months), even when children’s early language ability was controlled. This suggests that children’s spontaneous imitation of new words may help to facilitate vocabulary growth. This raises the question of whether parent translation facilitates word learning because children repeat the translated word, making it easier for that word to enter their verbal lexicon. However, Masur and Eichorst (2002) also highlighted that some children who did not imitate novel words still showed significant increases in vocabulary, indicating that word imitation is not the only mechanism involved in word acquisition.

A final outstanding issue is that previous studies have coded parent responses as either translations or non-translations and do not provide further detail about non-translation responses. Such responses may further facilitate language acquisition by providing general feedback or praise, which may serve to keep children attentive and engaged in the interaction.

The current study investigated the full range of parent responses to extending gestures in school-aged children with varying degrees of language proficiency. The study had three aims; first I explored the types of responses school aged children's gestures elicited from parents and asked whether parents of children with developmental language disorder (DLD) respond to their children's gestures in the same way as parents of typically developing (TD) children and children with low language (LL) and educational concerns. I predicted that first parents of all groups may produce more varied responses in contrast to those reported with younger children, due to differences in the types of gestures children produced and different task demands. In addition, I predicted that parents of children with DLD and LL would produce proportionately more translations than parents of TD children, to help support their child's language and communication needs. In addition, I predicted that parents of children with DLD would be likely to produce more requests for clarification, given that these groups produce less accurate hand gestures than their peers (see Chapter 4). My second aim was to explore the relationship between parent translations and language ability in school-aged children. I predicted that parents who produced more gesture translations would have children with more severe language difficulties, reflecting parents' use of verbal strategies to facilitate communication. My third aim was to examine how children respond to parental translations. I was particularly interested in the extent to which children in all groups repeat the translated words or phrases, which I considered would be evidence of active attention to the parent response that could facilitate language learning.

6.3. Method

6.3.1. Recruitment

Children were recruited as part of the Surrey Communication and Language in Education Study (SCALES), a population study of language disorder at school entry (Norbury et al., 2016). Reception class teachers completed the Children's Communication Checklist-S, (CCC-S, a short-form of the CCC-2, Bishop, 2003) for 7,267 children aged 4-5 years old in state-maintained schools in Surrey, a county in South East England (Stage 1). From this screen, the bottom 14% (stratified by season of birth and gender) of children were classified as high-risk (HR) for language disorder, whilst children scoring above this threshold were classified as low-risk (LR) of DLD. Following this, 529 monolingual children took part in an in-depth assessment of language, non-verbal cognition and motor skills in Year 1 of school (ages 5-6 years; 329 HR and 200 LR children, see Norbury et al., 2016, for details). For the current gesture study, I aimed to visit approximately 10% of the total in-depth cohort, over-sampling high-risk children at a ratio of 2:1. One hundred and thirty families were contacted, and invited to take part in the study; 50 families did not consent and a further eleven families initially consented, however suitable arrangements could not be made for the home visit. Sixty-three monolingual parent-child dyads (61 mother-child) consented and were observed for this study. There were no statistically significant differences between those families who opted in and those that opted out, on measures of social economic status, t (111) = -.08, p=.937, d=.02, speech and language concerns, χ^2=1.06, p=.304, or high-risk status, χ^2=1.58, p=.209 (Opt-in: 41 high-risk; Opt-out: 38 high-risk).

6.3.2. Defining Groups

Prior to home visits for the current study, children completed an in-depth test of language and cognitive function at their school with a trained member of the SCALES research team. A total language composite score was derived from tests of expressive and receptive vocabulary (Brownell, 2010); receptive and expressive grammar (Bishop, 2003; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011); narrative retelling and comprehension (Adams, Cooke, Crutchley, Hesketh, & Reeves, 2001). The core language battery consisted of tests that did not have current UK standardisations, either because they were standardised in North America, or were recently developed. Furthermore, co-standardising measures allows for direct comparison across measures. I therefore adjusted raw scores for child age using the full weighted SCALES sample (see Norbury et al. 2016 for details of this procedure). Children were categorised as DLD (n = 21) if their total language composite z-score was 1SD below the SCALES population mean. Typically developing (TD) children (n = 18, 8 males) were low-risk at screen and scored within the normal range on the total language composite. Twenty-one children were high-risk at screen, indicating communication skills -1SD below the normative mean at school entry, but scored within the normal range on the total language composite a year later. These children obtained intermediate total language composite scores that were significantly lower than TD peers, and significantly higher than children with DLD (Table 6.1). In addition, eight of these children are receiving special education support at school and six had previously been referred to speech-language therapy services. Due to their history of language and communication concerns and ongoing special educational needs, they were not combined with the TD group, but instead formed an intermediate group of children with low language (LL) and educational concerns (n=21, 9 male). Including this intermediate group ensured that I could explore gesture use in relation to language across the whole spectrum of language abilities.

Table 6.1.

Means (SD) of background measures for children in each language group.

Measure	TD (n=18)	LL (n=21)	DLD (n=21)	F	*p*	η^2
Age (months)	87.50 (5.53)	89.00 (5.11)	89.19 (5.54)	.56	.575	.02
Non-verbal ability	29.00[a] (4.86)	26.48[a,b] (3.57)	24.19[b] (3.68)	6.88	.002	.51
Language composite	.61[a] (.81)	-.40[b] (.45)	-1.67[c] (.62)	61.49	<.001	.68
Vocabulary composite	174.11[a] (20.07)	154.05[b] (10.64)	129.71[c] (14.81)	40.76	<.001	.59

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. All means are raw scores other than the language composite which is reported as a z-score. Different superscripts within the same row indicate differences between group means that are significant at $p < .05$. The language composite score was derived from tests of expressive and receptive vocabulary; receptive and expressive grammar; narrative retelling and comprehension. The Vocabulary composite combines expressive and receptive vocabulary scores.

6.3.3. Procedure

6.3.3.1. Referential Communication Task

In this task, parent and child sat opposite each other and both had a board in front of them which the other person could not see, though they could see each other. Children and parents performed both describer and listener roles across four trials, which was counterbalanced across participants. The child always started in the describing role and this alternated thereafter. The describer was given a board with eight animal pictures (either cats, dogs, mice or rabbits) displayed in a specific order on a 4x2 grid. The listener was given a blank board and 12 cards which included the eight target cards and four distractor cards. The describer was instructed to describe the pictures on each of their cards and the order they appeared on their board so that the listener could locate the correct card and place it in the correct position. Parents and children were free to communicate naturally throughout the task.

All drawings were in black and white and were designed to be visually similar, to ensure that pictures could not be identified with one description and to encourage participant discussion. For example, a child could not just say "the cat with the pointy ears" as there would be multiple cats with pointy ears (see Appendix B). All sessions were video-recorded and coded off-line.

For the current analysis, only data obtained when the child was in the describing role was included; parent and child gesture data are reported in detail elsewhere (Chapter 5).

6.3.4. Verbal transcription and gesture coding

Verbal dialogue was transcribed using Systematic Analysis of Language Transcripts software (Miller & Iglesias, 2012). Gestures were coded from the videos by myself and a trained research assistant using Observer XT software (Grieco et al., 2013). The number of different gesture types produced by children during each of these tasks were coded. Gesture types included: *Deictic gestures*, or pointing gestures used to draw attention to a particular object, person or location in the environment; *Representational gestures*, which show a close relationship to the object, action, idea or concept that they refer to (e.g. making a circular shape with hand to represent a ball); *Conventional gestures* which are culturally specific and convey meaning without the need for speech (e.g. nodding to symbolise yes); and *Beat gestures*, rhythmic movements which emphasise aspects of speech (McNeill, 1992).

Gesture function was also coded as either extending or redundant. *Extending gestures* included gestures that were produced with speech but which added extra information (e.g. "the cat had a tail like that", whilst simultaneously producing a curly tail gesture) and also gestures produced in isolation, in the absence of the verbal equivalent. *Redundant gestures* included gestures that reinforced the spoken message; although these gestures may highlight important aspects of an utterance, they do not add extra information to the utterance (e.g. "the cat had a curly tail", whilst simultaneously producing a curly tail gesture).

6.3.4.1. Parent Responses

Parental responses to children's extending gestures were then coded. First the modality of each response was coded as either verbal, non-verbal or bimodal (both verbal and non-verbal). Following this, all verbal responses were categorised (see appendix F for examples). I was particularly interested in whether parent responses were *translations*, *requests for clarification* or *positive feedback.* In addition to this coding revealed other responses that were too rare for formal analysis, these included *prompt for the verbal equivalent* and *verbatim repetition* of child's utterance (see Table 6.2). Parents also produced *'other' verbal* responses (e.g. response unrelated to child's utterance), which although did not occur often, my observations were that 'other' responses may reveal something interesting about the DLD group and so were included.

The percentage of verbal, nonverbal and bimodal responses were calculated (number of verbal responses/total number of extending gestures). Following this, the percentage of each verbal type was calculated (e.g. number of translations/total number of verbal responses), this included both verbal alone and bimodal responses.

Table 6.2.

Percentage of each verbal response across the whole sample

	Translation	Request clarification	Positive feedback	Prompt for verbal equivalent	Verbatim repetition	'Other' verbal
Percentage	18.39 (20.5)	22.04 (19.83)	47.96 (26.06)	1.86 (6.08)	3.23 (7.49)	6.51 (11.21)

6.3.4.2. Child Responses.

Finally, children's responses to parent translations or requests for clarification were coded. Translation responses were coded as either: repetition of the translated word, 'yes or' no response, continue with the task (no verbal response), or correction of the translated word (see appendix G for examples).

Request for clarification responses were coded as either: 'yes or no', add information, unrelated response, or no response. As additions and unrelated responses were rare they are not included in the following analysis.

6.3.5. Reliability

Ten percent of participant videos were double coded, blind to the child's diagnostic group. Disagreements were resolved through discussion. The inter-reliability indicated good reliability for all verbal response categories: Translation (83.33% agreement, kappa=.75), prompt for verbal equivalence (100% agreement, kappa=1.00), request for clarification (83.33% agreement, kappa=.75), positive response (93.3% agreement; kappa=.79), verbatim repetition (100% agreement, kappa=1.00), and 'other' responses (100% agreement, kappa=1.00)

6.4. Results

6.4.1. Data Analysis plan

Analysis focused on differences in parent responses to children's extending gestures, in relation to child language ability. A series of ANOVAs compared language groups on the proportion of parent responses to children's extending gestures and children's responses to parent translations and requests for clarification. As data were proportional, an arcsine transformation was used for all analysis. Untransformed percentages are reported in the text and graphs. Cohen's *d* effect sizes are reported and interpreted as an effect size of .2 is a small effect, .5 a medium effect and .8 a large effect (Cohen, 1988).

6.4.2. Child gesture

On average, 36% of children's gestures were extending gestures, M_{TD}=32.61% (SD=14.50); M_{LL}=28.14% (10.65); M_{LI} =49.20% (SD=23.78). Overall the most common gesture type was representational gestures, 66.84% of children's extending gestures were representational. As reported previously (Chapter 4) there was a main effect of group on gesture function, $F(2, 56) = 8.40$, $p = <.001$, η_p^2 =.23 as children with DLD produced significantly more extending gestures than either the TD (p=.030, d= .84) or LL (p=.002, d= 1.15) groups. One child in the DLD group did not produce any extending gestures and was excluded from the following analysis. As the DLD group produced proportionately more extending gestures than the TD group, parent response comparisons were analysed as a percentage of responses within each category.

6.4.3. Do children's gestures elicit verbal responses?

First I considered the proportions of parental verbal, non-verbal, bimodal and no responses. There was considerable variation in parent responses, but parents of all groups most commonly provided a verbal response to child gesture, M_{TD}=57.90% (SD=22.54); $M_{LL=}$47.46% (17.86); M_{LI} =54.67% (SD=22.87). However, they frequently did not respond at all to children's extending gestures, M_{TD} =37.70% (SD=21.13); M_{LL}=38.39% (20.47); M_{LI} =37.41%, (SD=19.68). Solely non-verbal responses were extremely rare; when parents used non-verbal cues they were almost always accompanied by speech. There were no group differences in the proportion of verbal ($F(2,59)$=1.01, p=.370, η_p^2=.04), non-verbal ($F(2,59)$=.01, p=.988, η_p^2 =.01), bimodal ($F(2,59)$=.70, p=.503, η_p^2=.02) or no responses ($F(2,59)$=.997, p=.375, η_p^2=.03) made by parents (see Table 6.3 for raw scores).

Table 6.3.

Mean (SD) raw scores of total parent responses to children's gestures.

	Total number	Whole sample (n=59)	Range	TD (n=18)	LL (n=21)	DLD (n=20)
Verbal response	451	7.64 (5.47)	0-24	7.44 (6.66)	6.81(4.48)	8.70 (5.34)
Non-verbal response	9	.15 (0.58)	0-4	.22 (.37)	.10 (0.3)	.15 (.69)
No response	308	5.22 (5.48)	0-28	3.33 (2.38)	5.57 (4.83)	6.55 (7.52)
Bimodal response	47	.80 (1.32)	0-28	.67 (1.37)	.62 (.92)	1.10 (1.62)

Note. TD: typically developing, LL: low language, DLD: developmental language disorder.

6.4.4. Are parents using language that is beneficial to language learning?

Next I considered the type of verbal responses produced, and included both verbal only and bimodal responses. Parents of all groups were most likely to respond with positive feedback, M_{TD}= 49.14% (SD=25.21), M_{LL}= 52.13% (SD=28.69); M_{LI}=42.59%, (SD=24.20). Less commonly, parents produced requests for clarification, M_{TD} =16.62% (SD=15.9); M_{LL}= 23.55% (SD=23.63), M_{LI} =25.05% (SD=18.46) and direct verbal translations, M_{TD} =23.62% (SD=27.98); M_{LL}=23.56% (SD=23.63); M_{LI} = 18.14% (SD=16.79) (see table 6.4 for raw scores). Other responses (repetition, prompts for verbal language, other) were exceedingly rare. Groups did not differ in the proportion of responses that provided positive feedback (F(2,55)=.64, p=.531, η_p^2=.02), request for clarification (F(2,55)=1.25, p=.296, η_p^2=.04), or translations (F(2,55)=.77, p=.467, η_p^2=.03). There was a borderline effect of language group for 'other' verbal response (F(2,55) = 2.97, p =.060, η_p^2=.10). There was a trend for parents of children with DLD to produce proportionally more 'other' responses than parents of TD children (M_{TD} =3.06%; M_{LI}=10.24%); these generally included utterances focused on child behaviour, such as asking the child to look or sit down. Thus parents of children with DLD may spend proportionately more time managing behaviour than parents of TD children.

Table 6.4.

Mean (SD) raw scores for each type of parent verbal responses

	Total	Whole Group	Range	TD	LL	DLD
Positive Feedback	230	3.90 (3.45)	0-19	4.11 (4.59)	3.71 (2.69)	3.9 (3.13)
Translation	87	1.48 (1.59)	0-7	1.5 (1.5)	1.19 (1.25)	1.75 (1.97)
Request clarification	120	2.03 (2.06)	0-8	1.78 (2.34)	1.71 (1.59)	2.6 (2.21)
Prompt for verbal equivalent	9	.15 (.41)	0-2	0.17 (.51)	0.19 (0.4)	.10 (.31)
Other verbal	35	.59 (.95)	0-4	.28 (.58)	.48 (1.03)	1.00 (1.03)
Verbatim repetition	17	.29 (.67)	0-3	.28 (.46)	.14 (0.48)	.45 (.94)

Note. TD: typically developing, LL: low language, DLD: developmental language disorder.

6.4.5. How are parental verbal responses related to child language ability?

Next I explored the relationship between translations and request for clarification in relation to language abilities. Given the wide variation, those that never translate (n=21) or never request clarification (n=16) were excluded. This enabled me to focus on the parents who did produce these responses, and whether these responses were related to language.

As demonstrated in Table 6.5, across the whole sample, vocabulary was not significantly related to the proportion of parent translations, requests for clarification, positive reinforcement or other responses. When analysing groups separately, these non-significant results remained with the exception of the relationship between parent translations and vocabulary within the DLD group. Table 6.5 demonstrates a significant negative association between parent translations and vocabulary, $r(15) = -.741$, $p=.002$, for parents responding to children with DLD.

Table 6.5.

Correlation matrix indicating the relationship between vocabulary and parent responses.

Parent Response	Whole sample	TD	LL	DLD
		Vocabulary		
Translation	.011	-.037	-.142	-.741**
Request for clarification	-.096	-.284	-.253	-.071
Positive response	.107	.390	-.217	-.013

Note. TD: typically developing, LL: low language, DLD: developmental language disorder. **$p<.001$.

6.4.6. Do children actively acknowledge their parent's verbal responses?

Due to the small numbers of child responses, the following section provides descriptive statistics only. Following a translation, children frequently either acknowledged the translation with a 'yes or no' response, M_{TD}=36.36% (SD=40.01); M_{LL}=55.56% (SD=45.13); M_{LI}=44.13% (SD=44.94) or continued with the task without acknowledging their parents input, M_{TD} =45.45% (SD=42.22); M_{LL}=23.61% (SD=39.22); M_{LI} =34.92%, (SD=40.80). There were few instances of children actually repeating the translated word, M_{TD} =8.33% (SD=20.75); M_{LL}=12.50% (SD=31.08); M_{LI} =6.67%, (SD=6.14), or correcting a parent's incorrect translation M_{TD} =9.84% (SD=17.80); M_{LL}=8.33% (SD=18.69); M_{LI} =14.29% (SD=28.07) (see table 6.5 for raw scores).

Following a request for clarification, children in both groups predominantly responded with a confirmatory 'yes or no' response, M_{TD}=53.75% (SD=38.21); M_{LL}=27.60% (SD=32.59); M_{LI} =50.74% (SD=32.22) or added further information, M_{TD} = 42.08% (SD=36.98); M_{LL}=54.69% (SD=41.72); M_{LI} =37.25% (SD=31.78). Contrary to their responses to translations, TD children always provided a verbal response to a request for clarification and similarly, LL and DLD children rarely did not respond at all, M_{LL}=2.08% (SD=8.33); M_{LI} =8.09% (SD=17.08).

Table 6.6.

Mean (SD) raw scores for children's responses to parent translations and request for clarification.

Parent Response	Child Response	Total	Range	Whole Group	TD	LL	DLD
Translation	Yes/No	37	0-4	.63 (.95)	.50 (.86)	.67 (.97)	.70 (1.03)
	Repetition	9	0-2	.15 (.48)	.17 (.51)	.14 (.48)	.15 (.49)
	Correction	11	0-2	.19 (.43)	.17 (.38)	.14 (.48)	.25 (.44)
	No Response	29	0-4	.49 (.89)	.67 (1.08)	.24 (.54)	.60 (.99)
Request	Yes/No	53	0-5	.90 (1.15)	.94 (1.39)	.57 (.87)	1.2 (1.15)
	Add	54	0-5	.92 (1.13)	.72 (1.02)	.86 (1.01)	1.15 (1.35)

Note. TD: typically developing, LL: low language, DLD: developmental language disorder.

6.5. Discussion

This study is the first to explore parent responses to school-aged children's gestures and the extent to which these responses are related to children's language ability. Overall, there were no group differences in the types of responses parents provided to extending gestures. In contrast to early childhood, I observed more varied responses to children's extending gestures, with all parents predominantly responding with positive feedback. In addition, translations and requests for clarification were also observed. Across the entire sample, the proportion of parent translations was not associated with language ability. However, group analyses indicated a significant negative association for the DLD group only. Thus, parents of children with DLD produce proportionately more translations for children with the most severe language disorders. Exploration of children's responses to parents' verbal translations indicated that children rarely repeat parent translations. The implications of these findings are now considered in relation to the study aims.

6.5.1. Do school-aged children's extending gestures elicit verbal responses from parents?

Contrary to my initial prediction, parents of children with DLD and LL were as likely as parents of TD children to produce verbal responses to extending gestures. This is consistent with Dimitrova et al. (2015) who reported similarities in parental responses across children with different developmental difficulties. Over 50% of parent responses were verbal, and the most common verbal response was to provide positive feedback for the child's communication attempt. Translations and requests for clarification were the next most common responses and occurred in response to approximately one-third of children's gestures. Surprisingly, for a large proportion of opportunities (38%), parents did not respond to their children's extending gestures at all. Similarly parents of children with DLD, LL and TD did not differ in the proportions of each type of verbal response produced. Thus, parents of school-aged children produce a wide variety of responses to their children's gestures.

At first glance this seems at odds with previous research which suggested that parents respond over 90% of the time with verbal responses and that parents predominantly respond with verbal translations (Dimitrova et al., 2015). One reason for the disparity between studies may be the type of task; the current study employed a goal-orientated task in comparison to the naturalistic play settings used by Dimitrova et al. (2015). Goal-orientated tasks may elicit more praise responses from parents, in an attempt to keep their child engaged in the challenging task. This in turn would reduce the opportunity for parents to produce responses that may facilitate language development, such as translations. However, and perhaps more crucially, differences in participant ages and subsequently the gestures they use might contribute to these discrepant findings. Previous studies have focused on pointing gestures whereas the current study explored responses to all gesture types, though representational gestures were most commonly produced at this age. In addition, the incidence of extending gestures was relatively low and certainly less frequent than that observed in studies of early childhood.

Deictic gestures are closely tied to the intended referent (Özçalışkan et al., 2014), which may prompt verbal object labelling from parents more readily. Representational gestures on the other hand often express referent's shape, action or function and so these types of gestures may not as obviously elicit verbal labelling. In the context of the current task, representational gestures may elicit positive responses that indicate to the child that the intended meaning of the gesture has been understood. In contrast, deictic gesture may indicate that the child is unfamiliar with the object or object label, and therefore directly elicit responses that facilitate word learning.

Indeed some investigators have suggested that it is only deictic gesture that predicts later language abilities (Özçalışkan et al., 2016). Thus, in early language development deictic gestures may be most beneficial, while the types of responses representational gestures elicit may not drive later language development. However, the Özçalışkan et al. (2016) study considered children who were not yet producing representational gestures, so the impact of these gesture types on language development was not measured. The results suggest that children use gesture in different ways throughout childhood and that parents alter the way they respond to extending gestures as their child's language develops. Longitudinal research exploring the role of both deictic and representational gestures in children's longer term language development is needed to examine how different gestures facilitate language acquisition throughout childhood.

6.5.2. How are parental verbal responses related to child language ability?

Contrary to my initial prediction, gesture translations were not associated with language ability across the whole sample. The fact that vocabulary was not related to parent translations further supports the idea that parent responses to school-aged children's gestures differ from those reported in infant studies. Again, parent responses at this age appear to be more focused on attention and task completion rather than facilitating language development.

However, within the DLD group, parent translations were significantly negatively related to vocabulary. Thus parents of children with the most severe language disorder produced the highest proportion of verbal translations. Given that some children within the sample have profound language deficits and have difficulties producing complex multi-word sentences, this may indicate that parents of children with the most severe language disorders respond to gestures in similar ways to parents of younger TD children. Future research with younger, language ability matched comparison groups may further elucidate whether gesture patterns in DLD are simply immature, or qualitatively different to those seen in typical language development.

6.5.3. Do children actively acknowledge their parent's verbal responses?

Studies have indicated that items translated by parents are more likely to enter a child's verbal lexicon than items not translated (Dimitrova et al., 2015; Goldin-Meadow et al., 2007). To explore the mechanism behind this, I examined children's responses to parent translations. The extent to which children imitate verbal input from parents has been related to language growth (Masur, 1995; Masur & Eichorst, 2002), thus, it was predicted that children would repeat the translated word or sentence, helping to facilitate language change. However, children very rarely spontaneously repeated the target utterance; instead they were more likely to respond with a simple 'yes or no' response or not respond at all. This finding makes it more challenging to identify the mechanism by which parent translations help facilitate language learning. This study is limited in that I was not able to directly measure whether specific items translated by parents were more likely to enter a child's verbal repertoire at a later date, and whether this is more likely if children repeat the parent translation. Obviously children learn many linguistic forms that they hear, but do not actively imitate, so it is possible that exposure to translations is sufficient to facilitate language development. Future longitudinal research comparing the likelihood of translated words/phrases entering the child's language repertoire, whether or not they have actively engaged with the response, would further elucidate the mechanism by which parental translations facilitate language development. Intervention studies may provide the strongest evidence concerning the mechanism by which parent translations facilitate learning. For example, intervention studies could manipulate the semantic complexity of parent translation of extending gestures and explore the long-term language benefits this may have. In addition, interventions have the potential to help parents see extending gestures as opportunities to provide more language content, especially for those with language problems.

6.5.4. Summary and conclusions

The results demonstrate that most of the time children's extending gestures elicit verbal responses from parents. However, unlike in early childhood, parent responses did not predominantly function to facilitate language development, but rather to help facilitate children's attention and task completion. One key explanation for this may be that young children predominantly produce deictic gestures, which have been positively associated with language development. However, in older children, representational gestures are more common. Thus the findings highlight that representational gestures may be less likely to directly support language development, but may be essential in facilitating communication.

The results demonstrate that the nature of parental responses does not vary across parents of TD, LL or DLD children. However, within the DLD group, parents of children with the most severe language disorders did produce the highest proportions of gesture translations. This suggests that parents of children with the most profound language difficulties may utilise translations as a means to facilitate communication and provide optimal language models.

Although parents translate their children's gestures approximately 30% of the time, children rarely actively respond to parent translations by repeating the translated word. These findings indicate that in early childhood pointing gestures alone may facilitate language development, but in school-aged children, the types of extending gestures produced elicit rather different parent responses that may be determined more by task demands than by child language ability. In addition, child responses raise intriguing questions about the extent to which parent translations facilitate language learning in school aged children.

Chapter 7: The impact of gesture production training on children's verbal and non-verbal word retrieval

7.1. Abstract

Gesture plays an important role in children's early language development and may also help children learn new words. Less is known about whether gesture exposure or gesture production is key to facilitating language development. The aim of the current study is to assess the impact of gesture exposure and gesture production on word learning in 7-9 year old children with varying language abilities. The present study measured children's ability to learn six unfamiliar science words in one of three conditions: no gesture, gesture exposure only, or a gesture production condition in which children were encouraged to imitate target gestures. Overall there were no group differences in children's ability to verbally recall words. However, children in the gesture production condition remembered more of the target gestures and were more likely to produce gestures during picture naming. In addition, when taking children's non-verbal responses into account, children in the gesture production condition conveyed more correct words (either through gesture or speech) than children in either the gesture exposure or no gesture conditions. The results suggest that encouraging gesture production provides children with a means to express information that they are not yet able to verbalise.

7.2. Introduction

Gesture plays an important role in children's early language acquisition; children's early gesture production selectively predicts the onset of two word combinations (Iverson & Goldin-Meadow, 2005), the complexity of children's sentences, and later vocabulary (Rowe & Goldin-Meadow, 2009a). This relationship is in part influenced by the non-verbal communication children are exposed to in early childhood. For instance, Rowe, Özçalışkan, and Goldin-Meadow (2008) reported that parent gesture predicts child gesture use, which in turn predicts children's language ability.

It is also common for teachers to use gesture to support language during lessons (Flevares & Perry, 2001). Teachers' gestures improves children's ability to learn new concepts and ideas, and to understand complex instructions (Church et al., 2004; Cook & Goldin-Meadow, 2006; Cook, Mitchell, & Goldin-Meadow, 2008; Goldin-Meadow et al., 2009). For example, Church et al. (2004) reported that children had a greater understanding of the task when the lesson was given using gesture and speech together in comparison to speech alone. This is in line with the dual coding theory which suggests that information presented in two modalities helps to reinforce the message and thus facilitates learning (Clark & Paivio, 1991).

In addition, the positive effect of teacher gesture on learning may be at least partially attributable to the notion that when children observe their teachers gesturing, they too gesture more. Children who mimic their teacher's gestures are more likely to correctly solve maths problems than those that do not imitate adult gesture (Cook & Goldin-Meadow, 2006). It has been proposed that the act of gesturing helps lighten the cognitive load, leaving more available resources to solve the task (Goldin-Meadow et al., 2001). Similarly, Goldin-Meadow, Cook and Mitchell (2009) taught children to produce either a correct gesture for solving a problem, a partially correct gesture, or did not gesture at all. They reported that those children who produced either correct or partially correct gestures outperformed children who produced no gestures at all. In addition, children who produced the correct gesture outperformed those who produced only partially correct gestures. This finding supports the idea that producing gesture helps children learn new concepts and ideas, and further indicates that the more accurately children gesture, the more beneficial gesture is to task success.

The extent to which gesture helps children learn new strategies and concepts, however, may be determined by language ability. Wakefield and James (2015) asked children to produce gestures whilst learning the concept of palindromes. These gestures either matched or mismatched speech. Children in both gesture groups were more likely to learn how to solve palindromes than children who were in the speech only condition. However, when exploring learning in relation to language ability they reported that the gesture advantage was only evident for children with high phonological competence. For children with low phonological competence there was no effect of learning condition on task performance. The authors suggest that for this task, gesture was only an advantage for those children who had the baseline skills to solve the task. This may have implications for the extent to which gesture can support word learning as it suggests that conceptual knowledge may need to already be present to provide support for word learning.

7.2.1. Can we increase children's gesture production?

If gesture production supports learning and problem solving, then encouraging children to increase their use of gesture has the potential to facilitate learning. Critical questions are whether people can be taught to gesture, and what type of exposure is required to learn both the gesture and the verbal information it represents. Goodwyn, Acredolo and Brown (2000) encouraged parents of typically developing infants to either increase their verbal labelling behaviours, model symbolic gestures alongside speech, or gave no specific instruction. Children's language was measured using a variety of assessments at 15, 19, 24, 30, and 36 months. Goodwyn et al. (2000) reported that those children whose parents had been encouraged to use gesture achieved significantly higher scores on measures of receptive language at ages 19 months and 24 months. In addition, they achieved higher scores on measures of expressive vocabulary at 15 and 24 months. Children whose parents had been encouraged to gesture also demonstrated the largest gesture repertoire. However, child gesture was measured from parent report during fortnightly phone interviews, and thus may have provided a biased estimate of gesture use. For example, parents were not blind to intervention status and so those parents told to gesture may have been more likely to notice and remember the gestures compared with those not told to gesture. The fact that the gesture trained group did not show language gains at all time points suggests the extent to which gesture facilitates language development may be limited. Finally, they did not directly measure the impact child gesture had on child language and it may be that parent gesture use impacts children's language indirectly through child gesture use, as demonstrated by Rowe et al. (2008).

LeBarton, Goldin-Meadow and Raudenbush (2015) extended these findings by increasing child gesture use directly. During naturalistic play sessions, the experimenter labelled pictures of novel objects and either produced a pointing gesture, produced a pointing gesture and instructed the child to also point, or gave no additional cues. Those children who were instructed to point used more pointing gestures during the experiment and also demonstrated the greatest increase in gesture vocabulary (number of different words expressed in gesture) and spoken language development generally from baseline measures of parent-child interaction (16-18 months) to follow-up, two weeks after intervention. This study highlights two factors; first that we can manipulate children's gesture use directly, and this may have subsequent impact on their spoken communication, at least in the short term. Second, simply exposing children to gesture may not be as effective as instructing children to produce the gestures themselves, both for increasing natural gesture use and for increasing verbal production. However, due to the age of participants it is likely that children were predominantly producing pointing gestures. Thus, although all gesture types were coded as a measure of gesture vocabulary, it is questionable whether an increase in pointing at different referents is an indication of increased gesture vocabulary. Furthermore whilst this study demonstrates that gesture production may impact the amount of spoken language and non-verbal communication children subsequently use, the authors did not report whether gesture exposure and/or production enabled the children to learn the novel words. In addition, they did not include a longer term follow up. It is therefore difficult to draw conclusions about how increasing gesture use facilitates word learning and also what the lasting impact of gesture use is.

7.2.2. Gesture's role in language learning

In early childhood, gesture cues presented alongside speech have a positive impact on children's word learning. McGregor, Rohlfing, Bean, and Marschner (2009) taught typically developing two year olds the word "under", accompanied by speech and gesture, speech and a picture, or speech alone. Children in both the gesture and picture conditions learnt words faster than those in the speech alone condition; however, children only extended the word to other contexts if it was taught during the gesture condition. Consistent with this, Capone and McGregor (2005) demonstrated that young children were more successful in recalling novel words without assistance and had better knowledge of the object's function if a word had been taught with an accompanying gesture rather than speech alone.

In later childhood, similar gesture advantages have also been demonstrated. For instance, McNeil, Alibali and Evans (2000) gave preschool children either simple or complex instructions for a block building task, accompanied by either reinforcing or conflicting gestures. They reported that reinforcing gestures supported language comprehension, but only when instructions were complex. Children may therefore be more likely to rely on non-verbal cues when the verbal message is complex. In contrast, when instructions are simple and the cognitive load is light, children may have less need to draw on non-verbal cues.

Whilst these studies suggest gesture may support language learning and comprehension, they have only explored the impact of gesture exposure and not gesture production. One study which has is Tellier (2008) who taught monolingual French school-aged children six English words; one group had verbal instruction only, while the other group were instructed to produce a gesture that accompanied each word. Following training, word learning was assessed using both word recognition and picture naming tasks. Tellier (2008) reported a gesture advantage for both of these measures of word learning. However, this study did not employ a comparison group only exposed to gesture. Such a comparison group is required to ascertain whether gesture exposure is enough to support word learning or whether it is the act of gesturing which helps to facilitate word learning.

7.2.3. Word learning in relation to children with low language proficiency

To date, the majority of studies investigating the impact of gesture on language learning have focused on typically developing children, while there is a paucity of studies regarding children who have delayed language or lower levels of language competence. However, an exception is Rowe, Silverman and Mullan (2013) who studied bilingual and monolingual children with either high or low language abilities. Children were taught six novel words in three conditions; word alone, word and picture, or word and gesture. Neither the presence of gesture nor the presence of a picture had a positive impact on verbal word production for children with either high or low language abilities. However, there was a significant main effect of condition on word comprehension and a significant interaction between condition and language background (monolingual or bilingual). Bilingual children with low language abilities achieved higher scores on the comprehension task for words taught in the gesture condition, relative to monolingual children with low language. At one week follow-up, however, this group difference was attenuated. Bilingual children with high language abilities did not differ from monolingual children with high language abilities on any of the conditions. This study suggests the possibility that gesture is most beneficial for those with the lowest language abilities. However, the effects appear to be short-lived and this study did not report the impact of non-verbal cues on monolingual or bilingual children with low language in relation to more verbally able peers.

Studies that have explored gesture use in monolingual children with language disorder demonstrate that gesture use supports children's slow mapping of novel names (Lüke & Ritterfeld, 2014) and comprehension of spatial locations such as 'on' and 'under' (Weismer & Hesketh, 1993). However, gesture exposure does not appear to confer advantage for word production during fast mapping tasks. Children with low language proficiency have difficulties fast mapping new words (Alt et al., 2004; Rice, Oetting, Marquis, Bode, & Pae, 1994) and as a result gesture exposure only may not be sufficient to counteract this deficit. Crucially, however, these studies have not investigated the impact of encouraging gesture production on children's novel word learning. Thus, there is currently no evidence that gesture can be taught to children with lower levels of native language competence, or that teaching such children to gesture facilitates language learning. Such evidence is critical for developing clinical and educational practice aimed at supporting language development in more vulnerable learners.

7.2.4. Summary

Gesture plays an important role in early language development and experimentally increasing children's gesture use can have a positive impact on children's learning and subsequent gesture and language use, at least in the short term. In addition, encouraging children to produce gestures may be more beneficial to increasing gesture and oral language, compared with gesture exposure alone. Experimental studies indicate that gesture cues may help children learn novel new words, but that this facilitation may be dependent on the child's oral language abilities. The majority of these studies have included children with typically developing language, thus it is unclear how gestural cues aid word learning in children with a more diverse range of language abilities.

7.2.5. Current study

The current study investigated children's novel word learning across three conditions: gesture production, gesture exposure only, or no gesture. This work extends previous research by examining how gesture impacts word learning for children with varying degrees of language skill and also compares the impact of gesture production versus gesture exposure on children's ability to learn new words. It was hypothesised that children in both the gesture production and gesture exposure conditions would recall more novel words than children in the no gesture condition. In addition, it was predicted that only children in the gesture production condition would produce more spontaneous gestures during picture naming, which was anticipated to facilitate recall compared to children in the gesture exposure only group. Finally, it was anticipated that children with lower levels of language competence would benefit the most from gesture cues, and this might be particularly evident when they were encouraged to produce gesture.

7.3. Method

7.3.2. Training groups

As I recruited children with TD language, low language and children with DLD, children were randomly allocated within each band to one of three training groups (*No gesture*: 8 TD, 6 LL, 7 DLD; *Gesture exposure*: 7 TD, 8 LL, 7 DLD; *Gesture production*: 6 TD, 6 LL, 10 DLD). This ensured that each training group included a diverse range of language abilities (see Table 7.1). All three training groups were presented with pictures of target words accompanied by auditory verbal labels across three learning games. In the experimental condition, *Gesture Production (n=22)*, each time a target word was labelled verbally it was accompanied by a hand gesture (e.g. "here is a gadfly", whilst simultaneously producing an iconic "gadfly" gesture). Crucially, children were instructed to attend to and produce the gestures, in addition to the verbal labels during training and recall tasks.

I also included two control conditions in which children were not encouraged to gesture. In the *Gesture Exposure* group (n=22), children were again presented with gestures alongside spoken target words, but were <u>not</u> given any instructions regarding attending to or producing these gestures. In the second control condition, *Word Alone* (n=21), children were presented with verbal labels for each target picture but given no additional non-verbal cues. Including two control groups enabled me to first, compare word learning when gesture is and is not present, and second, to compare word learning when children have been encouraged to gesture in comparison to when they have just been exposed to gesture cues.

7.3.3. Procedure

Measures of oral language, non-verbal reasoning and motor skill were obtained as part of the larger SCALES battery. Children were seen at school by a trained member of the SCALES team when they were in Year 1 (age 5-6 years). Subsequently, the gesture training task was completed in the child's home by myself or a trained research assistant. During the session children were taught six new words in one of three conditions; word alone, gesture exposure or gesture production. During a series of computer based learning trials children were exposed to each of the words six times. Learning was measured through a receptive learning game, a picture naming task and a gesture recall task (for the gesture exposure and gesture production only). Each home visited lasted for approximately 30 minutes. All sessions were video recorded for later scoring and coding.

7.3.4. Background Measures

A total language composite score was derived from tests of expressive and receptive vocabulary (Brownell, 2010); receptive and expressive grammar (Bishop, 2003; Marinis, Chiat, Armon-Lotem, Piper, & Roy, 2011); narrative retelling and comprehension (Adams, Cooke, Crutchley, Hesketh, & Reeves, 2011; see Norbury et al. 2016 for details). In addition, children's non-verbal reasoning was assessed using the Wechsler Preschool and Primary Scale of Intelligence Block Design subtest (WPPSI-III; Wechsler, 2003).

Table 7.1.

Background Data for each training group.

	No Gesture	Gesture Exposure	Gesture Production	Range	F	p	η_p^2
Vocabulary raw score	157.1 (29.1)	154.77 (24.4)	146.23 (23.83)	81-221	1.07	.351	.03
Total language z-score	-0.38 (1.37)	-0.36 (1.22)	-0.84 (1.05)	-3.01-1.97	1.09	.343	.03
Block design raw score	26.48 (5.58)	26.09 (3.29)	27.00 (4.27)	16-38	.230	.795	.01

Note. Mean values with different superscripts in the same row differ at $p < .05$.

7.3.5. Gesture Training Task

7.3.5.1. Materials and Stimuli

The gesture training task was presented on a laptop computer. For each trial a colour photograph was presented along with the orthographic form and a colour video verbally labelling the picture and for gesture trials producing the gesture (see Figure 7.1 for example stimuli).

Figure 7.1. Example stimuli

7.3.5.1.1. Words

Six low-frequency words associated with secondary school (ages 11-16) Science curriculum were selected from stimuli created by Henderson, Weighall and Gaskell (2013). These words were *Smolt, Breccia, Crawdad, Troposphere, Gadfly* and *Photon*. In addition three familiar words were also used as stimuli, which included *Sun, Lion* and *Fire*. Three familiar words were included to encourage children to complete the task as it ensured that children who had difficulties learning the novel words were able to correctly identify some of the target pictures.

7.3.5.1.2. Gestures

Gestures selected were iconic in nature, see Appendix H. All gestures, with the exception of *Breccia, Lion* and *Fire* included motion. Five of the gestures were uni-manual and three were bimanual (see Appendix H).

7.3.6. Learning Phase

Prior to training, the researcher showed pictures of each word one at a time and asked if the child could name the picture. None of the children correctly named any of the six novel words, indicating that these words were unfamiliar to the children. For all learning phases a picture of the target word was presented alongside a video of a female verbally labelling the picture. In addition, for the two gesture training groups, each time the target word was verbally labelled it was accompanied by a gesture. The gesture production group were explicitly told to not only listen to the words but also attend to the actions that accompanied each word (see Table 7.2). They were also encouraged to use gesture when trying to remember the words.

7.3.6.1. Stage one: Familiarisation

Each picture was presented one at a time on a laptop screen, accompanied by a video labelling the picture ("this is a *smolt*"). Children were asked to watch and listen carefully and try and remember each of the words.

7.3.6.2. Stage Two: Production.

Each picture was labelled again, however for this trial children were asked to repeat the word e.g. "this is a *smolt*, can you say *smolt*?". Children in the gesture production condition were also asked to imitate each gesture as well as the word.

7.3.6.3. Stage Three: Definition.

Pictures were presented along with a video defining each word "A *smolt* is a baby salmon". Children were instructed to watch and listen carefully. Children were not asked to repeat the word or gesture for this trial.

Table 7.2.

Stimuli and instructions given at each learning phase for each group.

Learning Phase		No Gesture	Gesture exposure	Gesture production
1.Familiarisation	Stimuli	verbal word	verbal word and gesture	verbal word and gesture
	Instruction	watch and listen	watch and listen	watch and listen
2.Production	Stimuli	verbal word	verbal word and gesture	verbal word and gesture
	Instruction	repeat the word	repeat the word	repeat the word <u>and</u> imitate gesture
3.Definition	Stimuli	verbal word	verbal word and gesture	verbal word and gesture
	Instruction	watch and listen	watch and listen	watch and listen

7.3.7. Test Phase

Children's learning was assessed across three stages (see Table 7.3):

1. Word to picture matching: Children played a game of picture bingo against the researcher. Children were given a laminated sheet of paper with all nine target pictures. Videos were presented on a laptop in a random order instructing the child to find a certain picture, e.g. "where is the *smolt*?". The child was instructed to repeat the word (and gesture for the gesture production group) and then cross off the correct picture on their board. If the child correctly identified the picture the experimenter said "well done, there's the *smolt*", if the child incorrectly identified a picture the experimenter said "here's the *smolt*" and pointed to the correct picture. The number of words correctly identified on the first attempt was recorded.
2. Picture Naming: Children were asked to name individual pictures. Children were given a prompt (first 2 phonemes of the word) if they could not remember the correct word, to encourage them to complete the task. This was repeated for all words. Prior to picture naming children had been exposed to each target word six times and had repeated each word (and gesture for the gesture production group) twice. Accuracy of correctly recalled words without a prompt was recorded. In addition, gestures produced during recall (taught gestures and other spontaneous gestures) were also recorded. From this measure children obtained a verbal recall score (the number of words the children were able to correctly recall verbally). In addition, a multimodal score was calculated which accounted for both verbal and non-verbal responses. A child's answer was scored as correct if they correctly identified the word verbally OR produced a correct gesture (taught or spontaneous iconic gesture). Both taught and spontaneous gestures were included so as to measure multimodal responses in the no gesture group, who had not been exposed to any taught gestures.
3. Gesture Recall: For the two gesture conditions, children were presented with a picture and asked if they could recall the action that accompanied the word; accuracy of gesture production was recorded.

Table 7.3.

Stimuli and instructions given at each test phase for each group.

Test Phase		No Gesture	Gesture exposure	Gesture Production
1.Word-picture matching	Stimuli	verbal word	verbal word and gesture	verbal word and gesture
	Instruction	repeat the word and locate the correct picture	repeat the word and locate the correct picture	repeat the word, imitate the gesture and locate the correct picture
2.Picture Naming	Stimuli	picture	picture	picture
	Instruction	Name the picture verbally	name the picture verbally	name the picture verbally
3.Gesture Recall	Stimuli		picture	picture
	Instruction		produce gesture	produce gesture

7.3.8. Reliability

Coding of gestures produced during picture naming and gesture recall were double coded by a research assistant blind to the children's diagnostic group. Inter-rater reliability was as follows, spontaneous taught gestures produced during picture naming: Kappa=.82 , p<.001; spontaneous iconic gestures produced during picture naming: Kappa=.74, p=.004; gesture recall: Kappa=.71, p=.009. Thus there was a substantial level of agreement reliability for all tasks (Landis & Koch, 1977).

7.4. Results

7.4.1. Data analysis plan

The following analyses only considered responses to the six unfamiliar words. A series of ANOVAs compared training groups on measures of receptive learning, picture naming and gesture recall. In addition, picture naming accuracy when non-verbal, as well as verbal responses were considered. For this measure of multimodal accuracy, responses were scored as correct if the child verbally named the picture, or produced an iconic gesture for that word (either taught or a spontaneous untaught gesture). In addition, the relationship between receptive learning, picture naming, gesture recall, spontaneous gesture production and vocabulary was also explored. Cohen's d effect sizes are reported, interpreted as .2 a small effect, .5 a medium effect and .8 a large effect (Cohen, 1988).

7.4.2. Does encouraging children to gesture help recall taught gestures?

First gesture recall was considered for learners in the two gesture conditions. Children in the gesture production condition recalled significantly more gestures than children in the gesture exposure only condition, $F(1,42)=10.00$, $p=.003$, $d=.23$, though the effect is small.

Table 7.4.

Means (SD) for picture naming and gesture recall for each intervention group

	No Gesture	Gesture Exposure	Gesture Production	Range	F	*p*	η_p^2
Gesture Recall	N/A	2.27 (1.58)	3.86 (1.75)	0-6	10.00	.003	.19
Picture recognition	5.48 (.75)	5.73 (.55)	5.37 (1.05)	2-6	1.16	.320	.04
Verbal picture naming	2.76 (1.90)	2.27 (1.58)	2.4 (1.53)	0-6	.487	.62	.02
Correct gestures produced during picture naming	.38[a] (.67)	.27[a] (1.28)	5.14[b] (2.66)	0-100	54.43	<.001	.64
Multimodal picture naming	2.86[a] (1.85)	2.41[a] (1.76)	4.32[b] (1.43)	0-6	7.68	.001	.20
% picture naming responses with gesture	5.56[a] (12.17)	9.09[a] (23.42)	64.39[b] (26.87)	0-100	49.64	<.001	.62
% correct picture naming responses with gesture	6.02[a] (18.03)	11.58[a] (31.49)	79.65[b] (33.13)	0-100	38.80	<.001	.59

Note. All data are raw data other than responses with gesture which are percentages. Mean values with different superscripts in the same row differ at $p < .05$.

7.4.3. Does gesture help school aged children learn new words?

All groups performed at ceiling on the picture recognition. Accordingly, there was no main effect of intervention group, $F(2,62)=1.60$, $p=.320$, $\eta_p^2=.04$. Picture naming, in contrast, was much more challenging for all groups. Therefore this task was analysed in two ways, first the number of words the children were able to correctly recall verbally. Second, plausible gesture responses were included as correct answers (multimodal answers). Gestures that were not taught were included so as not to penalise children in the no gesture condition who nevertheless may have drawn on non-verbal responses.

There was not a significant main effect of intervention group for children's ability to verbally name novel pictures, $F(2,62)=.49$, $p=.62$, $\eta_p^2=.02$. However, when non-verbal responses were considered, there was a significant main effect of intervention group, $F(2,62)=7.68$, $p=.001$, $\eta_p^2=.20$. Children in the gesture production condition produced more correct responses than either those in the gesture exposure only condition ($p=.001$, $d=1.19$) or the no gesture condition ($p=.017$, $d=.88$). There were no significant differences between the no gesture and gesture exposure only condition ($p=.661$, $d=.25$). In addition, when children in the gesture production condition provided a correct verbal response, it was very likely to be accompanied by a gesture (Table 7.2).

To explore whether gesture is more advantageous to children with lower language abilities exploratory analysis compared word learning across all three language groups. Ideally a significant interaction between language group and intervention group would have been evident, however due to small sample size this did not appear to be the case, $F(4,56)=.76$, p=.557, $\eta_p^2=.05$, (*No gesture*: 8 TD, 6 LL, 7 DLD; *Gesture exposure*: 7 TD, 8 LL, 7 DLD; *Gesture production*: 6 TD, 6 LL, 10 DLD). As such, the following results should be interpreted with caution, as they may be attributable to the small sample size.

For the TD group, there was not a significant effect of intervention group for either verbal picture naming, $F(2,18)=.450$, $p=.644$, $\eta_p^2=.05$, or multimodal picture naming, $F(2,18)=.1.13$, $p=.346$, $\eta_p^2=.11$. Similarly, for the LL group, there was not a significant effect of intervention group for either verbal picture naming, *F*(2,17)=.63, *p*=.549, η_p^2 =.07, or multimodal picture naming, *F*(2,17)=1.29, *p*=.301, η_p^2 =.13. For the DLD group, again there was not a significant effect of intervention group for verbal picture naming, *F*(2,21)=1.03, *p*=.373, η_p^2 =.10. However, there was a significant main effect of intervention group for multimodal picture naming, *F*(2,21)=7.20, *p*=.004, η_p^2 =.41. Children with DLD in the gesture production condition produced more correct multimodal responses than those in the gesture exposure only condition (*p*=.005, *d*=2.10). In addition, there was a trend for children in the gesture production group to outperform their peers in the no gesture condition (*p*=.066, *d*=1.10).

Table 7.5.

Means (SD) for verbal and multimodal picture naming by language and intervention groups.

		No gesture	Gesture exposure	Gesture production
Verbal picture naming	TD	3.25 (2.05)	3.29 (1.25)	2.50 (1.52)
	LL	2.83 (1.17)	2.25 (1.59)	2.00 (1.10)
	DLD	2.14 (2.27)	1.29 (1.38)	2.60 (1.84)
Multimodal picture naming	TD	3.38 (2.00)	3.29 (1.25)	4.50 (1.39)
	LL	2.83 (1.17)	2.62 (2.07)	4.00 (1.41)
	DLD	2.29 (2.22)	1.29 (1.38)	4.40 (1.58)

7.4.4. How does the presence of gesture influence children's use of gesture during picture naming?

First I considered how often children produced gestures during picture naming. For this analysis both the production of taught and spontaneous untaught gestures were included, as this enabled inclusion of the no gesture group and accounted for instances when children could not remember the taught gesture, but could recall enough information to form their own gesture. As can be seen in Table 7.2 children in the gesture production condition were more likely to produce gestures during picture naming than children in either the no gesture (*p*<.001, *d*=2.82) or gesture exposure (*p*<.001, *d*=2.19) groups. The no gesture group did not differ significantly from the gesture exposure only group (*p*=.807, *d*=.19).

7.4.5. Relationship between picture naming, language ability and gesture

Overall, there was a significant positive relationship between vocabulary ability and verbal picture naming, *r*(65)=.37, *p*=.003 (Table 7.4), indicating that children with more advanced language abilities learnt more words. However, vocabulary was not associated with gesture recall, *r*(44)=.05, *p*=.737, indicating that children with lower levels of language competence were not disadvantaged in gesture learning. Gesture production during picture naming was significantly positively related to gesture recall *r*(44)= .50, *p*=.001. Thus, not surprisingly, those children who utilised gesture during picture naming were the children who remembered more of the taught gestures.

Table 7.6.

Correlation matrix showing the relationship between language, picture naming and gesture production.

	Vocabulary	Gesture recall	Verbal picture naming	Multimodal naming
Gesture recall	-.05	-		
Verbal picture naming	.37**	-.11	-	
Multimodal naming	.20	.28	.80**	-
Gesture production (picture naming)	-.19	.50**	.07	.54**

***p<.01*

Note. Correlations were conducted with raw scores. Gesture recall includes only the gesture production (n=22) and gesture exposure (n=22) groups.

7.5. Discussion

This study uniquely explored the effect of gesture cues on children's word learning across a sample of children with varied language abilities. The key findings are that while there was no effect of brief gesture training on children's ability to verbally recall novel words, those children who were actively encouraged to produce gestures during learning remembered significantly more target items when gesture responses were also accepted. In contrast, the gesture exposure only and no gesture groups did not differ significantly from one another. In addition, verbal learning was positively correlated with existing vocabulary competence, while gesture learning was not. The implications of these findings are considered below.

7.5.1. Does encouraging children to gesture help them recall taught gestures?

Children in the gesture production group recalled significantly more of the target gestures than the gesture exposure only group. In addition, those children who learnt more of the target gestures were more likely to gesture during picture naming. This extends our knowledge as previous studies have not measured how accurately children learn the gestures they were exposed to, so it has not been clear whether gesture learning is linked to the task success reported in previous research. However, Goldin-Meadow et al. (2009) indicated that the accuracy with which children recall and produce taught gestures impacts task performance during problem solving. In addition, Church and Goldin-Meadow (1986) reported that 40% of children's gestures expressed correct information that was not present in speech during a Piagetian conservation task. Considered together with the current findings, it appears that gesturing during picture naming enables children to express knowledge that they are unable to verbalise. This suggest that encouraging children to produce (and thus practice) target gestures may be key to developing children's use of gesture as a communication strategy.

7.5.2. Does gesture help school aged children learn new words?

Contrary to the initial hypothesis, there was not a gesture advantage in relation to <u>verbal</u> picture naming. At first glance this seems at odds with the previous literature which shows a gesture advantage for word learning (Capone & McGregor, 2005b; McGregor et al., 2009b; Tellier, 2008). However, there are many possible explanations for this disparity, such as differences in the age of participants, the language ability of children, and the number of exposures to words and gestures. For example, both Capone and McGregor (2005) and McGregor et al. (2009) assessed two-year-old children and it may be that gesture plays different roles in language learning dependent on the developmental age and language level of the child.

Whilst Tellier’s (2008) study demonstrated a gesture advantage with older school aged children (4-6 years old), their study asked French children to learn new English words. Second language learning may involve at least partially different mechanisms to those involved in learning a first language. For example, second language learning requires children to learn novel words they already know, as a result gesture may influence learning in different ways. Also, the language abilities of participants in Tellier’s study are not clear, as the authors did not report comparisons of language proficiency between the two intervention groups. Thus, their sample may have included children with a narrower range of age-appropriate language abilities; such children may not have needed gesture to support learning. In addition, these studies had training sessions that spanned multiple weeks (Capone & McGregor, 2005b; McGregor et al., 2009b; Tellier, 2008), and are therefore perhaps more reflective of slow mapping processes. Thus children may have had more time to consolidate new words and gestures and subsequently utilise this information during recall.

The findings of the current study are consistent with Rowe et al. (2013), who similarly did not find a gesture advantage for verbal picture naming in a sample of school-aged children with varying degrees of language proficiency. Rowe et al. (2013) did report a gesture advantage for word comprehension, however this advantage was only evident for dual language learners with low language proficiency. As the children in the current study were at ceiling on the comprehension task, it is not possible to ascertain whether gesture exposure and/or production enhanced word comprehension. In addition, Rowe et al. (2013) also reported that the gesture advantage on word comprehension had attenuated at follow-up one week later. This suggests a limited long term advantage for gesture cues within this group. As Rowe et al. (2013) focused on bilingual children, their results are not directly comparable to the current study. However, it is theoretically interesting that the group with the lowest language proficiency (bilingual-low language), appeared to comprehend new words more if learnt with gestural cues, at least immediately after learning.

Interestingly, in the current study when children's non-verbal responses were considered, children in the gesture production group were more likely to express correct words (either through speech or gesture) than either the gesture exposure only or no gesture groups. Further to this, when considering each language group separately children with DLD in the gesture production intervention condition were more likely to express correct multimodal answers than children with DLD in the gesture exposure only group. However, a substantial benefit for gesture production was not found for either TD or LL groups. This implies that children who have learnt to associate verbal and non-verbal labels are able to express correct information through non-verbal communication that they cannot verbalise. It may be that gesture is most useful as a compensation strategy when verbal information is unknown or not readily accessible. If this is the case, then finding ways to encourage gesture use may be beneficial.

A note of caution is warranted though because isolating the language proficiency groups resulted in small sample sizes, which may have contributed to the null findings in the TD and LL groups. In addition, this study lacks a longer term follow-up and it is therefore uncertain whether the gesture production advantage is maintained for children with DLD. Further exploration with larger sample size and longer term-follow up would provide further insight into whether gesture is a useful aid in language learning interventions.

7.5.3. How do gestural cues influence gesture production during picture naming?

Consistent with LeBarton et al. (2015), children encouraged to gesture produced significantly more gestures during the picture naming task than either the gesture exposure or no gesture groups. In addition, the proportion of correct responses that included a gesture was higher for the gesture production group (79%) than the gesture exposure (11%) or no gesture group (6%). This finding indicates that children who were simply exposed to gesture did not spontaneously adopt this as a strategy to facilitate language learning, any more than those children not exposed to gesture.

Gesture production appears to enable children to express information that they cannot verbalise and so increasing gesture production may be a useful tool to facilitate communication, and possibly to create learning opportunities. However, gesture exposure alone is not sufficient for children to adopt gesture as a useful communication tool, at least in the brief learning tasks conducted as part of this study. Thus, gesture cues may not support language learning or understanding in the classroom, unless children are encouraged to produce the gestures themselves.

7.5.4. Relationship between picture naming, language ability and gesture

Breadth of vocabulary knowledge was positively related to picture naming, which implies that regardless of intervention group, those children with more advanced language skills were able to learn novel words more readily than those with less advanced language skills. However, there was no relationship between oral vocabulary and gesture learning, suggesting that language disorder may not hinder a child's ability to utilise gesture during communication. Indeed, Rowe et al. (2013) suggested the presence of gesture may influence word learning in different ways, dependent on children's language ability. For example, for children with language deficits gestures may support verbal label-object mapping, helping to facilitate word learning. However, for children who find word learning less challenging, gesture may provide semantic cues that develop their semantic knowledge of the word.

7.5.5. Limitations of the current study

The current study is limited in that assessment was limited to fast mapping of novel words after only six exposures to both words and gestures, however this number of word exposures is consistent with previous studies (Rowe et al., 2013). In addition, only two of the six word exposures required children to specifically produce the target word (and gesture for the gesture production group). Again, it may be that multiple opportunities to produce the target gestures are needed to consolidate the gesture-word pairs, which in turn may facilitate learning. It may be that more exposures and opportunities for word and gesture production are required for robust word learning in school-aged children, especially children with language learning difficulties.

This study only considered fast mapping and it would be useful to know whether gesture enhances consolidation of new learning over a longer period of time. A final limitation is that children in all conditions were exposed to pictures of each target word. Arguably this may explain why group differences in verbal word learning were not found, as children may have predominantly used the picture cue during word learning. Exploring gesture production and gesture exposure in the absence of any other non-verbal cues will help to determine the impact of gesture on learning above and beyond non-verbal cues such as pictures.

Small sample sizes meant that comparing the influence of intervention group across children with typically developing language and those with more severe language difficulties was limited. Other studies have demonstrated that children with language deficits can benefit from gestural cues (Lüke & Ritterfeld, 2014; Weismer & Hesketh, 1993), but these studies have not explored the impact of gesture production on word learning specifically. Although, this research indicates that gesture production may be beneficial to encouraging children with DLD to express correct information non-verbally, future research comparing gesture production with gesture exposure in a larger sample of children with language difficulties and typically developing language will help to elucidate the role of gesture in word learning for diverse populations.

7.5.6. Summary and conclusions

The current study demonstrated that encouraging children to gesture helps them learn concepts and express information that they are unable to verbalise, more than mere exposure to gesture cues. The fact that vocabulary was not associated with learning gestures implies that gesture may provide a mechanism for children with language difficulties to express information that they cannot readily verbalise. This in turn may lead to language learning through external factors. For example, Goldin-Meadow et al. (2007) demonstrated that gestures that are translated into words by parents are more likely to enter a child's verbal lexicon than gestures not translated. Thus, children who express information through gesture when unable to verbalise a word, may learn those words through the subsequent feedback received from adults translating their non-verbal responses. These findings have implications for gesture based intervention aimed at supporting children's learning. For example, encouraging adults to gesture may not be sufficient to encourage children to attend to and utilise the gestural information they see. Instead, parents, teachers, and/or other professionals should be sensitive to the gestures children produce and also encourage active gesture production as a mechanism for expressing the extent of their recently acquired knowledge.

Chapter 8: Discussion and Conclusions

8.1. Overview

Within the literature there has been debate regarding the communicative nature of gestures and the extent to which gesture and speech form an integrated communication system. Integrated models of language indicate that semantic knowledge, communicative intention, discourse and working memory contribute not only to the production of speech, but also to the production of gesture. These are areas that may be weak or impaired in children with DLD and so the extent to which children can use gesture to compensate for language weaknesses may be limited. However, models suggesting two separate systems indicate that gestures are formed before communicative intention and so language deficits may not impact on gesture production.

This thesis explored the impact of language deficits on gesture production in children with DLD and their parents. It was hypothesised that if language and gesture form an integrated system, then children with DLD would produce less accurate gestures and their ability to use gesture to compensate should be limited, resulting in the production of fewer accurate gestures and fewer extending gestures. In contrast, if gesture and language form separate systems, then children with DLD would utilise gesture to compensate for oral language weaknesses, by gesturing more frequently than their TD peers. However, the extent to which this is evident may depend on task demands. Furthermore, it is likely that other external factors, such as parent gesture use and parent responsiveness to gestures may influence the extent to which children use gesture and the extent to which gesture facilitates language learning in children with DLD.

This chapter outlines the findings of each chapter, in relation to previous research, followed by a discussion of the theoretical and educational implications of the findings. Finally limitations and future research are discussed.

8.2. Summary of findings

8.2.1. The relationship between language and gesture in children with DLD

The existing literature regarding gesture use in children with DLD has thus far produced conflicting findings. First, it is unclear whether children with DLD gesture at the same rate (Blake et al., 2008; Evans et al., 2001; Mainela-Arnold et al., 2006) or more often than their peers (Iverson & Braddock, 2011; Lavelli et al., 2015; Lavelli & Majorano, 2016; Mainela-Arnold et al., 2014). Second, questions persist about whether children with DLD produce more extending gestures to replace words they cannot verbalise (Blake et al., 2008; Evans et al., 2001; Iverson & Braddock, 2011; Lavelli et al., 2015; Mainela-Arnold et al., 2006), or whether their gesture functions are similar to TD peers (Lavelli & Majorano, 2016; Mainela-Arnold et al., 2014; Mainela-Arnold et al., 2006). In addition, there are also discrepancies in whether children with DLD have qualitative difficulties with gesture production (Hill. et al., 1998; Hill, 1998; Wray et al., 2015) or whether gesture is robust in children with DLD (Botting et al., 2010). As outlined in the introduction, the literature is fraught with limitations in sample sizes, differing diagnostic criteria, ages and measurements of gesture. As a result, comparison across studies is difficult.

The research outlined in Chapter Four assessed gesture accuracy and gesture frequency in children with DLD in comparison to TD peers and children with Low Language and educational concerns (LL). Gesture was measured across a hierarchy of tasks that included gesture imitation, elicited gesture production, spontaneous gesture production during narrative recall and spontaneous gesture production during more complex parent-child interaction.

Children with DLD showed weaknesses in gesture accuracy (imitation and gesture elicitation) in comparison to TD peers, but no differences in gesture rate. Children with LL only showed weaknesses in gesture imitation and used significantly more gestures than TD peers during parent-child interaction. Across the whole sample, motor abilities were significantly related to gesture accuracy but not to gesture rate. In addition, children with DLD produced proportionately more extending gestures than their TD peers, suggesting that they may use gesture to replace words that they are unable to articulate verbally.

The results provide mixed support for theories regarding the relationship between gesture and language. On the one hand, children with DLD appear to use gesture as frequently as their TD peers, and utilise gesture to express information not in speech. However, compensation in this respect was only observed during the more complex referential communication task. This suggests that when verbal communication is difficult, the drive to communicate may prompt use of gesture as a viable means of communication. On the other hand, qualitative differences in gesture production were observed in that children with DLD produced less accurate gestures relative to TD peers. This highlights an aspect of gestural deficit that occurs alongside language difficulties, supporting the notion that language and gesture form an integrated communication system (McNeill, 1992). However, it is important to highlight that children's difficulties with accurate gesture production do not hinder their motivation to use gesture during communication. Given that children with DLD are likely to use gesture to replace words they cannot verbalise, their motivation to use gesture provides them with the opportunity to use gesture to compensate for their language weaknesses. However, the accuracy of these gestures may be limited, making it more difficult for the interlocutor to understand and use the information they are trying to convey through gesture.

Chapter Four also demonstrated potential differences between children with early language delays and those with more persistent developmental language disorders; children with LL gestured significantly more frequently than TD peers. Given that this group of children were identified at school entry as having significant language and communication concerns, but did not meet criteria for DLD one year later, it is likely that many of these children exhibited early language difficulties which have now resolved. This finding is consistent with Thal and Tobias (1992) who reported that language delayed, but not language impaired, children gestured more frequently than their TD peers.

One important finding is the negative relationship between child language and child gesture rate, observed during the referential communication task. This is in contrast to studies of TD infants which demonstrate a positive relationship (Rowe et al., 2008). However, Rowe et al. (2008) only observed TD infants and thus the narrow range of language profiles may not have elucidated the facilitating role of gesture in early infant interaction. Indeed, Chapter Four reported a similar positive relationship between gesture rate and vocabulary when analysing the TD group only, but negative relationships when analysing either the DLD or LL groups. Unfortunately, the small sample sizes when separating groups meant that these differences were not statistically reliable. However, it does highlight that different trends were observed by reducing the language range to just TD children. The current findings demonstrate that gesture supports language throughout childhood however, in older children when the whole range of language abilities are considered, rather than promoting language learning, the key role of gesture may be to facilitate communication.

8.2.2. Parent gesture in relation to children's language

The fifth chapter of this thesis focused on parents' use of gesture. In early childhood parents modify their communication in line with the language abilities of their child and the demands of the situation (Tamis-LeMonda et al., 2008). In addition, positive relationships between parent gesture and child gesture, and child gesture and later child language have been reported (Rowe et al., 2008). Previous research with parents of children with DLD indicated that during shared book reading, parents of children with DLD combined gesture-speech utterances more often than parents of age matched TD peers (Lavelli et al., 2015). This echoes research with late-talking toddlers, which indicated that not only did parents of late talkers gesture more frequently than parents of TD children, but that gesture rates were higher during more complex tasks (Grimminger et al., 2010). However, less is known about whether this is still the case in later childhood and whether parents of children with DLD use non-verbal communication to facilitate communication more often than parents of TD children.

Chapter Five investigated parent gesture frequency and child gesture frequency and function in relation to child language ability in both narrative recall and a more complex interactive referential communication task. It was predicted that parents of children with DLD would gesture more frequently than parents of TD peers and that this may be most evident during the complex problem solving task. It was also predicted that positive relationships between parent gesture and child gesture would be observed. Contrary to previous TD studies, however, it was also predicted that a negative correlation between parent gesture and child language ability would be observed, whereby parents would gesture more frequently when children experience a more severe language disorder.

In line with previous research, parents of children with DLD gestured at a significantly higher rate than parents of TD children; however, this difference was only evident during a complex interactive problem solving task. Across the entire sample, parent gesture rate was positively correlated with child gesture rate, which echoes TD research (Rowe et al., 2008). However, parent gesture was negatively correlated with child vocabulary, implying that in later childhood, parent gesture functions to facilitate language rather than promote language acquisition. This is consistent with Lasky and Klopp (1982) who also reported a negative relationship between parental non-verbal communication and child language ability in children with DLD. Another explanation for this may be that the current thesis examined children with a wide range of language abilities and thus these findings may reflect differences in sampling rather than developmental changes. Longitudinal studies exploring parent gesture throughout childhood with children of varying language abilities would help to clarify whether the findings are due to developmental changes, or variability in children's language.

Finally, children's use of extending gestures was positively associated with the number of words produced by parents, suggesting that child gestures may elicit verbal responses from parents that aid communication (Goldin- Meadow et al., 2007). Overall the findings of Chapter Five indicate that parent gesture serves to compensate for children's oral language difficulties and maximise communication success. Parent gesture is therefore most evident when communication demands are high and parents receive direct feedback regarding children's communication understanding.

8.2.3. Parent responses to extending gestures

In early infancy, parents routinely translate their children's gestures which helps to facilitate word learning (Goldin- Meadow et al., 2007). However, previous research has not explored the mechanism behind this, or the other verbal responses parents produce in response to their children's gestures. In addition, no studies have explored whether parents of older children continue to translate their children's gestures.

Chapter Six explored the mechanism by which parent responses to extending gestures may help to facilitate language learning. In this study, parent communicative exchanges that included; a child's extending gesture, parent response and subsequent child response were coded. Over 50% of parent responses to child extending gestures were verbal responses, however surprisingly around 30% of the time parents did not respond to their children's extending gestures at all. Exploration of the types of verbal responses indicated that parents predominantly responded with positive encouragement or confirmation of intended message (e.g. "OK, I've got that one"). Otherwise, parents were likely to provide a verbal translation of their child's gesture or to ask for further clarification. Crucially, there were no language group differences, indicating that parent's responses were not influenced by children's language ability. Exploration of how children respond to parent translations indicated that children rarely repeated the translated word, but were equally as likely to either acknowledge the translation with a yes/no response or not respond at all.

These findings indicate that perhaps parents make more varied responses to their children's gestures in later childhood, and that parents of DLD children are likely to respond in similar ways to their children's gestures as parents of TD or LL children. This is consistent with Dimitrova et al. (2015) who reported similarities in parental responses across children with different developmental difficulties. However, it is still unclear what impact this has on language learning as often children do not actively engage in the responses that parents provide, questioning the extent to which parent translations help facilitate word learning.

The types of responses observed in parents may differ from previous research because of the age of children, but also because of the task employed. This task was very goal orientated and so parent focus may have been on successful completion of the task, rather than on providing language learning opportunities. Providing language learning opportunities may be more of a focus during interaction with younger children. In addition, differences may also reflect developmental differences in the types of gestures used in extending gestures. In early development, children predominantly produce deictic gestures, which may facilitate direct parent translations more readily. In the current sample, children were more likely to produce representational gestures, which may elicit different kinds of responses from parents, than deictic gestures.

8.2.4. The impact of gesture cues on word learning

The first three experimental chapters focused on spontaneous and elicited gesture communication. Whilst they demonstrate that gesture appears to be tightly linked to language capacity, whether and how gesture facilitates language learning is still uncertain. Previous research indicated that gestural cues may help young children learn words (Capone & McGregor, 2005a; McGregor et al., 2009b) and understand complex instructions (McNeil et al., 2000). This is echoed in studies of children with DLD, whereby gestures help children learn novel names and spatial locations (Lüke & Ritterfeld, 2014; Weismer & Hesketh, 1993). However, previous research has not measured the impact of gesture production and gesture exposure on children's ability to learn novel words.

Chapter Seven measured children's ability to learn six unfamiliar science words in one of three conditions: no gesture, gesture exposure only or a gesture production condition in which children were encouraged to imitate target gestures. Whilst previous investigations have suggested that there are gesture advantages during word learning, no previous studies have directly compared word learning when children are exposed to gesture, encouraged to produce gesture or given no gesture cues. In addition, this chapter explored gesture across a sample of children with varying degrees of language ability, thus highlighting implications for how gesture might be employed in intervention for children with DLD.

It was predicted that children in both the gesture production and gesture exposure conditions would recall more novel words than children in the no gesture condition. It was also predicted that children in the gesture production, but not gesture exposure condition, would produce spontaneous gestures during picture naming, thus facilitating word recall. Finally, it was predicted that gestural cues would be most beneficial to children with low language abilities and that this would be most pronounced for the gesture production group.

Contrary to my initial prediction there were no group differences in children's ability to verbally recall words. Although this contradicts previous research, as discussed in Chapter Seven, differences in the number of word exposures, the age and language proficiency of participants may have contributed to this difference.

Children in the gesture production condition did, however, remember more of the target gestures and were more likely to produce spontaneous gestures during picture naming. In addition, when taking children's non-verbal responses into account, children in the gesture production condition conveyed more correct words (either through gesture or speech) than children in either the gesture exposure or no gesture conditions. When looking at each language group separately, this result held for the DLD group only. This implies that children who have learnt to associate verbal and non-verbal labels can express correct information through non-verbal communication that they cannot verbalise. It may be that gesture is most useful as a compensation strategy when verbal information is unknown or not readily accessible. Overall, the results suggest that gesture supports learning and communication only when children are actively encouraged to attend to and produce relevant gestures, thus enabling them to express information that they are not yet able to verbalise.

8.3. Theoretical and Educational Implications

8.3.1. Implications for the gesture-speech system

One of the key aims of this thesis was to explore the relationship between language and gesture in children with DLD. Chapter Four demonstrated that children with DLD gesture as frequently as their TD peers and produce proportionately more extending gestures to convey information that is not in speech. At first glance, this appears to support the idea that gesture and speech form two separate systems, as children with DLD appear to use gesture to compensate for their language weaknesses. However, this can also be explained by theories of gesture-speech integration. Kita and Özyürek's (2003) model (Figure 8.1) suggests that gesture and speech are distinct parts of the same communication system, which are constantly communicating bi-directionally. This suggests that although there is a bidirectional relationship between the action generator and message generator, the communication planner has independent influences on both and also actions can be selected in isolation of the message generator (Kita & Özyürek, 2003). The fact that children with DLD were more likely to produce extending gestures suggests that when aspects of speech are unavailable (e.g. vocabulary deficits), instead of the whole utterance breaking down, the utterance is re-packaged to include a gesture for the word that is missing from the child's verbal lexicon. In this instance, the action generator interacts with the formulator (via the message generator), such that gesture can often reveal information that is not in speech. In addition, the fact that children with DLD gestured as frequently as their peers, provides further support for the idea that children with DLD have a typical drive to communicate (Bishop, 2000).

However, the extent to which these gestures facilitate communication may be limited, as Chapter Four also demonstrates that children with DLD display qualitative difficulties producing accurate gestures. Given the co-occurrence of gesture impairments alongside spoken language difficulties, these results further support the notion that language and gesture form an integrated communication system (McNeill, 1992). In relation to the Interface Model (Figure 8.1), many components of the model are likely to be impaired in children with DLD (e.g. working memory, semantic knowledge and vocabulary) all of which impact on the quality of gesture that is formulated in the action generator. For example, for an accurate gesture to be formulated in the action generator, semantic knowledge from the communication planner needs to be utilised. However, if children only have a weak semantic representation for a word (cf. Capone, 2007), then this may limit the accuracy with which gestures are produced in the action generator. In addition, even if semantic representations are present, co-occurring motor deficits may also render children's gestures less accurate and thus, less communicative.

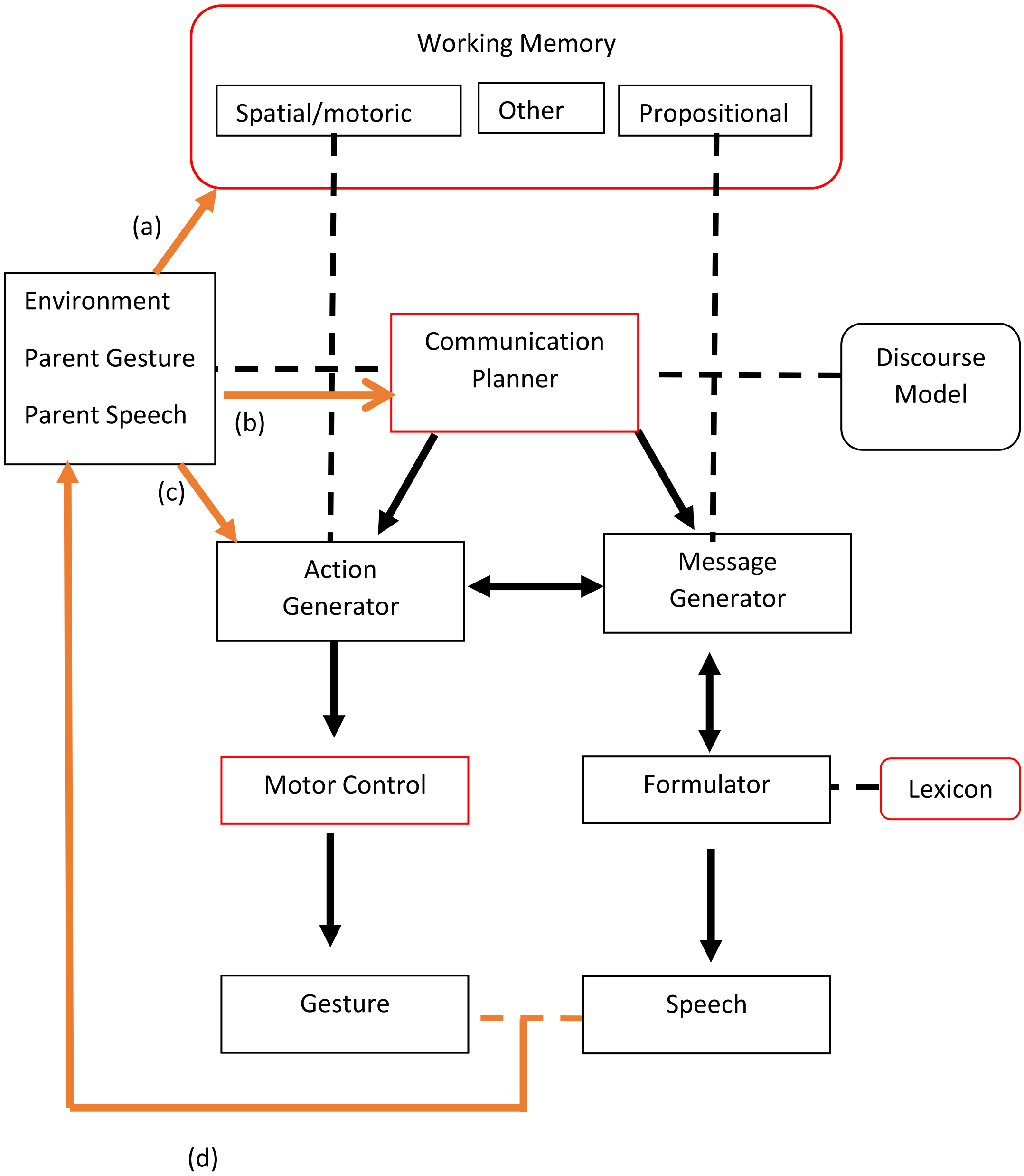


Figure 8.1. The Interface Hypothesis Model from Kita and Özyürek (2003).

Note. Red boxes indicate possible areas of impairment in children with DLD. Orange arrows indicate additions to the original model.

8.3.2. Implications for the relationship between parent gesture, child gesture and language

Research on early language development indicates that parent gesture is fundamental to children's early gesture use and that these gestures may help to drive language development. However, a key question is whether these developmental relationships change over time. It may be that gesture is particularly important in early language development, as children do not have an alternative means of communication. However, the main function of gesture throughout the lifespan may be to support communication, rather than to promote language acquisition per se. In early infancy child gesture and language are positively related (Rowe & Goldin-Meadow, 2009; Rowe, Özçalışkan & Goldin-Meadow, 2008). In contrast, Chapter Four illustrated that child gesture is negatively associated with child language ability in older children. Thus, once verbal language is established gesture may serve to support communication rather than drive language development.

The findings of this thesis also highlight the multiple roles that parent language and gesture have on children's gesture and subsequent language (as illustrated in Figure 8.1). First, parent gesture frequency was positively related to child gesture frequency. In relation to the Interface Hypothesis (Kita & Özyürek, 2003), this may indicate that children observe parent gestures, which feeds into the action generator (path c) and communication generator (path b), signalling that gesture is a useful communication tool.

In addition to this, Chapter Five illustrated that parent gesture is negatively associated with child language abilities and that parents predominantly produce reinforcing gestures. Taken together these findings suggest a facilitative function of parent gesture. For example, parent gesture may help to support children's working memory by providing additional reinforcing non-verbal cues, making communication more accessible (path a). Furthermore, parents may support the development of semantic knowledge by also representing words through gesture, providing children with a deeper semantic understanding of words. Finally, children are constantly receiving feedback from the environment (e.g. parents) about the adequacy of their communicative attempts (path d). Parent responses to child gesture provide crucial information about whether the child's gesture has been understood, providing opportunities for clarification and therefore helping to facilitate communication.

In sum, the theory proposed by Kita and Özyürek (2003) suggests that even if linguistic limitations result in the formulation of less accurate gestures, this may not hinder a child's ability to compensate for language weaknesses by representing information in gesture that cannot be verbalised. However, the extent to which this facilitates communication is limited, if gesture inaccuracy renders the intended message unclear. The findings indicate that the primary function of gesture may be to directly facilitate communication and to indirectly signal to children that gesture is an effective non-verbal communication strategy.

8.3.3. Clinical implications for diagnosis, assessment and intervention

The findings have potential implications for diagnosis and assessment of DLD. First, children with DLD did not differ from TD peers on measures of gesture frequency; thus a measure of gesture frequency alone may not be a useful tool to differentiate children with DLD from TD peers. Instead, measures of gesture accuracy may be more reliable indicators of language disorder as these measures assess working memory, motor sequence production and semantic knowledge, all of which children with DLD find challenging.

The findings also imply that gesture frequency may be a useful diagnostic tool for measuring whether early language difficulties represent a language delay, or a persistent DLD. Children in the LL group produced significantly more gestures than either TD or DLD peers. This supports Thal and Tobias (1992) who reported that language delayed but not language impaired children gestured more frequently than their TD peers. However, due to different measures of language proficiency used for SCALES at T1 (teacher CCC) and T2 (standardised assessments), the nature and extent of early language difficulties in the LL group is not certain. Thus, future research exploring gesture use in children at risk of DLD may help to establish whether gesture frequency is a useful diagnostic tool for distinguishing language delay and persistent DLD.

8.3.4. Treatment/intervention

The findings of this thesis have implications for gesture based intervention aimed at supporting children's learning. The gesture training study (Chapter Seven) highlighted that gesture cues may not provide an additional advantage to verbal word recall. However, gesture may help children express information that they cannot verbalise. Crucially children do not routinely do this unless they are specifically encouraged to do so.

Thus, interventions that include gestures to accompany novel words may not sufficiently facilitate word learning. Furthermore, interventions that focus on encouraging children to produce gestures during word learning may not help word recall directly, but may serve to encourage children to express information through gesture that they cannot verbalise and provide them with opportunities to communicate more effectively. However, given that often the gestures children with DLD produce may be inaccurate, interventions also need to focus on helping children to produce accurate, meaningful gestures that facilitate communication.

These findings highlight that the combination of adults using gestures when communicating with children and encouraging children to attend to and use gestures may help signal to children that gesture is a useful communication strategy. However, it also highlights the importance of adults noticing and responding to the non-verbal communication of children. If interventions successfully enable children to express information through gesture that they cannot verbalise, but their gestures are not acknowledged, then this would limit the extent to which encouraging gesture use could facilitate communication and language learning.

The training study outlined in Chapter Seven was very structured and the extent to which gestures can help to facilitate communication during spontaneous communication may vary. In addition to structured learning tasks, it is important to consider incidental learning of words and possibly grammar in more interactive and naturalistic contexts.

As discussed earlier, parent gestures not only influence child gesture use, but also provide semantic cues which help to reinforce the spoken message. In addition, parent's ability to recognise children's gestures and provide appropriate verbal feedback or translations may help to further link gesture and the intended verbal meaning. As such, parent-focused interventions aimed at encouraging parents to not only gesture but also to attend and respond appropriately to gestural information may serve to facilitate communication and language development (see Figure 8.2).

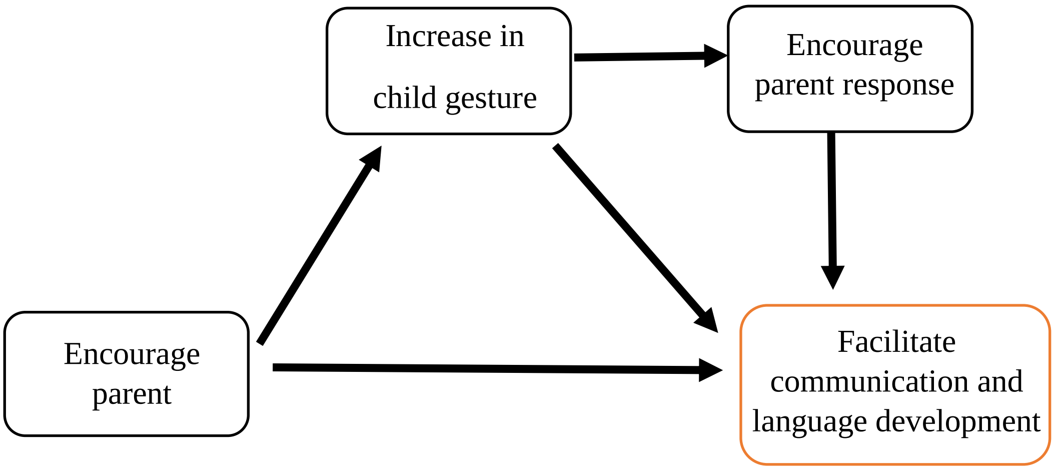


Figure 8.2. Demonstrating the implications of parent-based gesture intervention.

8.4. Strengths of the current research

The current study has a number of advantages over previous investigations: children were recruited from a population cohort which considerably reduced the age range of participants and motor, language and cognitive data were available for all children. In addition, the studies presented are the first to explore gesture imitation, elicited gesture production and spontaneous gesture production within the same cohort of children with DLD. As a result, this thesis addresses many of the limitations of previous research which included varying ages and gesture measurements, making comparison across studies difficult. Furthermore, there is little research considering how parents of children with DLD use and respond to gestures, as such the current research extends the existing literature by exploring how parent gesture may impact on language when a child's language is developing atypically. Finally, a major strength of the current research is the inclusion of children with a wide range of language abilities, which enabled the gesture-language relationship to be examined across the whole spectrum of language ability.

8.5. Limitations and directions for future research

8.5.1. Recruitment

Families that opted in or opted out of the study did not differ on measures of SES, children's risk-status, speech, language concerns or overall language severity (see Chapter Three). Nevertheless, this was a self-selecting sample and due to the nature of the study taking part in the home environment and requiring a parent to participate, many families with several children, or with siblings with developmental disorders opted not to take part. Thus, those children whose parents opted not participate in this study may have had more complex home circumstances than those that participated.

8.5.2. Group categorisation

This thesis included three groups of children for analysis: language impaired, typically developing and children with low language and educational concerns. Families were recruited before data from the SCALES project had been analysed and before the diagnostic groups in the larger study had been specified. High-risk children were oversampled to maximise the chances of recruiting children who met criteria for DLD.

The first consideration was which severity cut-off to use for the DLD group as there is much variation in how DLD is diagnosed within the literature. For this thesis, a cut-off of 1SD below the mean on a total language composite score was chosen as it has been suggested that even children -1SD below the mean experience functional language deficits (Reilly, Tomblin, et al., 2014). Indeed, 90.5% of children with DLD were rated by teachers as not achieving a good level of development on the Early Years Foundation Stage Profile (EYFSP) at the end of their first year at school.

Even though this was a lenient cut-off, only half of the participating high-risk children met this criterion for DLD, resulting in a group of children who were high-risk but did not meet criteria for DLD. Before looking at the gesture data, the categorisation of this group was considered. One possibility is that the screening measure used in SCALES identifies a large number of false-positives. If so, these children could be combined with the TD group, in order to assess a more representative group of children without DLD. This would have the advantage of avoiding a TD ‘super-group’ which could accentuate differences between the extremes of the distribution. However, the high-risk group were not ‘typical’ in the sense that many were reported to have been referred to speech-language therapy and many were currently receiving support for special education needs, because of problems with learning at school. In addition, 85.7% were not achieving a good level of development as measured by the EYFSP at the end of their first year at school. Given that history of DLD or learning problems is frequently given as an exclusion to TD group membership, it was decided that combining the groups could cloud important differences between those with and those without language deficits.

Another option was to exclude the high-risk group; however, this would have distorted the distribution as most of these children obtained intermediate language scores between the TD and the DLD groups. In addition, studies of late-talkers indicated that this group might tell us something interesting about children who have early language difficulties that later resolve. It was also possible that such children were identified because of more marked pragmatic or social communication deficits; although this did not turn out to be the case, it seemed important to include children from across the full range of language and communication competencies.

The next consideration was to combine these children with the DLD group and compare low versus high-risk children. However, this would have prohibited exploration of children with persistent language disorder versus TD peers, which was the primary question of interest. In the end, a decision was taken to keep the three groups. This meant that all children could be included in analyses, which was particularly important for correlational analyses, as it meant that I could explore relationships across children with the full range of language abilities. In addition, as demonstrated in Chapter Four, when the analysis was re-run combining the LL and TD group but excluding those with history of SLT or SEN, the pattern of results was unchanged.

8.5.3. Language matched group

The studies in the current thesis demonstrate differences and similarities in gesture use between groups of children matched for chronological age. However, previous studies have also demonstrated that children with DLD resemble younger TD children in the way that they use gesture. Thus, having a younger TD control group would have enabled exploration of whether gesture use is simply immature, or whether gesture use in children with DLD is qualitatively different on a number of indices.

8.5.4. Measures

8.5.4.1. Referential communication task

The referential communication task provided a measure of naturalistic parent-child interaction during problem solving. However, the goal oriented nature of this task may have influenced the types of gestures that children and parents used and also how parents responded to their child's gestures. For example, if parents' main aim was to complete the task correctly, then their focus would have been on task success and not on maximising language learning opportunities. The original testing plan included a parent-child play situations to assess more naturalistic communication. However, after pilot testing it was deemed that this was not appropriate for the age of the participants. Parents from pilot testing commented that they did not play with their children in this way anymore and so play was replaced with the referential communication task. Future research could explore other tasks that may elicit more naturalistic communication that may capture language learning opportunities (e.g. observations of meal times). This would also provide further exploration of whether parents alter their communication in line with the complexity of the situation. A mealtime interaction places no cognitive or task demands and so may elicit different behaviour from the referential communication task.

8.5.4.2. Gesture accuracy measures

Measures of gesture accuracy enabled examination of both meaningful and meaningless gesture accuracy in children with DLD. These findings clearly indicate that children have difficulties with gesture production *accuracy*. One implication of this is that children's attempts to use gesture during communication may be less successful because poor accuracy may obscure the intended message. However, in order to fully confirm this idea, a measure of gesture accuracy during spontaneous communication would be advantageous. Measuring gesture accuracy during spontaneous communication is difficult as firstly, not all children gesture and secondly, children do not all produce the same gestures. It is also possible that interlocutors are able to use contextual cues such that meaning is recoverable even if the accuracy of the gesture is poor.

One way to examine these possibilities would be to identify sections of videos from the narrative recall task with salient events that all children represented in speech. For example, a key feature of one of the stories was a mouse watering his plants, often children gestured a *hose* whilst re-telling this part of the story. It may be possible to look at those children who gestured this event and rate the accuracy with which they communicated a '*hose*' gesture, and the extent to which naïve observers recognised the gesture as something related to a *hose* or *watering*. This may give further indication of how successful children with DLD are at using gesture to compensate for oral language weaknesses.

8.5.5. Gesture Training Task.

Conclusions from the gesture training task are limited by a number of factors. First, the words taught only included nouns. In infancy, pointing gestures are more commonly related to the acquisition of nouns (Özçalışkan et al., 2016) while iconic gestures may specifically facilitate verbs use (Özçalışkan et al., 2014). Thus, the use of iconic gestures to teach nouns may in part explain why no intervention group differences were found. Training novel verbs would be an ideal next study with which to test these assumptions.

Second, the number of opportunities children had to either repeat the word verbally or to gesture was limited. Although all children were exposed to the words and gestures six times, they were only given two opportunities to produce the words and gestures. This limited exposure and practice may not have been sufficient to reveal differences in word learning between intervention groups. Providing more gesture production opportunities may facilitate word learning more readily.

Third, the analysis of this task was limited by the independent design and sample size. Initially, a repeated design was considered in order to increase the number of children within each condition and to better enable language group comparison. However, this would have meant that the gesture production condition would always have to be presented last, posing other complications of order effects. To increase participant numbers, additional children were recruited to this study, however due to time constraints it was not possible to recruit more. Future research employing similar tasks either with more participants or in a repeated measures design would ensure more power for analysis. This would also enable a language group comparison, which would provide further information about whether children with DLD benefit from non-verbal cues more than TD children.

8.5.6. Gesture comprehension

The current study did not include a measure of gesture comprehension, so as yet there are still uncertainties about how easily children are able to understand the gestures of others. This has important implications for the effectiveness of gesture-based interventions. If children with DLD have difficulties understanding the gestures adults produce, then the extent to which adult co-speech gestures facilitate communication may be limited.

8.5.7. Longitudinal Analysis

Finally, gesture measures were only administered at one time point, meaning that it was not possible to look at changes in gesture over development, nor the long-term impact of parent gesture or parent responses on children's language development. Future longitudinal studies exploring how parent and child gesture relates to children's later language abilities in children with DLD would be advantageous in understanding how parents can best support their child's language development. Longitudinal studies would also enable us to consider more directly whether parent gesture translations, and children's responses to them, impact on word learning. For example, future studies could compare language progression of children who repeated or acknowledged words their parents translated and those that do not respond at all. This would provide a clearer understanding of the mechanism by which parent translations help facilitate language learning.

In addition, the gesture training study did not include a follow-up assessment, and thus there is no evidence regarding the long-term impact of gesture training on word learning. A longitudinal design would have enabled an assessment of the long-term impact of gesture on word learning, which has wider implications for children with DLD.

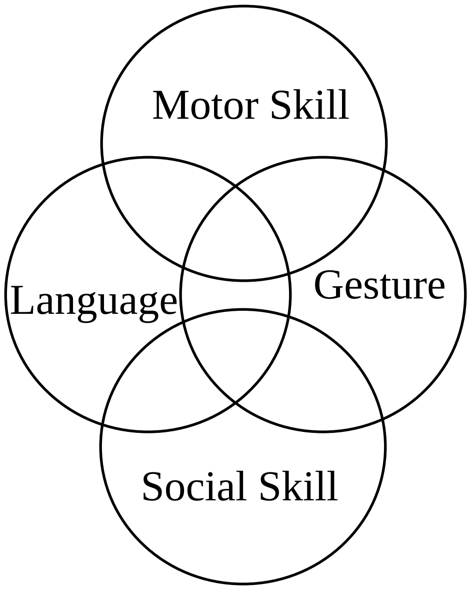


Figure 8.3. Diagram illustrating the complex interaction between language, gesture, motor and social skills.

8.6. Conclusion

The key findings of this thesis suggest that; (1) Children with DLD use gesture to compensate for their language weaknesses, however, the gestures they produce may be less accurate and so the extent to which they aid communication is uncertain. (2) Gesture frequency may help to differentiate children with early language and educational difficulties from those with persistent DLD. (3) Parents use gesture to compensate for their child's language difficulties, however parent gesture is most salient during complex communication tasks in which they are able to receive direct feedback about their child's language understanding. (4) The responses parents make to their children's gestures do not primarily serve to boost language, but rather serve to provide feedback that a gesture has or has not been understood. (5) Whilst gesture cues may not help children learn new novel words, encouraging gesture production during learning provides children with a strategy to express information that they cannot verbalise.

Overall, this thesis supports the notion that gesture and speech form an integrated communication system, whereby gesture is formulated simultaneously with speech. Crucially, when language breaks down a new utterance can be packaged and gestures can be selected in isolation to replace or extend speech. However, the extent to which gesture facilitates communication may depend on semantic knowledge, motor abilities or social skills (Figure 8.3). Crucially, despite presenting with difficulties with gesture accuracy, DLD does not hinder children’s motivation to use gesture as a communication strategy. As such, gesture may reveal information that is not in speech and encouraging children to gesture may prove a useful strategy to express knowledge that cannot be verbalised. In addition, gesture and spoken input from parents not only provides feedback but also facilitates communication and signals that gesture may be a useful communication strategy. Finally, the findings suggest that the relationship between language and gesture may change across the lifespan. In early infancy, it appears to drive language learning, whereas in later childhood it primarily functions to support communication, especially for children who find communication difficult.

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Appendices

Appendix A: Narrative Video Details

Descriptive statistics for each video presented to children during narrative task.

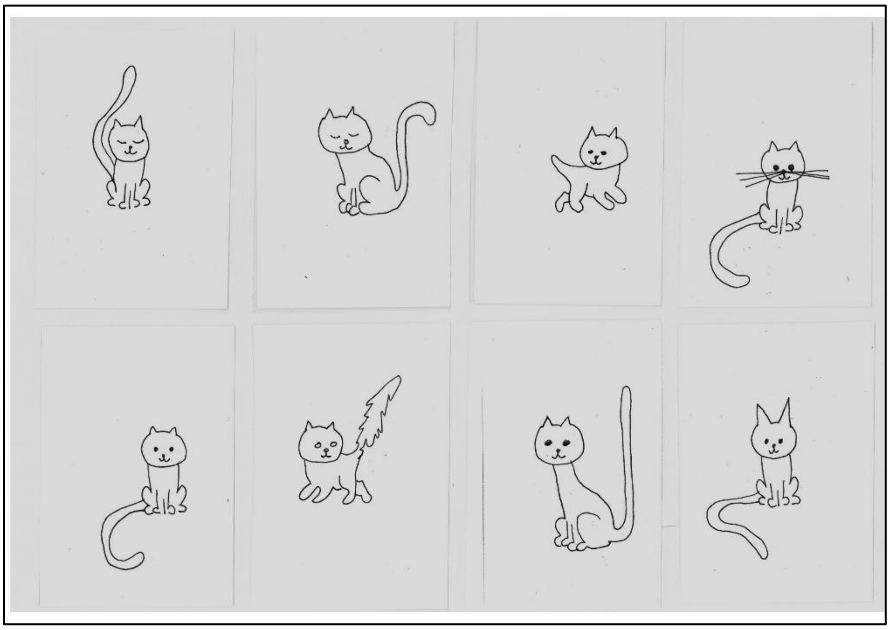
Video	Video length (seconds)	Mean(SD) number of words	Mean number of gestures	Mean Gesture Rate
Seesaw	63	108.39^{a} (39.12)	$8.42^{a,c}$ (6.98)	7.24^{ab}(4.86)
Apple tree	50	72.47^{b} (27.84)	5.05^{b} (3.83)	6.65^{b} (5.00)
Washing	41	77.67^{b} (25.34)	7.40^{c} (5.23)	9.08^{a}(5.62)
Water	37	106.68^{c} (42.40)	9.68^{a} (6.81)	8.81^{a}(5.67)

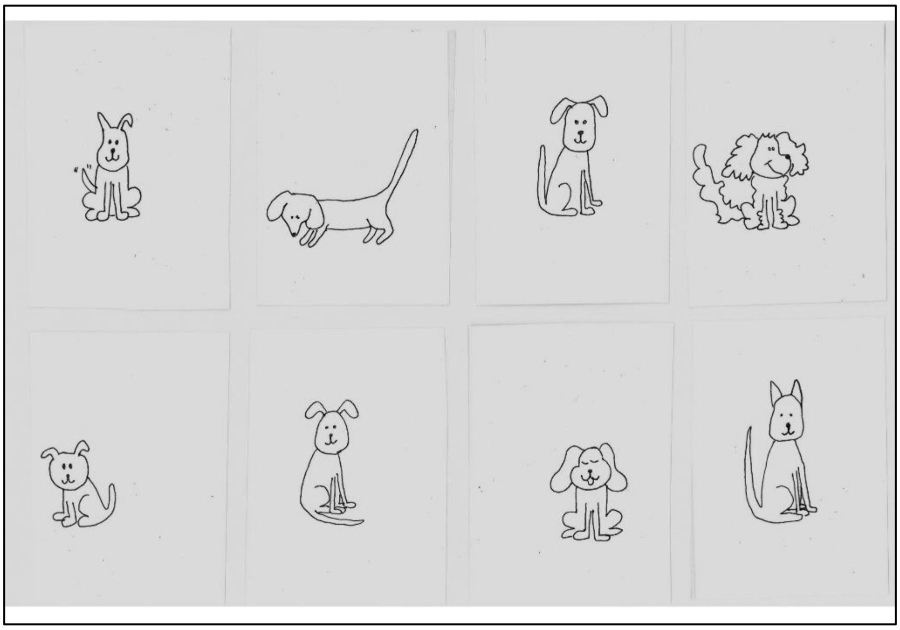
Note. Mean values with different superscripts in the same column differ at p < .05.

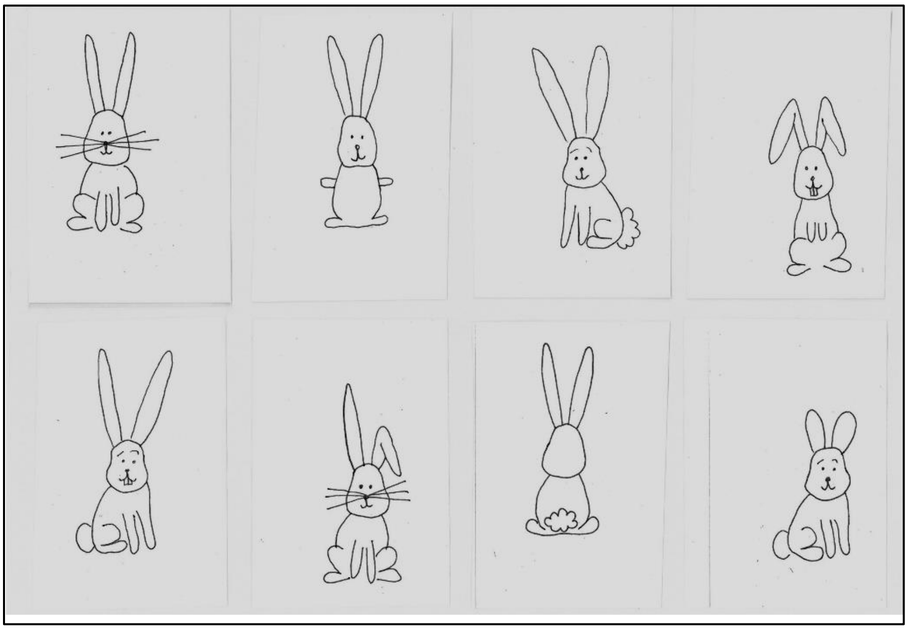
Descriptive statistics for each video presented to parents during narrative task.

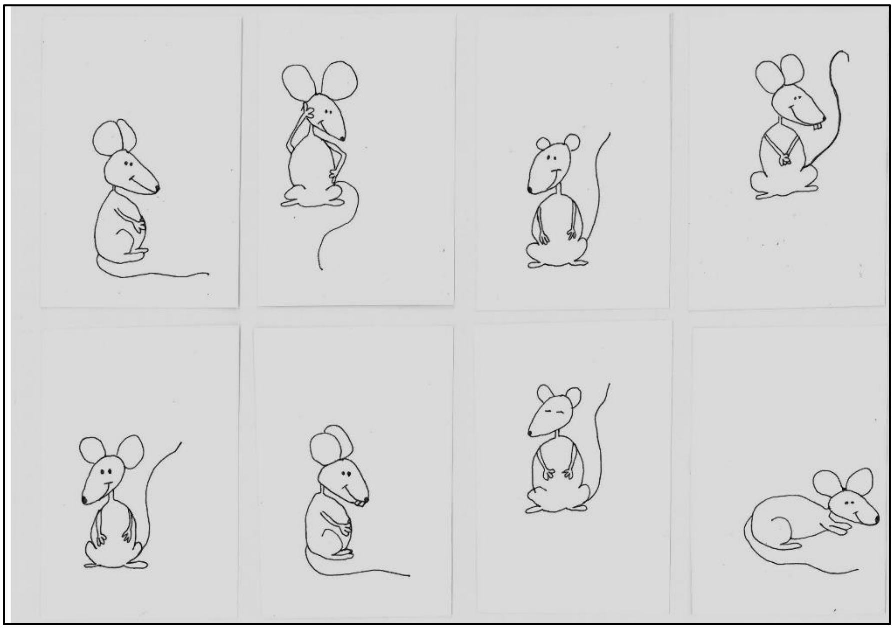
Video	Video length (seconds)	Mean(SD) number of words	Mean number of gestures	Mean Gesture Rate
Rollercoaster	46	127.98 (57.79)	9.93 (7.46)	8.49 (4.18)
Beach	39	118.37 (50.70)	9.98 (7.03)	8.03 (4.57)

Appendix B: Referential Communication Task Stimuli









Appendix C: Referential Task Trial Details

Child descriptive statistics for each trial.

Animal	Time taken	Mean(SD) number of words	Mean number of gestures	Mean Gesture Rate
Cat	216.62[a] (70.78)	178.46[a] (119.96)	9.93[a] (8.71)	5.49 (3.98)
Dog	280.80[b] (107.57)	234.63[a,b] (157.58)	16.36[b] (15.74)	6.24 (4.49)
Mice	321.59[c] (117.35)	244.44[b] (145.35)	16.66[b] (13.63)	8.09 (13.11)
Rabbit	246.81[d] (89.90)	215.68[a,b] (154.33)	15.44[b] (13.19)	7.22 (4.11)

Note. Mean values with different superscripts in the same column differ at p < .05.

Parent descriptive statistics for each trial.

Animal	Time taken	Mean(SD) number of words	Mean number of gestures	Mean Gesture Rate
Cat	216.62[a] (70.78)	266.42[a] (140.92)	7.68[a] (7.90)	2.80 (2.52)
Dog	280.80[b] (107.57)	348.36[b,c] (163.04)	9.73[a,b] (9.67)	2.88 (2.58)
Mice	321.59[c] (117.35)	394.80 [c] (221.01)	13.92[b] (13.12)	3.50 (.24)
Rabbit	246.81[d] (89.90)	296.58[a,b] (172.75)	8.46[a] (9.04)	2.58 (2.43)

Note. Mean values with different superscripts in the same column differ at p < .05.

Appendix D: Elicited Gesture Production Coding Guidelines

Guitar

Location: front of body with hands in diagonal placement to each other. One hand over tummy other hand out to the side.
Shape: Top hand in cup shape (holding shape), 2nd hand more open with fingers together or thumb and finger together (holding a pic)
Action: strumming with lower hand- up and down.

Train

Location: Arms to each side of the body

Shape: Both hands flat

Action: Circular both hands

Additional actions:

Sounding horn

Location: 1 arm above head

Shape: Fist clenched

Action: Move arm up and down (pulling horn movement)

*Two part gesture if both actions produced in first attempt.

Climbing a Ladder

Climbing

Location: In front of body, one hand above the other

Shape: Hands in gripping shape

Action: moving one hand up then the other also moving legs up and down (2 action points if hands and legs)

Ladder

Location: In front of body

Shape: Hands vertically indicating side of ladder/ hands horizontal indicating ladder steps.

Action: Moving from vertical to horizontal position indicating ladder shape
*Two part gesture if climbing and ladder separately.

Painting

Location: In front of body

Shape: Fist (holding paintbrush) or finger out representing brush

Action: brush strokes (any direction accepted)

Sleep walking

Location: any sleeping gesture (next to head, in front of body, lying down)

Shape: any sleeping gesture (hands together flat next to head, both hands stretched out, body in sleep position)

Action: closing eyes, walking

*Two part gesture if depict sleeping and walking separately

Monkey

Location: Side of body

Shape: arms curled under

Action: Up and down

Also accepted: monkey swinging action (from trees):

Shape: hand grasping shape.

Location: above head

Action: arms swinging above head

*Two part gesture if both actions produced in first attempt.

Sword fight

Location: in front of body

Shape: Hand(s) in grasping shape (holding sword) - accept 1 and 2 handed gestures.

Action: Any lunge/ slice action

*Two part gesture if depict sword and fighting separately.

Sad

Location: Face

Shape: downward mouth, lip turned

Action: mouth moved downward, looking down, mimic crying, hands to face

Appendix E: Spontaneous Gesture Coding Guidelines

Types of gesture

Deictic

Are best described as variations on pointing. This gesture is mainly produced using the index finger but could also be produced using other part of the body (e.g. whole hand, head). This gesture is generally used to draw attention to a particular object, person or location in the environment.

Conventional

These gestures are culturally specific gestures that convey meaning without the need for speech e.g. thumbs up, nodding head, and OK sign. These gestures convey a specific meaning, for example a nod of the head symbolises "yes". To be classed as a conventional gesture the gesture must be understood in isolation, without speech and without knowledge of the context.

Representational

Representational gestures combine iconic and metaphoric gestures. These are gestures that show a close relationship to the object, action, idea or concept that they refer to. These movements usually reflect aspects of what they are describing, for example a representational gesture may provide information about the size of an object.

Beats

A beat is a repetitive movement with the hand which emphasises aspects of speech.

E.g. during a speech politicians may make a fist and move their fist up and down, making down movements on words they want to highlight.

Gesture Meaning

During communication people will either communicate with gesture alone, speech alone or a combination of gesture and speech together.

Gesture alone

Gesture alone is coded when a gesture is produced with no accompanying spoken communication. This could either be, a gesture by itself e.g. point, thumbs up. Or gesture alone would also be coded if the gesture occurred after spoken communication. E.g. look followed by a [POINT GESTURE]. It would not be coded as gesture alone if the gesture began during spoken communication. E.g. look, whilst simultaneously producing [POINT GESTURE].

Gesture and speech

Gesture and speech is coded when gesture and spoken language occur simultaneously. For example, the gesture either begins at the same time or during speech. It would be classed as gesture alone if the gesture began, before or after speech.

When coding gesture and speech together we also want to look at the meaning of that gesture during speech. So after coding speech-gesture behaviour, we also need to code whether the gesture is redundant or extending.

Redundant gesture

A redundant gesture conveys the same information as speech. E.g. "The cat has a curly tail" [whilst making a curly motion with the hand]. The gesture simply emphasises the curly tail, it does not add any extra information for the listener.

Examples of Redundant gestures:

"His tail was up" [UP GESTURE]

"He took an apple from the tree" [GRABBING GESTURE]

"The wind kept going" [WIND BLOWING GESTURE]

"They n go round in a figure of eight" [FIGURE OF EIGHT GESTURE]

Extending gesture

Extending gestures are classified when the information created by the gesture provides the listener with extra information that is not in speech. "It's facing that way [whilst pointing to the right]. In this instance the gesture is giving the listener information about which way the object is facing. Information that they would not have been able to gain from simply listening to the speaker.

Examples of extending gestures

"He was like this in his chair" [ROCKING GESTURE]

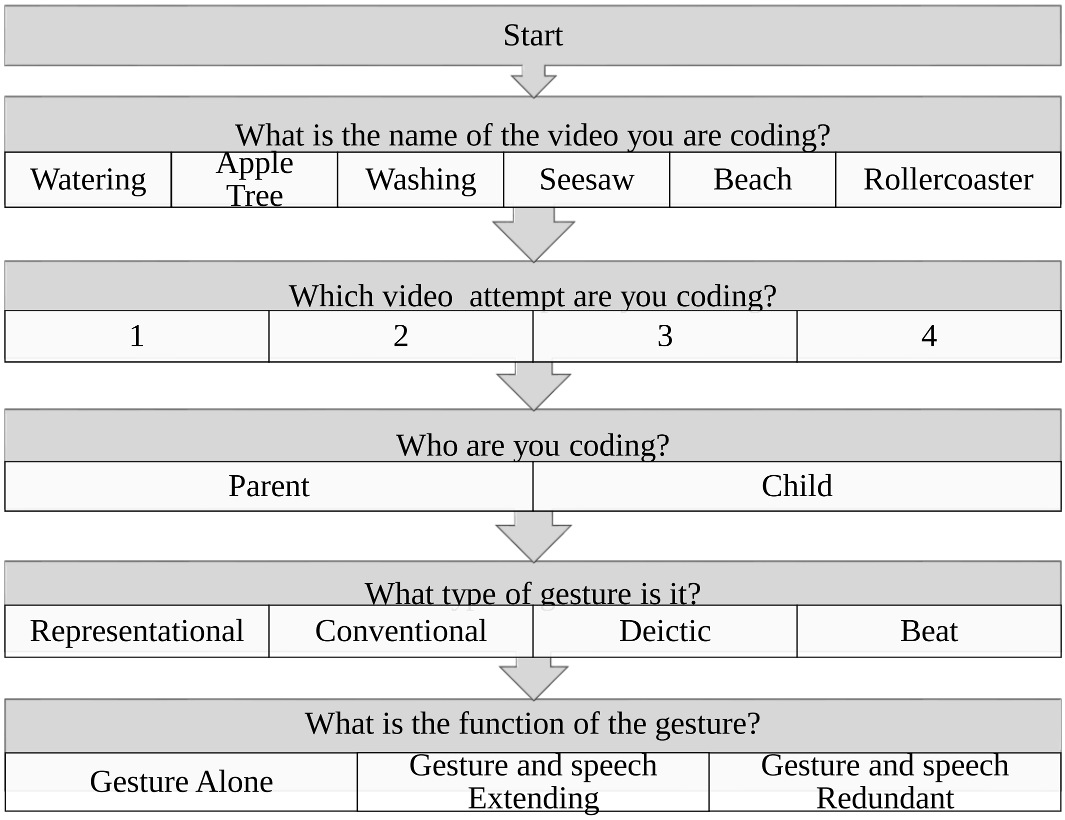
"He got one of them chairs" [ROCKING GESTURE]

"He was like this" [MOVING FOOT UP AND DOWN]

Gloss

Please gloss the gestures in the comments box.

Flow chart of coding procedure for the narrative task.



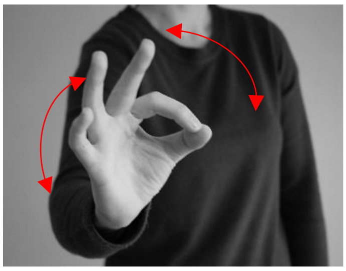
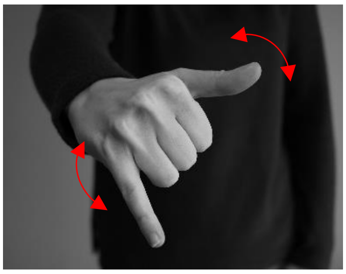
Appendix F: Examples of parent responses to children's extending gestures

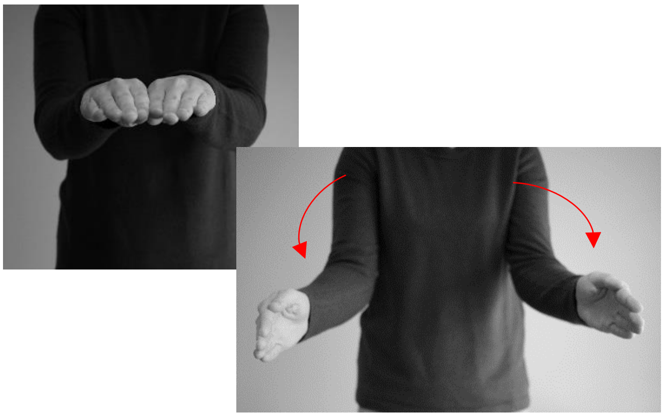
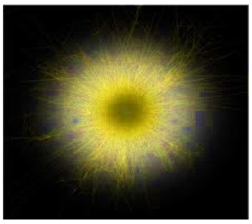
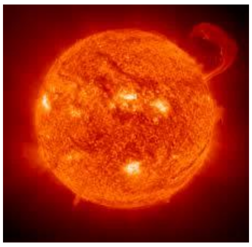
Parent Response	Examples
Translation	*c: It's like this [extending pointy tail gesture].* *p: pointy*
Request for clarification	c: *they're [extending ear gesture].* p: *yeah is it pointing upwards or is it pointing down?*
Prompt for verbal equivalent	c: *eyes closed facing that way [extending direction gesture].* p: *which is that way?* c: *she's facing forward.*
Positive feedback	c: *like it's like a it's like a worm going [extending tail gesture].* p: *okay alright got it.*
Verbatim repetition	c: *small [extending ear gesture].* p: *small*
Other Verbal	c: *turning that way [extending direction gesture].* p: *hold on let's just see.*

Appendix G: Examples of children's responses to parent translations or request for clarification

	Child Response	Examples
Parent Translation	Yes/No	c: no it's like this [extending body gesture]. p: standing. c: yeah.
	Repetition	c: and his um elbow no an no [extend knee gesture]. p: knee. c: knee part of this one is touching his right leg.
	Correction	c: his ears are going like [extending ear gesture]. p: floppy. c: no it's like [extending ear gesture].
Parent request for clarification	Yes/No	c: he/'s standing up like that [extending long body]. p: is he like a sausage dog? c: yes.
	Addition	c: and its tail is like that [extending tail gesture]. p: is it straight up or is it got a curve at the top? c: it's straight but then it's got curve like that [extending tail gesture].
	Unrelated	c: looking that way [extending direction gesture]. p: might have to show me that one again I think. c: it is third.

Appendix H: Gesture training study word picture and gesture stimuli

Word	Picture	Gesture
Gadfly		
Smolt		
Crawdad		
Breccia		

Troposphere		
Photon		
Sun		
Lion		

Fire