Can you see what I mean? The effects of iconic gestures on early word learning

by

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This thesis is dedicated to my late grandfather, George Mann, for teaching me the value of hard work, the importance of life-long learning, and the joy that can be found by appeasing your inner child.

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ABSTRACT

This study examined the impacts of co-speech iconic gestures (CS-IG) on fast-mapping in typically developing (TD) children. Twenty-three TD children 5-8 years of age were exposed to 6 novel toys – half referenced with a novel word and an IG depicting the object's action, half referenced with a novel word only. Participants were tested on word and gesture production and comprehension immediately following the exposure task and after a 10-minute delay. Results demonstrated that 7-8-year-olds performed better than 5-6-year-olds in immediate word production tasks, and that both age groups had better gesture production and comprehension performance after a delay when words were paired with gestures. Gesture comprehension also increased after a delay when words were not paired with gestures. CS-IG did not improve fast-mapping of novel words contrary to research with younger TD children. However, children gleaned information about the action performed on an object and strengthened this representation over time.

LIST OF ABBREVIATIONS USED

ANOVA	Analysis of variance
CELF-5	Clinical Evaluation of Language Fundamentals – Fifth edition
COVID-19	Coronavirus disease 2019
CVC	Consonant Vowel Consonant
CCVC	Consonant Consonant Vowel Consonant
CVCVCV	Consonant Vowel Consonant Vowel Consonant
DLD	Developmental Language Disorder
FM	Fast-mapping
M	Mean
NS	Not significant
SB4	Stanford Binet – fourth edition
SES	Socioeconomic status
SD	Standard deviation
SE	Standard error
TD	Typically developing

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CHAPTER 1 INTRODUCTION

Statement of Purpose

The purpose of this study was to investigate the effect of iconic gestures depicting the action that can be performed upon an object on fast-mapping immediately after exposure and again after a delay in typically developing (TD) children 5 to 8 years of age.

Background Information and Overview

Word learning begins with the first association between a word and its referent. This rapid and initial word learning process is called fast-mapping (Carey, 2010) or quick incidental learning (Rice, 1990; Oetting et al., 1995). In studies of fast-mapping, children receive one or a few exposures to a novel word and its referent and are then tested on their production and/or comprehension of the novel word. Foundational research shows that after just one exposure to a novel word-object pair, preschool children are able to build initial representations and identify the object based on its name, showing comprehension of the word (Dollaghan, 1985). Even toddlers 13 to 16 months of age have been shown to fast-map after only four novel word exposures (Kay-Raining Bird & Chapman, 1998). Fast-mapping is a domain-general ability such that children are not only able to fast-map novel words (Kay-Raining Bird, 2004) but also gestures (Sekine et al., 2015).

Gestures, which are visible actions of the body, can be used to communicate a message (Kendon, 2004). When gestures can be used in conjunction with speech, they are referred to as co-speech gestures. Co-speech gestures can be classified as beat (gestures that emphasize a particular word through a rhythmic pulse of the hands in an up and down motion), point or deitic (those that draw attention to an object by pointing to it), arbitrary or metaphoric (symbolic gestures that represent an object but relay no meaning about the object), pantomime (a gesture or sequence of gestures conveying a narrative line), and iconic (symbolic gestures that convey an aspect of the meaning of an object, such as flapping arms up and down to represent a bird) (McNeill, 1996; McNeill, n.d.). Iconic gestures indicate information about a referent such as its shape, actions that can be made upon or by it, or how it moves. For the current study, iconic gestures were used to portray the main action that could be performed upon novel objects. Throughout this paper, iconic gestures referring to physical features or shape of objects are referred to as shape gestures; and iconic gestures referring to actions that can be made upon an object or how an object moves are referred to as action gestures.

Co-speech gestures are thought to enhance memory and learning (Madan & Singhal, 2012) by facilitating the comprehension of spoken language (Beattie & Shovelton, 1999; Hostetter, 2011) and helping a speaker retrieve words in their lexicon (De Ruiter, 2000; Hostetter, 2011). Iconic gestures have been suggested to facilitate word learning by providing information about a word's meaning in another modality. The additional information provided by iconic gestures through another modality helps the listener to process the accompanying word and leads to bi-modal encodings (auditory and visual) which in turn can strengthen access to memory traces and lead to a deeper understanding of the word's meaning and how it is related to the word referent (Hostetter, 2011).

A comprehensive review of co-speech gestures found that co-speech iconic gestures facilitated the production and comprehension of messages for TD children over 3 years of age (Hostetter, 2011). However, only a few studies have specifically used co-speech iconic gestures to investigate fast-mapping of novel nouns (e.g., Luke & Ritterfeld, 2014). In addition, previous research has focused only on pre-school aged children's fast-mapping comprehension but not production (e.g., Tolar et al., 2008; Sekine et al., 2015), and the immediate but not longer-term effects of co-speech iconic gestures.

Therefore, the present study sought to extend the literature by investigating the contributions of co-speech iconic gestures to word learning through fast-mapping immediately after exposure and again after a delay. Age was also extended to investigate the facilitative effects of co-speech gestures in school-aged children between 5 and 8 years of age, as opposed to the preschool aged children 2 to 5 years of age investigated in previous literature. The original intent of the present study was to compare participants with Developmental Language Disorder (DLD) and TD participants. However, due to the advent of COVID-19, testing was completed online rather than in-person and the focus of the study changed to the fast-mapping of school-aged children only. Regardless, studying fast-mapping in school-aged TD children only is useful due to the dramatic increase in vocabulary development that occurs upon school entry as well as the fact that language becomes more decontextualized as children mature (Paul et al., 2018). Specifically, 5-year-old children have an average expressive vocabulary of about 2000 words (Biemiller, 2009) and learn approximately an additional 2000-3000 words each year (Nagy & Scott, 2000). As such, the question arises whether the same mechanisms in fast-mapping are in play for school-aged children and preschool-aged children. There are no studies on the impact of co-speech gestures on fast-mapping in school-aged children, however there is research demonstrating that school-aged children can integrate auditory and visual information (i.e., visual scenes on a video) to fast-map novel verbs and apply those novel verbs to new visual scenes (Casenhiser & Goldber, 2005). The study also investigated whether children could glean information about the object name and associate the action depicted in the gesture to the target object.

Theoretical frameworks for the facilitative effects of gestures in fast-mapping

Two theories are particularly relevant to encoding information in multiple modalities during word learning: the Emergentist Coalition Model and the Dual Coding Theory. The Emergentist Coalition Model accounts for very young children's attempts to learn new words. While the model addresses word-learning broadly, it also addresses the attentional processes required to make initial associations between a word and a referent, referred to as the "first-tier" of word learning (Hollich et al., 2000). In addition, experimental evidence in support of the model concerns very young children's attempts to fast-map (McGregor, 2008). Regarding a facilitative effect of co-speech gestures to word learning, the Emergentist Coalition Model has two main premises: that children use environmental cues such as gestures to aid in word learning, and that the role of environmental cues shifts as children develop. In the case of gestures, the role shifts from being used as a tool to attract attention to being used in social aspects of word learning, and finally to being used to represent the linguistic dimensions of the word itself (McGregor, 2008). As such, the model suggests that in very young children, iconic gestures may highlight semantic information about the referent (e.g., the function of an object), thus supporting the development of a more complete semantic representation of the word.

Dual Coding Theory, a learning theory proposed by Paivio (1971; 1986), posits an interaction between verbal and nonverbal cognition. Verbal cognition is associated with language representations and processing, such as word labels, while non-verbal cognition is associated with representing and processing objects and events (Sadoski, 2005). The underlying premise is that verbal and non-verbal representations can form in word learning and these two systems are mutually supportive (Clark & Paivio, 1991). The interaction of these two systems allows word retrieval through multiple pathways. For word learning, this means better recall of information that is presented initially in both visual and auditory modalities rather than a single modality

(Rowe et al., 2013). Therefore, Dual Coding Theory predicts that co-speech gestures will enhance word recall and understanding. While the theory addresses word-learning more broadly, it also suggests that the association between words and visual information occurs after only a few exposures (Clark & Paivio, 1991).

How easily visual and auditory information is associated in memory and the extent to which visual information facilitates word recognition and word retrieval varies with the task. Cognitive complexity changes with the demands of the task, the abstractness of the stimuli, and a person's past experience with various task components (Clark & Paivio, 1991). Sekine et al. (2015) considered the impact of cognitive load in their investigation of fast-mapping of co-speech gestures in 3- and 5-year-old children. On a screen, children were presented videos of everyday activities in three conditions: iconic gesture condition, spoken sentence condition, or spoken sentence plus iconic gesture condition. Immediately after each presentation, comprehension of the gesture was tested in a forced-choice task in which they had to point to a picture that best represented the message. Results showed that 3-year-old children performed significantly worse than 5-year-olds and their worst performance was in the verbal-gesture condition. This suggested that integrating visual and auditory information and mapping it to a correct picture was particularly demanding for 3-year-old (Sekine et al., 2015).

Gestures have also been shown to aid word learning in other circumstances. McGregor et al. (2009) found facilitative effects of co-speech gestures in young children. In a study investigating the use of gestures as a support for word learning, 24-month-olds were exposed to the word *under* four times with either a dynamic gesture depicting *under* (held right hand over left hand, then moved right hand under left hand), a still photo of the target object in the *under* position, or modeling *under* (researcher placed an unrelated object under another object). After training, children in the dynamic gesture condition performed better at demonstrating *under* when instructed with familiar and unfamiliar objects than children in the picture or modeling conditions, showing that they had learned and could generalize the meaning of the word to untrained objects. The researchers suggested that gestures reduced cognitive load by focusing attention to both the location and the movement relevant to learning the meaning of the word *under* (McGregor et al., 2009).

Other studies have further supported the facilitative effect of gestures for word learning. A study by Kapalková et al. (2016) compared the use of iconic gestures to picture support in a word learning study with 23-month-olds. Training occurred over 15 play-based sessions, each lasting 20 minutes. The number of word exposures in each session was not specified. A different object was taught in each of the first 10 sessions, with the last 5 sessions addressing all 10 objects. In the picture group, children were given a picture of a novel object and the experimenter labeled the pictured object with a novel word and encouraged imitation of the word. In the gesture group, the experimenter labeled the object in combination with producing a gesture depicting a combination of the object's function and shape. Children were tested on novel word productions through a picture naming task immediately after the first session in which the word was taught as well as 2 weeks and 6 weeks after training ended. Children trained with co-speech gestures produced significantly more correct labels at all three time periods relative to children in the picture condition, showing a beneficial effect of gestures in word learning compared to other visual supplementary information.

In summary, the Emergentist Coalition Model and the Dual Coding Theory supports the notion that verbal and non-verbal information can mutually support word learning. Yet, research in this regard to date has been somewhat conflicting regarding how the integration of verbal and non-verbal information may impact cognitive load. However, facilitative effects of co-speech iconic gestures were more likely observed in 2- to 5-year-olds with an increased number of exposures and increased simplicity of the fast-mapping task.

Early development of gestures

Gestures are an important component of early word learning in naturalistic contexts. Caregivers routinely point to objects to establish joint attention with a child before labeling the object (Carey, 2010), and this use of gestures by caregivers promotes language development (Capone Singleton & Saks, 2015). Gestures also serve as one of the child's first intentional forms of communication, emerging slightly before spoken language (Luke & Ritterfeld, 2014). The relationship between language and gestures is such that the earlier the child points to an object, the earlier its label is produced (Hodges et al., 2015).

Iconic gestures appear to have early and long-lasting benefits. Young children frequently exposed to co-speech iconic gestures show early and robust development of symbol use, gestural communication and spoken language relative to those who experience co-speech iconic gestures less (McGregor, 2008). A study by Goodwyn et al. (2000) demonstrated that co-speech iconic gestures may be particularly supportive of word learning. They trained a group of caregivers to increase either their verbal input only or verbal input in combination with co-speech iconic gestures to their 11-month-old infants. Caregivers trained to increase their co-speech iconic gestures used gestures that depicted either object function, object attributes, or actions performed upon the action. Overall, infants exposed to co-speech iconic gestures demonstrated stronger receptive and expressive language abilities than infants exposed to verbal input only when they were tested on standardized language measures at 15, 19, 24, 30, and 36 months (Goodwyn et al., 2000). Differences between co-speech iconic gestures depicting function, attribute or actions gestures were not investigated.

Object-gesture linking

For co-speech iconic gestures to be beneficial in word learning, the iconic gesture must be associated with a referent in memory and integrated with verbal information (Vogt & Kauschke, 2017). Studies investigating the mapping of gestures to a referent are reviewed next. The ability to map iconic gestures with their object referents develops over time (Carey, 2010; Capone & McGregor, 2015; Hodges et al., 2015). This is exhibited in a study investigating gesture-object mapping in children 18 and 26 months of age (Namy et al., 2004). During a training stage, children were shown familiar objects (i.e., car, rabbit, hammer, spoon) in combination with arbitrary gestures or iconic gestures depicting object function. There were no words associated with the gestures; the researcher directed the attention of the child to each object and referred to it by gesture five times. Gesture comprehension was tested by asking the child to indicate the target object when provided with the gesture. Results showed children of both ages successfully associated referent objects to iconic and arbitrary gestures. However, only 26-month-olds performed better with iconic as opposed to arbitrary gestures. The authors posited that the iconic gestures used in the study may not have been iconic for the younger children (Namy et al., 2004).

Additional research shows that both 2- and 3-year-olds are aware that iconic gestures convey important information to support understanding, but 3-year-olds interpret iconic gestures and map them to a referent object better (Tolar et al., 2008; Novack et al., 2015). Novack et al. (2015) exposed 2- and 3-year-old children one time to eight novel objects in combination with either an iconic gesture that demonstrated the function of the object, an incomplete action that did not demonstrate the function (acted upon the object but did not complete the movement, thus failing to demonstrate the function of the object), or no gesture in a fast-mapping task. There were no words associated with the gestures. Immediately following exposure to an object in each condition, the child was provided with the object and asked to demonstrate how it worked. Testing revealed both 2- and 3-year-olds accurately demonstrated the function of the novel object more often when paired with an iconic gesture than when no gesture was provided, but only the 3-year-olds were able to demonstrate the function of a novel object more often after an iconic gesture than after an incomplete action gesture. The authors interpreted this to mean that, although 2-year-olds benefited from iconic gestures compared to no gesture, they were not yet experts at interpreting the iconicity of gestures. In a follow-up study, 2-year-olds were presented the same eight novel objects in combination with iconic gestures that demonstrated the function of a novel object, or a point gesture that drew attention to a critical part of the objects (e.g., handle). Results showed that 2-year-olds were able to demonstrate the function of a novel object more after an iconic function gesture than point gestures and more than the 2-year-olds from the first study in the no gesture condition.

A gradual increase in successful iconic gesture-object mapping is also shown in a study examining 2- , 3-, and 4-year-old children (Marentette & Nicoladis, 2011). Children were exposed to both familiar and novel objects paired with either arbitrary gestures, iconic gestures depicting an action that could be performed on the object, or iconic gestures depicting the shape of the object. The gestures were not accompanied with spoken labels. After being exposed to an object-gesture combination three times, gesture mapping was tested by asking children to indicate the target object when provided with the gesture. Results showed that children performed equally well when iconic or arbitrary gestures were paired with familiar objects. However, for novel objects, children performed better in the iconic gesture compared to the arbitrary gesture condition. Further, accuracy increased with age only in the iconic gesture condition (Marentette & Nicoladis, 2011), demonstrating again that children's ability to interpret iconic gestures develops over time.

For iconic gestures to be beneficial to the fast-mapping of words, children must be able to link the gesture to the referent object. The research presented in this section shows that, while children as young as 18 months of age can successfully link a gesture to an object, the ability to interpret iconicity in a gesture develops over time among preschool-aged children, likely in conjunction with a child's familiarity or experience with the concept being represented in the iconic gesture. It may be that the ability to interpret the iconicity of a gesture continues to develop past preschool-age into school-aged children. However, previous research to date has not investigated this possibility.

Impact of iconicity type on fast-mapping

In the research outlined next, some types of gestures may be easier to interpret than others. Luke and Ritterfeld (2014) investigated the impact of iconic and arbitrary co-speech gestures on word learning in children with Developmental Language Disorder (DLD) and their age-matched TD peers in a series of two studies. In the first study, the authors had TD German-speaking preschoolers 3 to 5 years of age learn nine novel words in three experimental conditions: iconic shape gesture, arbitrary gesture, or no gesture. The words had between one to three syllables and were constructed following German phonotactic rules. The novel words were introduced as proper names for novel cartoon characters presented in pictures. Iconic gestures depicted shapes of the cartoon characters. For each word, there was a discovery game used to introduce each character. The child discovered each cardboard character underneath a cloth, while the experimenter named (and gestured in the arbitrary and iconic gesture conditions) the character twice and described its physical attributes. This was followed by a task in which the experimenter described the characters to the child who pointed to the images in front of them that matched the description. In a final leaping frog game, the character was named and gestured by the experimenter when the leaping frog landed on its card. Immediately after this training, fast-mapping production was measured with a picture naming task and receptive fast-mapping was subsequently measured in an identification task in which the children pointed to the correct character given their name. The TD children showed better expressive and receptive fast-mapping for words paired with gestures but had no preference between type of gesture. No analysis was completed on the words based on the number of syllables.

Looking towards iconic gestures only, the type of iconic gesture that is more easily interpreted seems to change as children develop (Hodges et al., 2015; Tolar et al., 2008). For example, in a study by Tolar et al. (2008), 2-, 3-, and 4-year-old children were presented familiar objects in two conditions: labeling or no labeling. In the labeling condition, children were asked to name pictured objects. If they did not correctly name the object, they were provided with the label. After verbal labeling, the researcher would then provide an iconic gesture which depicted either the action or the shape. In the no labeling condition, children's attention was simply drawn to the object and no label or gesture was provided. After the presentation task, comprehension of iconic gestures was tested using a forced-choice picture task. Results showed that successful mapping of iconic gestures to referent objects increased with age, supporting the notion that there is a protracted development of the interpretation of iconic gestures (Marentette & Nicoladis, 2011; Namy et al., 2004). The results also showed that children at all ages had better comprehension of iconic gestures conveying action over those conveying shape (Tolar et al., 2008).

In contrast to the findings of Tolar et al. (2008), Hodges et al. (2015), who tested 2-, 3-, and 4-year-olds using a similar methodology, found that only 2-year-olds correctly identified more objects associated with iconic gestures depicting action than those depicting shape. Three- and 4-year-olds did not perform differently when asked to identify a picture of a referent object in response to the two iconic gesture types. The authors attributed these findings to mean that comprehension of iconic gestures depicting actions emerges earlier but by 3 years of age children are able to equally demonstrate comprehension of both iconic gestures depicting action and those depicting shape.

Other studies have shown the opposite effect of gesture type on 2-year-olds. Capone and McGregor (2005) examined the effect of iconic gesture-type on fast-mapping of novel words in 2-year-old children. The children were exposed to 6 novel objects in three conditions: labelled with a novel word only, a novel word plus an iconic gesture depicting the action of the object, or a novel word plus an iconic gesture depicting the shape of the object. After a fast-mapping task involving exposing the child to each object by labeling it three times and allowing 60 to 90 seconds for the child to manipulate the object, a forced-choice object recognition task was administered. In this comprehension task, children were asked to identify the object from an array of four objects when presented with the novel word. Results showed that children had better fast mapping comprehension for words that were presented with iconic gestures indicating the object's shape. In addition, a picture naming task was administered. Results showed better word production performance in the shape gesture condition.

Similar results in favor of gestures indicating shape over action were found by Capone Singleton (2012). In this study, 2- and 3-year-old children were taught novel words associated with unfamiliar kitchen utensils accompanied by either a point gesture, an iconic gesture depicting an action performed by the object, or an iconic gesture depicting the object shape. Each object was labeled three times and the child was allowed to manipulate it before tested for novel word production in a picture naming task, and comprehension in a forced-choice picture task. Children in both age groups comprehended and produced more words in the iconic shape gesture condition than the iconic action gesture or the point gesture conditions and learned more words in the iconic action gesture condition than the point gesture condition. The author suggests that gestures were effective, in part, because they highlighted the meaning of the new word, with iconic shape gestures providing more semantic enhancement than iconic action gestures. However, comprehension results may have been influenced by the test stimuli. In the forced-choice picture task testing comprehension, children were shown the target object, a similar object, and a dissimilar object. The action of the target object and the similar object was the same while the shape of the target object and similar object differed. Therefore, the action gestures could correctly represent both the target and similar object, leading to more responses deemed incorrect.

In summary, previous research is conflicting in whether iconic gestures depicting action or shape are more beneficial to facilitating comprehension and production performance in fast-mapping. There seems to be more evidence demonstrating a greater facilitative effect of shape over action iconic gestures in 2-year-olds, but not necessarily in older children. Older children appear to benefit more from iconic action gestures, but some studies did not demonstrate facilitative differences between shape and action iconic gestures in older children. However, studies reviewed did demonstrate a benefit of iconic gestures over point gestures. The current study expanded upon age range previously investigated by studying the facilitative effects of iconic action gestures in school-aged children 5 to 8 years of age. Investigating older children will contribute to previous literature and help to interpret whether iconic action gestures can be facilitative in these older children.

Summary

In summary, the Emergentist (Hollich et al., 2000) and the Dual Coding Theory (McGregor et al., 2009) suggests that speech and gestures can be mutually supportive during word learning by visually displaying relevant semantic information associated with the referent, at least in preschool children. While integrating the visual information from a gesture with the auditory information from a spoken word and linking it to an object referent may be cognitively demanding, establishing verbal and non-verbal representations also provides multiple pathways for information to be retrieved, making word retrieval potentially simpler (Clark & Paivio, 1991).

The ability to fast-map iconic gestures separately from a word label has been demonstrated, and this ability becomes more proficient with age. Children as young as 18 months of age can successfully link a gesture to an object, as demonstrated by comprehension tasks, but the ability to interpret the iconicity of a gesture seems to develop gradually and is dependent on experience with gestures and world knowledge (Marentette & Nicoladis, 2011; Namy et al., 2004; Novack et al., 2015; Tolar et al., 2008). Specifically, a gesture is only iconic if a child has the world knowledge to interpret its meaning, otherwise it is arbitrary.

Further, gestural learning differs depending upon the type of iconic gesture. Generally, research suggests that preschool-aged children interpret iconic gestures depicting action more easily than those conveying shape (Capone & McGregor, 2015; Hodges et al., 2015; Namy et al., 2004; Novack et al., 2015; Tolar et al., 2008).

The studies reviewed demonstrate that co-speech iconic gestures can facilitate novel word production and comprehension in fast-mapping tasks. Although research has yet to identify the underlying reason behind why iconic gestures impact word learning, it has been suggested that receiving a co-speech iconic gesture may help children focus their attention on a particular aspect of a novel word thus enhancing their development of a semantic representation for a novel word (Goodrich et al., 2009; Mumford & Kita, 2014). That is, co-speech iconic gestures are suggested to enrich word learning by supplementing semantic information that establishes more robust word knowledge in fast-mapping tasks. Consistent with these hypotheses, fast-mapping studies (e.g., Capone Singleton, 2012; Luke and Ritterfeld, 2014; Tolar et al., 2008) have shown that co-speech iconic gestures can improve fast mapping production and comprehension.

The present study

The present study investigated the ability of TD children, 5 to 8 years of age, to produce and comprehend novel words and iconic action gestures in two conditions: novel words paired with iconic action gestures, and novel words produced without a gesture. The primary research interest was on the effects of co-speech iconic gestures that demonstrate the main action that could be performed upon an object. The expectation was that these gestures would supplement semantic information in word learning by providing a visual clue to the meaning of the word.

The study was designed to a) determine if receiving a novel noun paired with a co-speech iconic gesture would improve fast-mapping of the novel word, b) examine fast-mapping of the iconic gesture, c) examine age differences in fast-mapping performance, d) examine how the fast-mapping of novel words and iconic gestures changes after a delay, and e) determine how production and comprehension performance compares.

It was hypothesized that both age groups would perform better on novel words that were matched with iconic gestures than no gestures, due to previous studies demonstrating facilitative effects of co-speech iconic gestures on fast-mapping production and comprehension performances (e.g., Capone & McGregor, 2005; Capone Singleton, 2012; Luke & Ritterfeld, 2014; Namy et al., 2004). It was also hypothesized that both age groups would identify and produce the action that can be performed upon an object more with than without iconic gestures, as previous research demonstrates that children as young as 18 months of age can successfully link a gesture to an object and demonstrate comprehension of the gesture after fast-mapping (Namy et al., 2004). Since the ability to fast-map has been shown in literature to become more proficient with age (Marentette & Nicoladis, 2011; Novack et al., 2015; Tolar et al., 2008), it was hypothesized that children 7 to 8 years of age would out-perform children 5 to 6 years of age on production and comprehension tasks. In addition, since memory decays relatively quickly over time without rehearsal or additional encoding (Cowan, 2008), it was hypothesized that production and comprehension of novel words and iconic gestures would decrease after a delay. Lastly, it was hypothesized that children would have better comprehension of novel words and iconic gestures than production since comprehension processes are simpler than the processes required for word and gesture production.

The present study contributed to previous literature in a number of ways. First, it studied these issues in school-aged children. Children 5 to 8 years of age was chosen because originally the study set out to investigate the impact of co-speech iconic gestures on the fast-mapping of children with DLD. Setting an age-range of 5 to 8 years allowed for children with DLD to be matched in chronological age and language age (approximately 2 to 3 years of age) to TD children. However, due to recruitment difficulties, this comparison did not occur. Nonetheless, it was considered important for future studies of children with DLD to document fast-mapping using the present paradigm in typically developing school-aged children. In addition, as children enter school-age, there is a dramatic increase in vocabulary development and language becomes more decontextualized (Paul et al., 2018). As such, the question arises whether the same mechanisms in the facilitative effects of iconic gestures on fast-mapping are in play for school-aged children as in preschool-aged children. Second, previous studies investigated comprehension but not production of co-speech iconic gestures (Tolar et al., 2008; Sekine et al., 2015). This study investigated children's production and comprehension of iconic gestures as well as novel words to learn whether children can learn the gesture and demonstrate how to use the novel toy. Finally, previous studies only investigated the immediate effects of exposure to co-speech iconic gestures. The present study added to the literature by investigating how the effects of co-speech iconic gestures changed after a delay in comparison to words associated with no gestures. By investigating the effects of co-speech iconic gestures after a delay, information could be gathered on how long the potential facilitative effects of co-speech iconic gestures lasts without additional encodings.

CHAPTER 2 METHODOLOGY

Participants

The study included 23 TD, English monolingual children from across Canada between the ages of 5 and 8 years of age. Inclusionary and exclusionary criteria are outlined in Table 1. Typical development was established through both caregiver report and direct standardized testing. The criterion for typical development on the standardized tests was no more than one standard deviation below the mean. All participants met this criterion and no participant scored more than two standard deviations above the mean. Participant characteristics are outlined in Table 2.

Table 1

Inclusion and exclusion criteria

Inclusionary Criteria	Exclusionary Criteria
Typical hearing Typical general development Monolingual learners of English No diagnosis or suspected problems affecting language development Score within -1.0 to + 2.0 standard deviation on sentence-recall subtest of CELF	Diagnosed or suspected language or developmental delays Exposed regularly to other languages (besides core French in school)

Table 2

Participant Characteristics: means (standard deviation)

Variable	Participants 5 to 6 years of age	Participants 7 to 8 years of age	Group Comparisons (t-tests) p value and significance
Number	12	11	
Chronological age (years)	5.28 (0.58)	7.02 (0.59)	p = < 0.001*
CELF-5 *Recalling Sentences* raw score	34.64 (7.38)	50.83 (9.72)	p = < 0.001*
CELF-5 *Recalling Sentences* scaled score	12.45 (1.97)	13.17 (2.62)	P = 0.467 (NS)
SB4 *Verbal Knowledge* raw score	26.45 (3.36)	31.17 (3.64)	p = 0.004*

Variable	Participants 5 to 6 years of age	Participants 7 to 8 years of age	Group Comparisons (t-tests) p value and significance
SB4 *Verbal Knowledge* scaled score	11.91 (2.17)	11.67 (2.64)	p = 0.811 (NS)
Manual Dexterity Screening	4.73 (0.47)	4.92 (0.29)	p = 0.264 (NS)
Caregiver A's education (see table 3 for categories)	5.64 (1.03)	5.67 (0.65)	p = 0.934 (NS)
Caregiver B's education (see table 3 for categories)	4.64 (1.50)	4.82 (1.54)	p = 0.782 (NS)
Income (see table 4 for categories)	4.18 (0.98)	4.75 (0.45)	p = 0.101 (NS)

Note: NS = not significant; * = significant or p < 0.05, CELF-5 = Clinical Evaluation of Language Fundamentals – fifth edition, SB4 = Stanford Binet Intelligence Test-fourth edition. *CELF-5 recalling sentences* scaled scores: normative mean = 10, SD = 3. *SB4 verbal knowledge* scaled scores: normative mean = 10, SD = 3.

On standardized measures of language ability, participants' scaled scores were as follows. Scores on the *Recalling Sentences* subtest of the *Clinical Evaluation of Language Fundamentals – fifth edition (CELF-5)* (Wiig et al., 2017) ranged from 9 to 16 (*M* = 12.45, *SD* = 1.97) for 5 to 6-year-old participants and ranged from 8 to 16 (*M* = 13.17, *SD* = 2.62) for 7 to 8-year-old participants. For the *Verbal Knowledge* subtest of the *Stanford Binet Intelligence Scale - fifth edition (SB4)* (Roid, 2003), 5- to 6-year-old participants' scaled scores ranged from 9 to 15 (*M* = 11.91, *SD* = 2.17) and 8 to 16 (*M* = 11.67, *SD* = 2.64) for 7- to 8-year-old participants.

A *Manual Dexterity Screener* was administered, not as a criterion for participation, but was rather used as a descriptive measure to account for any variation in participant's dexterity when performing gestures. For the *Manual Dexterity* screening, all participants started with 5 points and were deducted one point for each observed red flag as outlined below in *Manual Dexterity Screener* under *Procedures.* For participants 5 to 6 years of age, scores ranged from 4 to 5 (*M* = 4.73, *SD* = 0.47) and scores ranged from 4 to 5 (*M* = 4.92, *SD* = 0.29) for participants 7 to 8 years of age.

Independent samples t-tests compared age group scores on the *CELF-5 Recalling Sentences*, *SB4 Verbal Knowledge*, and *Manual Dexterity* scores (see Table 2). There was a significant difference between age groups' raw scores for the *CELF-5* and *SB4* subtests, but not for scaled scores. Each group performed appropriately for their age bracket but performance on each measure improved with age. No significant differences were present between group scores for *Manual Dexterity.*

Three proxies for socioeconomic status (SES) were used as reported through a caregiver questionnaire: caregiver 1's education, caregiver 2's education, and family income (see Table 2). Caregiver education was measured by asking the level of education completed by each caregiver (e.g., some high school, high school, college, university, etc.; see Table 3). Family income was measured by asking annual family income amount separated into various income brackets (e.g., 0 – 30 000) as shown in Table 4. Caregivers could choose not to report on income or education level; however, all chose to report. Independent samples t-test compared groups on each measure of SES and found no significant group differences on any measure.

Table 3

Caregiver Education Values

Caregiver Education Values	
Level of Education	Value
Some high school	1
Highschool or equivalent	2
Vocational/technical school	3
College	4
Bachelor's degree	5
Master's degree	6
Doctoral degree	7
Professional degree	8
N/A, other, prefer not to say	0

Table 4

Family Income Values

Family Income Values	
Annual Income ($)	Value
0 – 30 000	1
30 000 – 60 000	2
60 000 – 80 000	3
80 000 – 125 000	4
125 000 +	5
N/A, I do not know, I prefer not to say	0

Recruitment. Participants were recruited by word of mouth, social media posts, online newsletters, and through posters in public spaces including libraries and the *Discovery Centre* in Halifax, Nova Scotia.

Materials

Equipment and technology. Due to COVID-19, the study was transferred to an online format. All participants were tested using the online format. With ethical approval, the Zoom application was used to videoconference and record the session with participants, and caregivers were provided with recommendations for videoconferencing (see Appendix A). Caregivers were also provided a list of required materials for the study (see Appendix B). Caregivers were asked to stay in the room with the participant, or to remain nearby for assistance in the case of technological difficulties. If caregivers remained in the room, they were asked to not prompt or provide any answers to the participant.

PowerPoint was used to display the stimuli to participants through the use of screen share. In order to keep participants focused and engaged, participants could earn stars to add to their online star chart, with the completion of each activity, for a total of eight stars. In addition, children received a *Junior Scientist* certificate through mail or e-mail (caregiver indicated preference) to thank them for their participation in the study.

Eligibility questionnaire. Caregivers completed a brief questionnaire (see Appendix C) and returned it to the examiner prior to the experimental session to ensure that participants met specified inclusion and exclusion criteria for the study. If participants were eligible for the study based on the questionnaire, a testing date and time were scheduled with the participant's caregiver.

Caregiver questionnaire. Caregivers completed a short questionnaire prior to the testing session (see Appendix D) and returned it to the examiner by email. This questionnaire provided SES information.

Articulation screener. A short articulation task was administered in which 22 words were elicited, using online picture cards presented on PowerPoint, to document any baseline speech production errors which could impact the word production probe. The screener was developed by the researcher to assess initial, medial and final consonant sounds specifically included in the study stimuli. The sounds assessed included: /p/, /b/, /k/, /s/, /l/, /v/, /kl/ and /sm/ in the word initial position; /t/ and /n/ in the word medial position; and /g/, /k/, /b/, /f/, and /d/ in the word final position. Each word was transcribed in real time by the examiner using the International Phonetic Alphabet. Two participants were identified by caregivers as having articulation difficulties. Both participants were able to produce all target sounds included the study appropriately. See Appendix E for the articulation screener.

Manual dexterity screener. All participants completed the manual dexterity testing to ensure that participants had adequate ability to produce the study's target gestures. The manual dexterity screener was developed by the researcher using four activities from the *Motor screener* of the *Developmental Indicators for the Assessment of Learning – fourth edition (DIALS-4)* (Mardell & Goldenberg, 2011) to screen for the following red flags for fine motor and imitation skills in school-aged children (5 to 7 years old): a) shaky or stiff movements, b) weak arms or hands, c) inability to cut along a straight line, d) inability to hold a writing utensil with thumb and fingers, and e) inability to draw a circle, square and cross (Children's Therapy & Family Resource Centre, 2011). See Appendix F for the manual dexterity screener.

Recalling sentences. Participants were tested on the *Sentence-Recall* subtest of the *CELF-5.* The *Recalling Sentences* subtest is a standardized measure of language with documented accuracy in distinguishing language impairment (Theodorou et al., 2017). While the *Recalling Sentences* subtest is a measure of morphosyntax, it also measures vocabulary production and verbal memory recall abilities, skills required for a fast-mapping task. Children were asked to listen carefully and repeat sentences exactly as they were modelled, with no repetitions allowed. Raw and scaled scores ($M = 10$, $SD = 3$) were generated.

Verbal knowledge. Participants were tested on the *Verbal Knowledge* subtest of the *SB4.* The *verbal knowledge* subtest assesses vocabulary ability, or verbal cognition (Carroll, 1993; Kaufman, 1994). Participants were asked to demonstrate their verbal knowledge by identifying named verbs from an array of five photos, as well as provide definitions or descriptions of the target words. Raw and scaled scores ($M = 10$, $SD = 3$) were generated.

Experimental stimuli

Six novel words (Table 5), objects, and six novel action gestures indicating the action of the novel objects (Table 6) were used in the study. Using novel words, gestures, and objects was important to capture word learning processes and account for a participant's previous experience with the words. In addition, using novel words to refer to novel objects allowed us to adhere to the principles of mutual exclusivity and the principle of contrast (Gray, 2003; Kiernan & Gray, 1998) because participants could maintain a 1:1 correspondence between a word and its referent, temporarily simplifying the quantity of information participants must consider when learning novel words.

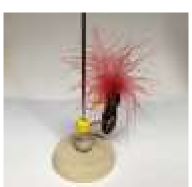
Table 5

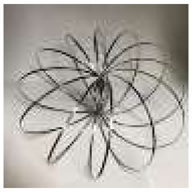
Stimuli: novel object labels

Novel noun orthographic	Novel noun IPA
Ved	/vɛd/
Lotib	/lotɪb/
Klig	/klɪg/
Baif	/baɪf/
Punik	/pʌnɪk/
Smig	/smig/

Table 6

Stimuli: novel objects and associated gesture descriptions

Novel object	Gesture description
	Place open palms together. Rub hands together.
	Position right hand in a fist as if holding something. Move hand up and down.
	Place left hand in the center flat and facing up. Bring together the fingers of the right hand and place in the center of palm. Move right hand upwards. On the way down, zig zag in and out from midline.
	Hold right hand up with thumb, first and second finger out to meet at a point. Open and close fingers in a pinching motion. Tuck the other two fingers into fist.

Novel object	Gesture description
	Hold right hand in a fist and move in a counter clockwise circular motion. Take left hand with fingers held together and move up and down just above right hand.
	Hold hands out, parallel to ground, with palms facing each other. Bring together towards middle in a clapping like motion.

Novel objects. Novel objects were selected to be ones that children would be unlikely to have experience with or be able to name. The novel objects were toy-like items made of wood, metal and plastic substances. All objects were colourful in order to be attention-grabbing to participants. To ensure object novelty, caregivers were provided pictures of the objects in advance (Appendix G) and asked to indicate whether their child was familiar or unfamiliar with each. All caregivers indicated that their child was not familiar with any of the novel objects.

Novel gestures. Novel gestures displayed the main action that could be performed upon the object (see Table 6).

Novel words. Six novel words were created as labels for the novel objects, as listed in Table 5. The novel labels were randomly generated by assigning each English phoneme a number and allowing a random number generator to combine phonemes into two CVC, two CCVC, and two CVCVC patterns. Illegal English phonotactic combinations and real words were rejected. Consonants were restricted to earlier acquired phonemes (Table 7) in which there is 90% mastery for ages 3.0 to 3.5 years (Dodd et al., 2003). Vowels were not restricted as research suggests that all vowels are mastered in a child's speech by 3 years of age. CVC, CCVC, and CVCVC word structures were used as all three word structures are present in the speech of children 2 to 3 years of age (Stoel-Gammon, 1987; Dodd, 1995; Watson & Skucanec, 1997) and mastery of most initial consonant clusters occur around 4.5 to 5.5 years of age (Priester et al., 2011). Early acquired phonemes and word structures were used as research suggests that hand gestures may disrupt word learning if the phonetic demands of the stimuli are too high (Kelly & Lee, 2012).

Table 7

Phonetic acquisition of consonants in 90% of the children (n=684) age of mastery according to Dodd et al., (2003).

Age	Present
3.0 to 3.5 years	p, b, t, d, k, g m, n, ŋ f, v, s, z, h w, l-, j
3.6 to 3.11 years	tʃ
4.0 to 4.5 years	ʒ dʒ
4.6 to 4.11 years	
5.0 to 5.5 years	ʃ
5.6 to 5.11 years	
6.0 to 6.5 years	ɹ
6.6 to 6.11 years	
7.0 + years	θ, ð

Procedures

Stimuli validation. A gesture-to-referent matching task was completed by five graduate students, three studying Speech-Language Pathology and two studying Audiology (age range 23 to 29; all female), to ensure that the gestures unambiguously represented the action of a given object. In this task, each adult was separately provided time to interact with each object to discover how it worked. They were then presented with the iconic gestures representing the action of the object and asked to match each to the target novel object. Adults successfully matched the gestures to the objects. Only two adult participants made an error in matching a target object to an iconic gesture. However, one later self-corrected. The errors they made were on separate items (i.e., the fifth and sixth novel object listed in Table 5).

The same adult participants were asked whether they could provide a label for any of the objects and asked if they were familiar with any of the objects. No adults were able to provide a label for any of the objects, and all indicated that they were unfamiliar with the objects suggesting that the objects are novel.

Later, the same five adult raters, who were native speakers of English, returned and were asked whether each non-word was (1) a word they knew in English and (2) if the non-word could be a plausible English word. All five adults agreed that each novel word was not a real word in English, but all were plausible words phonotactically. Four additional words were discarded as the adults identified them as sounding very similar to a real word in English.

Stimuli randomization. First, novel words were paired to the novel objects and their associated gestures, using the Latin square method. Then, the order of presentation was randomized using the Latin square method, resulting in six orders. Following this, the first three words were assigned to one gesture condition, and the next three words were assigned to the other gesture condition. The order of gesture condition (word + gesture first or word + no gesture first) was then counterbalanced across participants in each age group such that half the participants had word + gesture first and half had word + no gesture first. For the word and gesture production and comprehension probes, the order in which participants were asked to label or identify (word or gesture) the stimuli was also randomized.

Pilot procedures. Two child participants were included in pilot testing (see Table 8 for participant characteristics). Neither participant was eligible for the study due to their age being outside the study range (participant a) or they were bilingual (participant b). Both participants successfully completed the training and experimental procedures, as outlined below. No adjustments were made to the protocol in response to the pilot.

Table 8

Participant Characteristics: Pilot

Variable	Participant A	Participant B
Chronological age (years)	4;11	7;4
Language	English	English, Korean
CELF-5 *Recalling Sentences* raw score	18	56
CELF-5 *Recalling Sentences* scaled score	10	15
SB4 *Verbal Knowledge* raw score	21	32
SB4 *Verbal Knowledge* scaled score	10	12
Manual Dexterity Screening	5	5
Caregiver A's education (see table 3 for categories)	6	6
Caregiver B's education (see table 3 for categories)	7	6
Income (see table 4 for categories)	5	4

Note: CELF-5 = Clinical Evaluation of Language Fundamentals – fifth edition, SB4 = Stanford-Binet Intelligence Test-fourth edition. *CELF-5 recalling sentences* scaled scores: normative mean = 10, SD = 3. *SB4 verbal knowledge* scaled scores: normative mean = 10, SD = 3.

Pre-experimental tasks. For each participant, the following activities were completed prior to beginning the experimental fast-mapping tasks: eligibility questionnaire, caregiver questionnaire, *Recalling Sentences* subtest of *CELF-5*, *Verbal Knowledge* subtest of *SB4,* manual dexterity screener and training, in that order. Two participants also completed the articulation screener after they completed the manual dexterity screener.

Practice trials, experimental task. The experimental fast-mapping (FM) task began with two FM practice trials. The first FM practice trial involved one familiar object and label with no associated gesture (see Table 9). The second FM practice involved one unfamiliar object and label with an associated gesture. Participants received the instructions: *I have another game for us to play today, but before we begin, I will show you how my games work. I have a couple of toys for us to play with in this treasure box, but they are a surprise! So, let's find out together.*

Table 9

Practice stimuli: object, label and gesture description

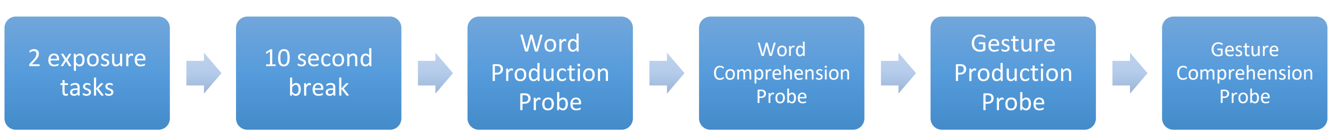
Familiarity	Object	Gesture description	Label
Familiar object	Toy hammer	Hand in fist (palm facing down) moving up and down as if nailing something.	Hammer
Unfamiliar object	Egg slicer	Hands flat, palms down and parallel with floor, one on top of other, moving open and shut.	Vup

The researcher first presented the familiar object, and subsequently the unfamiliar object. For each trial, the participant watched an animation, developed by the researcher, of a treasure chest opening and the target object popping out. Immediately following, a video of the researcher was presented saying: e.g., *Hammer. This is a hammer.* The word "hammer" was not accompanied by a gesture. Then the researcher showed the object to the participant by slowly rotating it, and subsequently demonstrated how the object worked. The unfamiliar object label: *Vup. This is a vup* was accompanied by the object's gesture. Each video clip was approximately 20 seconds in length.

The two FM practice trials were followed by a 10 second non-verbal animation clip of *Pingu*. Following this, the participant's production and comprehension of the practice words and gestures were tested. Figure 1 outlines the sequence of training activities.

Figure 1

Fast-mapping practice protocol



Corrective and affirming feedback were provided to participants in the practice probes. For the word production probe, participants were asked to produce the target label by naming a picture of the object presented to them. Participants were asked, *What is toy #1 called? What is* *toy #2 called?* If participants incorrectly produced the target object label, or they did not respond at all, corrective feedback was provided by saying: *It's a [word]. You say [word].* If the participant provided the gesture instead of the label they were prompted by the researcher: *Good job! Can you tell me with your words, too?* If the participant produced the label correctly, the experimenter praised them saying: *You are right! Good job!* and moved on.

For the word comprehension probe, images of both practice trial objects were shown to the participant. Participants were provided the instructions: *I'm going to name the toys and I want you to tell me the toy's number (either #1 or #2) when I name it. Which one is the hammer? … Which one is the vup?* If the participant could not indicate the correct object, the researcher said: T*he [word] is this one. Now you point to the [word]*. If the participant pointed to the correct object, the researcher praised them saying: *You are right! Good job!* and moved on.

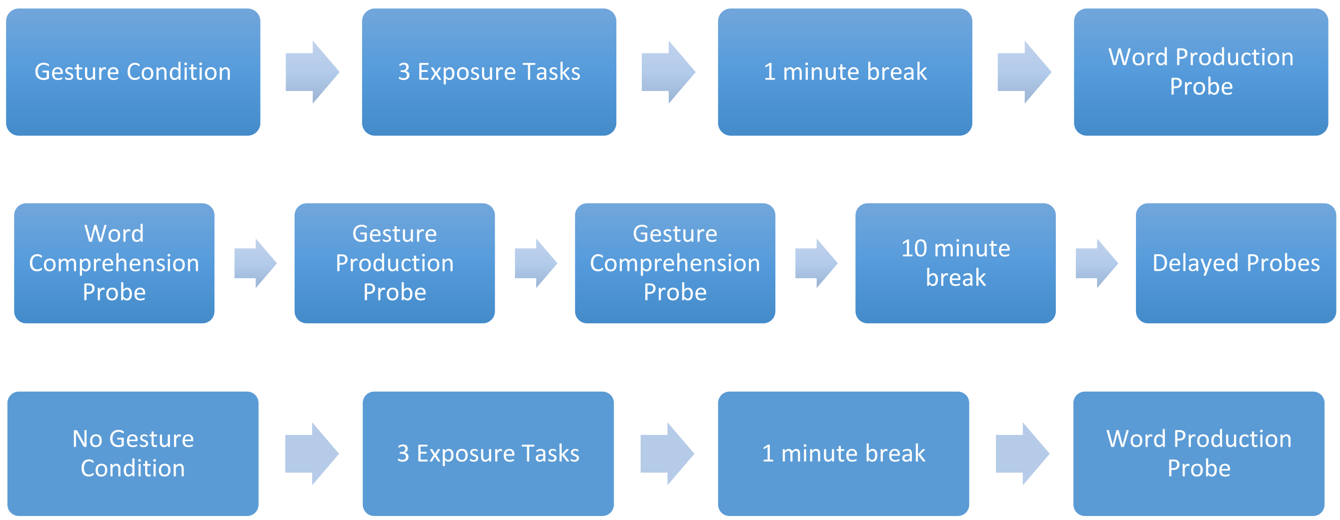
In the gesture production probe, both images were shown to the participant. Participants were asked: *Now I would like to know how each of the toys work. Use your hands to show me how to use toy # [1 or 2].* If the participant could not produce the correct action or if they produced the wrong action, they were prompted by the researcher: *Look, this one does this [gesture]. Now you do it*. If the participant produced a partially correct gesture, they were provided corrective feedback: *Look, this one does this [gesture]. Now you try again.* If the participant produced the correct gesture, the researcher praised them saying: *You are right! Good job!* and moved on.

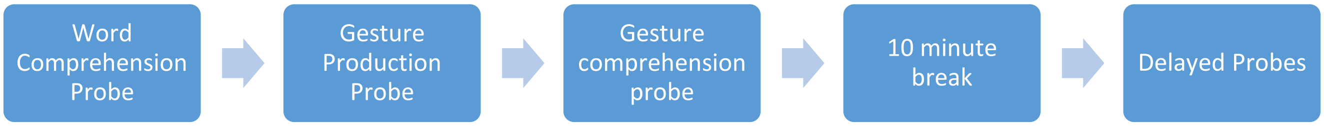
Finally, the gesture comprehension probe was administered. Participants were instructed: *Now watch the video and tell me which toy works like that, either #1 or #2.* If the participant could not indicate the correct object, the researcher said: T*he [gesture] is this one. Now you point to the [gesture]*. If the participant pointed to the correct object, the researcher praised them saying: *You are right! Good job!* and moved on.

Experimental fast-mapping (FM) tasks. Six FM tasks were administered, three in each of two conditions: gesture and no-gesture. Each condition (gesture or no-gesture) began with three experimental FM exposure tasks. A one-minute break followed consisting of a non-verbal video clip. The first video was *Tom and Jerry*, the second video clip was *Pingu*. After the break, word production, word comprehension, gesture production, and gesture comprehension probes were administered (i.e., immediate probes). The production probes were tested first to avoid further immediate exposure to the object labels and gestures associated with them. The gesture comprehension probes were included in the no gesture condition to determine how easily participants can identify the objects based on a gesture they had not yet seen. A ten-minute break followed and then the probes were re-administered in the same order (i.e., delayed probes). For the 10-minute break, participants had the option to stretch their legs, use the bathroom, get a snack, watch a video (*Tom and Jerry* or *Theodore Tugboat*), or play a game (*Xs and Os* or *Snakes and Ladders*). Figure 2 outlines the sequence of activities in each gesture condition.

Figure 2

Experimental protocol of fast-mapping task by condition





Exposure tasks. Participants were provided with the instructions: *Now that we know how the game works, let's find out what is in our two treasure boxes together.* Participants were then shown randomized stimuli one at a time. For each trial in the no gesture condition, the participant watched an animation, developed by the researcher, of a treasure chest opening and the target toy popping out. Immediately following, a video of the researcher was presented saying: *[novel word]. This is a [novel word].* Then the researcher showed the randomly matched object to the participant by slowly rotating it, and subsequently demonstrated how the object worked. Each video clip was approximately 20 seconds in length. In the gesture condition, the exposure task was exactly the same except the toy label was accompanied with the corresponding gesture. Imitations of the word or gesture were neither encouraged nor discouraged. After the three exposure trials in a condition, participants had a one-minute break consisting of a non-verbal video clip. Test probes were subsequently administered without corrective feedback as follows.

Word production probe. The immediate and delayed word production probes were both administered using a picture-naming task. Pictures of the three objects were displayed to the participant and labeled as #1, #2, or #3 accordingly. Participants were asked to produce the target label by naming each picture presented to them: *What is toy #1 called? What is toy #2 called? What is toy #3 called?* If the participant provided the gesture instead of the label they were prompted by the researcher: *Nice try but tell me with your words, please. What is toy #__ called?* If the participant produced a label (correctly or incorrectly), the researcher responded: *Thank you!* and moved on. If the participant did not produce a label for the object, the researcher said: *You don't know? OK. Let's try another one. What is toy #__ called?*

Word comprehension probe. A picture selection task was used to administer immediate and delayed word comprehension probes. In the word comprehension probe, pictures of the three objects were displayed to the participant and labeled #1, #2, or #3 accordingly. The participants were provided the instructions: *I'm going to name the toys and I want you to tell me the toy's number (either #1, #2, or #3) when I name it. Which toy is the [word]?* In this probe, the participants were only provided the verbal label for the object. If the participant indicated a toy (correctly or incorrectly), the researcher responded: *Thank you!* and moved on. If the participant did not respond the researcher said: *You don't know? OK. Let's try another one. Which toy is the [word]*?

Gesture production probe. In the immediate and delayed gesture production probes, images of the three objects were displayed to the participant and labeled #1, #2, or #3 accordingly. Participants were provided the instructions: *Now I would like to know how each of the toys work. Use your hands to show me how to use toy # [1, 2, 3].* If the participant provided the label or a verbal description instead of the gesture, they were prompted by the researcher: *Nice try but show me using your hands please. How do you use toy # [1, 2, 3]?* If the participant produced the gesture (correctly or incorrectly), the researcher responded: *Thank you!* and moved on. If the participant did not produce a gesture for the object, the researcher moved on saying: *You don't know? OK. Use your hands to show me how to use toy # [1, 2, 3].*

Gesture comprehension probe. Immediate and delayed gesture comprehension probes were administered in a similar way as described for the word comprehension probes. Participants were instructed to watch a video of the researcher producing a gesture and indicate the correct corresponding object. Images of the three objects were displayed beside the video and labeled #1, #2, or #3 accordingly. The participants were provided the instructions: *Now watch the video* *and tell me which toy works like that, either #1, #2 or #3.* If the participant indicated a toy (correctly or incorrectly), the researcher responded: *Thank you!* and moved on. If the participant does not respond the researcher moved on saying: *You don't know? OK. Let's try another one.*

Delayed probes. Upon completion of the fast-mapping exposure tasks and immediate test probes for each condition, a 10-minute break occurred. After the break, the test probes were repeated in the same order to gain insight on effects of delay on production and comprehension.

Scoring

Scoring was completed by the researcher after the experimental session through the use of recorded videos. Participants' responses for each target object in the word production probes were scored by providing one point for the correct word structure, one point for the produced word containing the correct number of phonemes, and one point for every correct phoneme produced in the correct order (see table 10). The proportion correct was then calculated for each of the three novel words presented in each condition (gesture, no gesture) by taking the points obtained for each target word divided by the total possible points a participant could score for each target word (see table 11). The average of the three proportions was then calculated (maximum score per condition = 1).

Table 10

Word production probe scores

Variable	Value
Incorrect / no answer	0
Correct word structure	1
Correct number of phonemes	1
Number of correct phonemes in order	1 (+)

Table 11

Total possible points per target word

Target word	Value
Baif	5
Punik	7
Smig	6
Ved	5
Lotib	7
Klig	6

Participants' responses for the gesture production probes were scored based on the presence of the following gestural features: correct number of hands (1 vs. 2), hands in correct orientation, space (i.e., in the correct location), and correct movement for a total of 4 points per novel gesture. Scores were summed across the three novel gestures was calculated for a maximum score of 12. See table 12 below for an outline of gesture production scoring.

Table 12

Gesture production probe scores

Variable	Value
Incorrect / no answer	0
1 feature included	1
2 features included	2
3 features included	3
All 4 features included	4

Word and gesture comprehension probes were scored as follows for each target word in the study: correct = 1, incorrect = 0. The scores for each target word or gesture in a condition were summed for a maximum of three points.

Scoring reliability

The researcher scored the responses for the word and gesture production and comprehension probes for all participants. A second trained rater (fourth year geography undergraduate student with no prior knowledge of study) scored the responses for the word and gesture production and comprehension probes for 10% of participants 5 to 6-years-old and 10% of participants 7 to 8-years-old (two participants each for a total of four participants).

Participants were selected randomly by the second trained rater. Interrater reliability of scoring for word and gesture production and comprehension probes across participants was calculated using Cohen's Kappa, a measure of the proportion of agreement *over and above* chance between two raters.

For word production, there was moderate agreement between the two raters: $\kappa = 0.477$, $p < 0.001$; and for gesture production, there was similarly moderate agreement between the two raters: $\kappa = 0.570$, $p < 0.001$. For word comprehension, there was almost perfect agreement between the two raters: $\kappa = 0.902$, $p < 0.001$. Similarly, for gesture comprehension, there was almost perfect agreement between the two raters: $\kappa = 0.811$, $p < 0.001$.

Data analysis

Four three-way repeated measures Analysis of Variance (ANOVAs) were conducted, with word and gesture production and comprehension scores as the dependent variables. In the ANOVAs, there was one between-subjects factor (age: 5- to 6-year-olds, 7- to 8-year-olds) and two within-subject factors (time: immediate, delayed; condition: gesture, no-gesture). Significance was set *a priori* at $p \leq 0.05$ but corrected using a Benjamini-Hochberg correction for all post-hoc analyses investigating significant interactions using t-tests. Statistical analyses were completed using IBM Statistics SPSS software.

CHAPTER 3 RESULTS

Word production

Word production was scored by the averaging the proportion correct for the three novel words presented in each condition for each participant. Descriptive statistics for fast-mapping word production performance by age, time and condition are presented in Table 13. See Appendix H for all statistical results.

Table 13

Descriptive statistics for the word production probes: Means and standard deviations by time, condition and age (max = 1)

Time/Gesture Condition	Age group	Mean	Std. Deviation	N
Gesture - Immediate	5 to 6 years	0.11	0.14	11
	7 to 8 years	0.41	0.34	12
Gesture - Delayed	5 to 6 years	0.05	0.10	11
	7 to 8 years	0.19	0.20	12
No gesture - Immediate	5 to 6 years	0.06	0.10	11
	7 to 8 years	0.30	0.28	12
No gesture - Delayed	5 to 6 years	0.08	0.11	11
	7 to 8 years	0.13	0.14	12

ANOVA revealed a significant main effect of time (F (1, 21) = 13.54, p = 0.001; n_p^2 = 0.392), with higher word production performance during the immediate probes (M = 0.218, SE = 0.032) than the delayed probes (M = 0.112, SE = 0.025).

A significant interaction of time by age (F (1, 21) = 9.50, p = 0.006; n_p^2 = 0.311) was also found. Table 14 shows the means and standard errors for the interaction of time by age. The time by age interaction is depicted in Figure 3.

Table 14

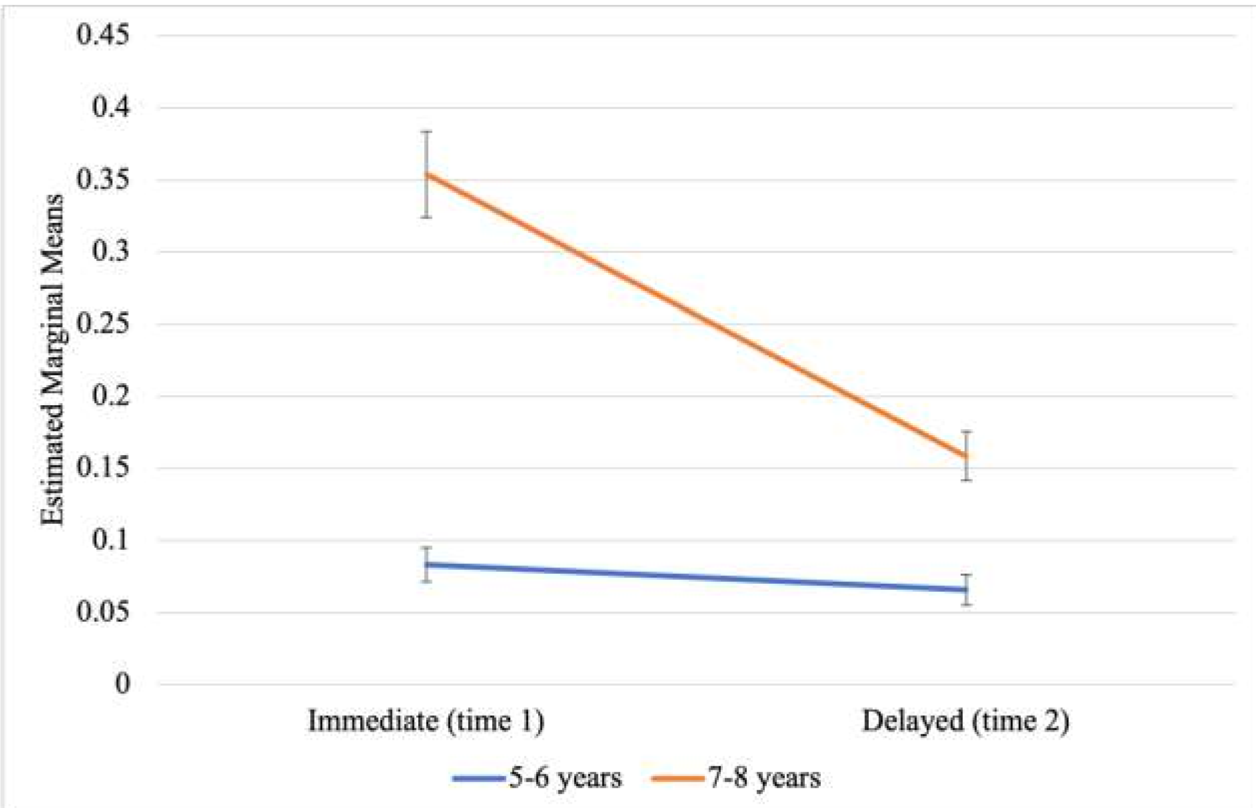
Means and standard errors for interaction of time by age

Age group	Time	Mean	Std. Error
5 to 6 years	Immediate (time 1)	0.08	0.03

Age group	Time	Mean	Std. Error
5 to 6 years	Delayed (time 2)	0.07	0.03
7 to 8 years	Immediate (time 1)	0.35	0.05
	Delayed (time 2)	0.16	0.04

Figure 3

Time by age interaction for word production probes



Note: error bars represent standard errors for each mean

Four post-hoc t-tests were completed to investigate the interaction further. Benjamini-Hochberg correction for the four comparisons adjusted the significance to $p \leq 0.025$. Two independent t-tests compared the age groups on immediate versus delayed word production probes. For the immediate probes, there was a significant difference between 5- to 6-year-olds and 7- to 8-year-olds (t (21) = -4.202; $p < 0.001$) with the 7- to 8-year-olds performing better than the 5- to 6-year-olds. For the delayed probes, there was no significant effect between age groups.

Two post-hoc paired samples t-tests compared each age group's immediate versus delayed word production probes. For 5- to 6-year-olds, there was no significant effect. For 7- to 8-year-olds, there was a significant difference between the immediate and delayed probes (t (11) = 3.752; p = 0.003), with significantly better performance in the immediate than the delayed probes.

To determine whether phonetic complexity impacted the production results, the percentage of target words participants correctly produced for CVC versus CCVC versus CVCVC word structures was investigated. Correct productions were counted if every phoneme in a target word was produced correctly and in the correct order. For the CVC word structure, overall participants produced 17.4% of words correctly. Participants produced 19.5% of words with CCVC word structure correctly, and 10% of words with CVCVC word structure. Chi-squared analysis did not reveal any significant differences between the amount of correct productions across the outlined word structures: x^2 (2, 138) = 1.406, p = 0.495.

Word comprehension

Word comprehension probes were scored as correct = 1 or incorrect = 0 summed across the three words in a condition, for a maximum of three points. Descriptive statistics for fast-mapping word comprehension performance by age, time and condition are presented in Table 15. The 3-way ANOVA revealed no significant main effects or interactions. See Appendix H for all statistical results.

Table 15

Descriptive statistics for the word comprehension probes: Mean and standard deviations by time, condition and age (max = 3)

Time/Gesture Condition	Age group	Mean	Std. Deviation	N
Gesture - Immediate	5 to 6 years	1.09	1.04	11
	7 to 8 years	2.25	1.14	12
Gesture - Delayed	5 to 6 years	1.64	1.36	11
	7 to 8 years	2.33	1.23	12
No gesture - Immediate	5 to 6 years	1.82	1.17	11
	7 to 8 years	2.00	1.28	12
No gesture - Delayed	5 to 6 years	1.73	1.10	11
	7 to 8 years	2.00	0.95	12

Gesture production

Gesture production was scored by identifying the number of gestural features (i.e., number of hands, orientation, space, and movement) produced correctly for a total of 4 points per novel gesture and summing across the three words in a gesture condition (maximum per condition = 12). Descriptive statistics for fast-mapping gesture production performance by age, time and condition are presented in Table 16. See Appendix H for all statistical results.

Table 16

Descriptive statistics for the gesture production probes: Mean and standard deviations by time, condition and age (max = 12)

Time/Gesture Condition	Age group	Mean	Std. Deviation	N
Gesture - Immediate	5 to 6 years	5.55	2.21	11
	7 to 8 years	7.83	2.41	12
Gesture - Delayed	5 to 6 years	6.27	2.15	11
	7 to 8 years	8.75	2.90	12
No gesture - Immediate	5 to 6 years	5.45	2.46	11
	7 to 8 years	5.75	2.26	12
No gesture - Delayed	5 to 6 years	6.09	2.55	11
	7 to 8 years	6.42	2.64	12

A significant main effect of time (F (1, 21) = 11.70, p = 0.003; n_p^2 = 0.358) was found, with higher gesture production performance after a delay (M = 6.883, SE = 0.453) relative to the immediate probes (M = 6.146, SE = 0.392).

A significant main effect of gesture (F (1, 21) = 4.56, p = 0.045; n_p^2 = 0.178) was also found, with higher gesture production performance in the gesture condition (*M* = 7.100, *SE* = 0.499) compared to the no gesture condition (*M* = 5.938, *SE* = 0.488).

The complexity of the gesture was also investigated in relation to the percentage of target gestures participants, correctly produced for each object. Correct productions were counted if all four features (i.e., number of hands, orientation, space, and movement) were correctly included in the gestural production. Scores were combined across age, time and gesture condition. Participants produced 56.5% of gestures for object #1 (refer to table 6 for objects and their corresponding gesture), 19.5% of gesture for object #2, 19.5% of gestures for object #3, 8.7% of gesture for object #4, 0% of gestures for object #5, and 63% of gestures for object #6. Chi-squared analysis revealed a significant difference between the amount of correct gesture productions across the objects: x^2 (5, 276) = 79.347, $p < 0.001$.

Gesture comprehension

Gesture comprehension probes were scored as correct = 1 or incorrect = 0 with scores summed across the three items in a condition, with a maximum of three points. Descriptive statistics for gesture comprehension performance by age, time and condition are presented in Table 17. See Appendix H for all statistical results.

Table 17

Descriptive statistics for the gesture comprehension probes: Mean and standard deviations by time, condition and age (max = 3)

Time/Gesture Condition	Age group	Mean	Std. Deviation	N
Gesture - Immediate	5 to 6 years	2.18	1.08	11
	7 to 8 years	2.67	0.78	12
Gesture - Delayed	5 to 6 years	1.91	1.14	11
	7 to 8 years	2.67	0.78	12
No gesture - Immediate	5 to 6 years	1.18	0.75	11
	7 to 8 years	2.50	0.80	12
No gesture - Delayed	5 to 6 years	2.00	1.18	11

Time/Gesture Condition	Age group	Mean	Std. Deviation	N
No gesture - Delayed	7 to 8 years	2.75	0.62	12

A significant interaction of gesture by time (F (1, 21) = 9.50, p = 0.006; n_p^2 = 0.311) was found. Table 18 shows the means and standard errors for the interaction of gesture by time. The gesture by time interaction is depicted in Figure 4.

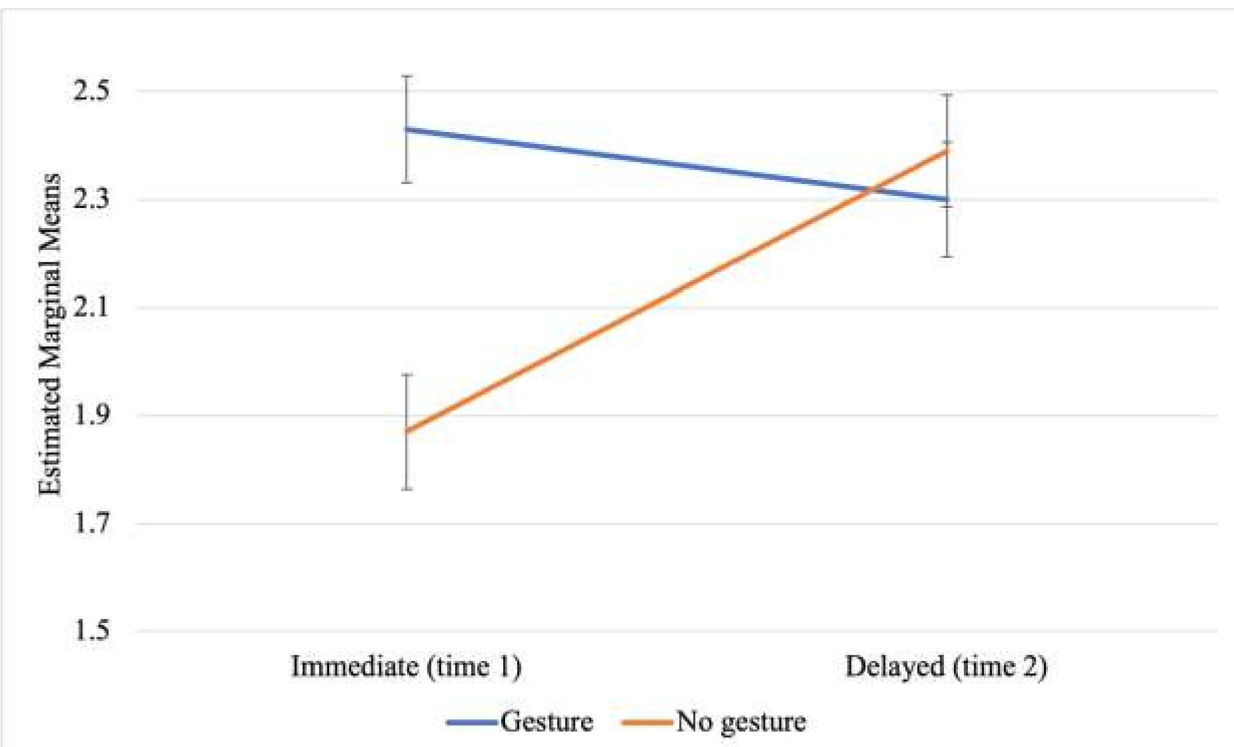
Table 18

Means and standard errors for interaction of gesture by time

Gesture group	Time	Mean	Std. Error
Gesture	Immediate (time 1)	2.43	0.20
	Delayed (time 2)	2.30	0.21
No gesture	Immediate (time 1)	1.87	0.21
	Delayed (time 2)	2.39	0.21

Figure 4

Gesture by time interaction for gesture comprehension probes



Note: error bars represent standard errors for each mean

Four post-hoc paired t-tests were completed to investigate the interaction further. Benjamini-Hochberg correction for the four comparisons adjusted the significance to $p \leq 0.025$. Two paired t-test compared the gesture groups (gesture and no gesture) at immediate versus delayed probes respectively. For the immediate probes, gesture approached significance (t (22) = 2.072; p = 0.05) with better gesture comprehension in the gesture than then no gesture condition. For the delayed probes, no significant effect of gesture was found.

Two paired t-tests also compared immediate and delayed probes across gesture condition (gesture and no gesture). For the no gesture condition, time approached significance (t (22) = -2.021; p = 0.05) with better comprehension in delayed probes compared to immediate probes. For the gesture condition, no significant difference of time was found.

Comprehension and Production Comparisons

Participant performance on comprehension and production probes was also compared. To allow for comparisons, performance on word production probes and gesture production probes were re-scored to be either correct = 1 or incorrect = 0, summed for a maximum of 3, to match the scoring of the comprehension probes. For the word production probes, correct was defined as a word production with all target phonemes in the correct order. For the gesture production probe, correct was defined as the gesture production correctly containing all four gestural features (i.e., number of hands, orientation, space, and movement). Word and gesture production and comprehension scores were then calculated by averaging the summed scores (max = 3) for each of the probes for each age group (immediate word/gesture production, gesture condition; delayed word/gesture production, gesture condition; immediate word/gesture production, no gesture condition; delayed word/gesture production, no gesture condition). Comprehension probes were calculated in the same way for the four comprehension probes for each age group (immediate word/gesture comprehension, gesture condition; delayed word/gesture comprehension, gesture condition; immediate word/gesture comprehension, no gesture condition; delayed word/gesture comprehension, no gesture condition). See Table 19 for the means and standard deviation by group and probe.

Table 19

Means, standard deviations, and standard errors for comprehension and production

Age group	Probe	Mean	Std. Deviation	N
5 to 6 years	Word production	0.05	0.15	11
	Gesture production	0.68	0.39	11
	Average production	0.37	0.27	11
	Word comprehension	1.57	0.75	11
	Gesture comprehension	1.82	0.71	11
	Average comprehension	1.70	0.73	22
7 to 8 years	Word production	0.35	0.34	12
	Gesture production	0.98	0.67	12
	Average production	0.67	0.51	12
	Word comprehension	2.15	0.86	12
	Gesture comprehension	2.65	0.45	12
	Average comprehension	2.40	0.66	12

Informally, each age group performed better on word and gesture comprehension probes than production probes.

CHAPTER 4 DISCUSSION

This study investigated the ability of TD children, 5 to 6 years of age and 7 to 8 years of age, to fast-map novel nouns and iconic gestures depicting action. The objectives of the study included: a) determine if receiving a novel noun paired with a co-speech iconic gesture would improve fast-mapping of the novel word, b) determine if receiving a co-speech iconic gesture improves comprehension and production of the gesture, c) examine age differences in fast-mapping performance, d) examine how the fast-mapping of novel words and iconic gestures changed after a delay, and e) determine how production and comprehension performance compare.

It was hypothesized that a) both age groups would perform better on words that were matched with iconic gestures than no gestures, b) both age groups should be able to identify and produce the action performed upon an object more easily with than without gestures, c) that children 7 to 8 years of age should out-perform children 5 to 6 years of age on production and comprehension tasks, d) that production and comprehension of words and gestures would decrease after a delay, and e) that children would have better comprehension for words and gestures than production.

Overall, it was found that for word production, only 7- to 8-year-olds had greater fast-mapping performance on the immediate probes than on the delayed probes and 7- to 8-year-olds performed better than 5- to 6-year-olds on the immediate probe only. There were no significant effects for word comprehension. For gesture production, there was a main effect of gesture such that children could produce more gestures if they saw the gesture paired with a word than if no gesture was demonstrated. In addition, children had better gesture production performance in the delayed probes than the immediate probes. Gesture comprehension, on the other hand, was better for the delayed than the immediate probes in the no gesture condition only. It was also found, for both age groups, that comprehension performance was better than production performance. These findings will be discussed in detail below.

Objective 1: Did co-speech iconic gestures improve novel word fast-mapping performance?

Evidence of fast-mapping novel words. Participants did successfully demonstrate fast-mapping of the novel words in both comprehension and production in the present study, extending fast-mapping evidence to school-age children. However, word production scores were low, with a mean of 0.05 for children 5 to 6 years of age and a mean of 0.35 for children 7 to 8 years of age (maximum score = 3.00).

A possible explanation for the low word production scores is that the word fast-mapping task was too difficult. In the task, participants were exposed to three words and required to hold them in memory through a one-minute video clip prior to being tested for comprehension and production in order to separate the last exposure task and the immediate recall task. To reduce task demands in future research, the task could be changed to require children to produce the target word immediately after each exposure or immediately after all three exposures, rather than after a one-minute video.

Better performance was obtained on the comprehension task. Word comprehension scores were a mean of 1.57 for children 5 to 6 years of age and 2.15 for children 7 to 8 years of age (maximum score = 3.00). Thus, on average, one half to three quarters of all words were comprehended correctly. This is to be expected as comprehension simply requires recognition rather than retrieval of the target word. It could be argued that the word comprehension score was inflated, at least to some degree. In the word comprehension task, children were presented images of all three target objects. One at a time, children were provided one of the novel words and asked to identify the corresponding object. In this situation, participants could use the process of elimination, should they recognize one of the target toys, to indicate the correct answers. This may have resulted in better comprehension performance.

Impact of co-speech iconic gestures on fast-mapping of words. Previous studies on the effects of co-speech iconic gestures on fast-mapping have shown children between 2 to 5 years of age demonstrated better fast-mapping comprehension performance for words paired with iconic gestures than words paired with arbitrary gestures or no gestures (e.g., Capone & McGregor, 2005; Capone Singleton, 2012; Luke & Ritterfeld, 2014; Namy et al., 2004). As such, it was hypothesized that both age groups would perform better on words that were matched with co-speech iconic gestures than no gesture. However, in the current study, a facilitative effect of gesture on word production and word comprehension was not found.

There are multiple possible explanations as to why no effect of gesture was found for word production and comprehension. As outlined in the previous section, it could be that the fast-mapping task was too difficult; gestures may not help if the cognitive load is too high. It could also be the case that the facilitative effects of co-speech iconic gestures would be more obvious in extended mapping rather than fast-mapping tasks, such as demonstrated in previous studies with TD children 2 to 3 years of age (Capone & McGregor, 2005) and 3 to 5 years of age (Luke & Ritterfeld, 2014).

In addition, previous studies finding better fast-mapping performance for words paired with iconic gestures (depicting action or shape) included participants aged between 2 and 5 years (e.g., Capone Singleton, 2012; Luke & Ritterfeld, 2014; Namy et al., 2004). In the present study, participants were between 5 and 8 years of age. It may be that the facilitative effects of gestures can only be observed in younger children. Participants did not reach ceiling in word production or comprehension tasks, demonstrating that children have not peaked in their fast-mapping performance for novel words. However, it may be that older children do not require the level of visual support that iconic gestures provide younger children in order to fast-map words, such that the facilitative effects of iconic gestures are no longer evident. For school-aged children, decontextualized learning is more prevalent such that they learn new concepts without contextualized supports (e.g., gestures). It may be that these older children are sufficiently skilled in decontextualized learning and do not benefit from the contextualized support of gestures for fast-mapping. However, while school-aged children are able to successfully learn in decontextualized settings, contextual language support is a successful strategy to support children with language impairment (Wallach, 2008).

The Dual Coding Theory hypothesized that the way the two modalities (i.e., auditory and visual) contribute to learning would vary with task and stimuli (Clark & Paivio, 1991). In the present study, the stimuli included two novel words in each of the following word structures: CVC, CCVC, and CVCVC (total six novel words). Overall, participants produced target words with all phonemes in the correct order for words with a CVCVC word structure only 10% of the time, compared to 17.4% for CVC and 19.5% for CCVC word structures. This suggests that, although not significantly different, the CVCVC word structure was particularly difficult to reproduce accurately, and this added complexity may have reduced the likelihood that iconic gestures would facilitate word learning.

Consistent with this interpretation, previous research has shown that hand gestures can disrupt word learning if the phonetic demands of the stimuli are too high (Kelly & Lee, 2012). In Kelly and Lee's (2012) study, college-aged English monolingual participants were taught Japanese words containing consonant singletons and geminates (doubled consonants, e.g., *ite* =

stay, *itte* = go) associated with gestures or no gestures. Geminates were considered phonetically difficult as they are not used in the English language. Participants benefited from gestures when learning words containing singletons but not geminates.

In the study by Luke and Ritterfeld (2014), TD participants 3 to 5 years of age also did not demonstrate better expressive or receptive fast-mapping performance for words associated with co-speech iconic gestures depicting shape versus co-speech arbitrary gestures. These authors used novel words up to 3 syllables in length. Thus, in the present study, minimizing word structure to a single CVC and CCVC would have been less phonetically demanding for participants, and as such gestures may have better supported the word learning.

Lastly, previous studies finding a benefit of gestures in novel fast-mapping (e.g., Capone & McGregor, 2005; Capone Singleton, 2014) allowed participants time to manipulate the objects. Although not possible in this study given the online format due to the environmental situation of COVID-19, providing participants with the opportunity to interact and view the toy in-person may have provided increased saliency leading to a facilitative impact of gesture.

Objective 2: Did co-speech iconic gestures improve gesture fast-mapping performance?

For iconic gesture to be beneficial for fast-mapping, children must be able to link the gesture to the referent object. Previous research demonstrates that children as young as 18 months of age can successfully link a gesture to an object and demonstrate comprehension of the gesture after fast-mapping (Marentette & Nicoladis, 2011; Namy et al., 2004; Novack et al., 2015). For this reason, it was also hypothesized that children should be able to comprehend and produce the action performed upon an object more easily when exposed to an iconic gesture indicating the action performed upon the object than without such a gesture. This hypothesis was supported in the current study.

For gesture production, a main effect of gesture was found such that children had higher gesture production performance when novel words were paired with co-speech iconic gestures in the exposure task than when they were not paired with gestures. Similarly, for gesture comprehension, in the immediate probes there was better recognition performance in the gesture as opposed to the no gesture condition. In other words, participants were able to produce and comprehend iconic gestures more accurately when the iconic gesture was modeled in the fast-mapping exposure task.

This seems self-evident, but in the current study's design, participants viewed a video of the researcher manipulating the object. In the video, direct manipulation of the object mimicked the gesture produced to reference the object in the word + gesture condition. Thus, participants could extract the action of a novel object from simply observing the researcher manipulate the object, as demonstrated by participants providing production and comprehension responses when asked, even in the no gesture condition. However, even though the gesture and the actions performed directly on the object were very similar, modeling the iconic gesture separate from demonstrating the action on the object provided participants with a more accessible way to communicate that action and greater ease in the recognition of the action.

The results demonstrate that children could successfully glean information about the action from both the modelled gesture and the action performed upon a novel object. Of note, however, is that some gestures were produced more easily than others (i.e., correct gesture productions that included all four gesture features previously outlined and combined across age, time and gesture condition: object #1 = 56.5% and object #2 = 63%, versus object #5 = 0%) suggesting that the saliency of the gestures in relation to their corresponding objects differed.

There is limited previous research investigating whether children can demonstrate comprehension and production of co-speech iconic gestures presented in a fast-mapping task (i.e., Sekine et al., 2015; Tolar et al., 2008). For example, Tolar et al. (2008) presented 2-, 3-, and 4-year-old children with familiar objects that were either named or not. Iconic gestures were used to depict either an action associated with the object or a shape. Children at all ages were able to successfully demonstrate comprehension of iconic gestures. These results are similar to the present study finding that children can successfully demonstrate comprehension of the iconic gesture when receiving a co-speech iconic gesture than no gesture. However, unlike previous research, the present study investigated the production of gestures after a fast-mapping task, extending previous research to include gesture production.

Objective 3: How did fast-mapping performance change with age?

It was hypothesized that children 7 to 8 years of age would out-perform children 5 to 6 years of age on production and comprehension tasks. Previous research suggests that the ability to fast-map develops with age and that fast-mapping in a co-speech gesture context may be dependent on experience with gestures and the ability to interpret the iconic aspect of the gesture (Capone & McGregor, 2015; Hodges et al., 2015; Namy et al., 2004). As a result, it was assumed that children 7 to 8 years of age would have more experience with gestures and would be more able to interpret iconicity than children 5 to 6 years of age, and as such, have an increased ability to understand the meaning of iconic gestures and associate them to an object (Namy et al., 2004).

In the present study, these hypotheses were partially supported. Children 7 to 8 years of age performed significantly better than children 5 to 6 years of age in the immediate word production probe, demonstrating that 7- to 8-year-olds were better able to produce novel words than 5- to 6-year-olds in this fast-mapping task. Significant effects of age were not found in the other three probes: word comprehension, gesture production, or gesture comprehension.

A possible explanation for the lack of age effects in word and gesture comprehension could be that comprehension is easier than word production. Producing a word or gesture requires multiple processes not required when a child simply has to recognize the word or gesture. As such, it may be that children 5 to 6 years of age could perform similarly to children 7 to 8 years of age due to decreased task difficulty.

In addition, although there are variable results, gestures depicting the action of an object seem to be interpreted more easily than gestures depicting the shape of an object (Hodges et al., 2015; Marentette & Nicoladis, 2011; Namy et al., 2004; Tolar et al., 2008). Since the gestures used in this study were iconic action 5- to 6-year-olds may have performed similarly to 7- to 8-year-olds in both production and comprehension probes due to action gestures being relatively easy to interpret and produce by these ages.

As mentioned previously, there was no obvious benefit of iconic gestures on fast-mapping for either age group. Integration of multiple modalities for fast-mapping is thought by some to increase the cognitive load for word learning (Sekine et al., 2015). Yet, 5- to 6-year-olds did not perform significantly differently than 7- to 8-year-olds suggesting that, at least for the ages studied here, cognitive demand differences cannot account for the lack of facilitative effects of gestures on word learning.

In addition, previous research found developmental gains to be present in the use of co-speech iconic gestures for fast-mapping, such that children's production and comprehension accuracy after receiving an iconic gesture increased with age (e.g., Novack et al., 2015; Sekine et al., 2015; Tolar et al., 2008). This was not found in the present study, suggesting that, between 5 to 8 years of children no developmental phenomenon is taking place for word comprehension or gesture production and comprehension.

Objective 4: How did fast-mapping of novel words or gestures change after a delay?

In the current study, fast-mapping for words and gestures was tested one minute after exposure tasks (immediate) and again after 10 minutes (delayed). It was hypothesized that production and comprehension for words and gestures would decrease after a delay. This hypothesis was partially supported in the study.

Novel word production and comprehension probes. For word production, it was found that only participants 7 to 8 years of age performed significantly better in the immediate probe relative to the delayed probe. This demonstrates that word production decrements occur after a delay. On average, participants 7 to 8 years of age correctly produced more than double the words in the immediate probe (M = 0.35) than they correctly produced in the delayed probes (M = 0.15). Memory decays relatively quickly over time without rehearsal or additional encodings, even if the information is successfully transferred from a child's short-term memory to long-term memory (Cowan, 2008). This likely accounts for the difference between older participants' performance on immediate versus delayed probes.

Previous research investigating the use of co-speech iconic gestures in fast-mapping has not compared immediate and delayed recall. However, some studies have investigated immediate and delayed novel word production without gestures in fast-mapping. For example, in a study by Vlach and Sandhofer (2012), 5-year-old children interacted with 6 novel objects and 4 familiar objects. In a fast-mapping exposure task, only one of the novel objects was labeled with a novel word *koba*. Word production was tested immediately, one week later, and one month later. In the immediate probe, most children correctly labeled *koba* but novel word production performance one week later and one month later was significantly reduced. The present study indicates that a decay in retention abilities can occur after only a 10-minute delay.

Contrary to expectation, participants 5 to 6 years of age did not produce significantly more novel words in the immediate probes than in the delayed probes. The one-minute delay prior to recall may have been made novel word productions particularly difficult for the younger participants. This is confirmed by the results of the word production probes. The younger children produced an average of 0.10 novel words (max = 1) on immediate probes and 0.05 (max =1) on the delayed probes, demonstrating performance close to floor on these tasks and little room to go down after a delay.

For the word comprehension probe, there was not a significant difference between immediate and delayed performance for either 5 to 6-year-olds and 7 to 8-year-olds in any condition. Both age groups performed well on both the immediate and delayed word comprehension probes although neither group reached ceiling at either time period. It would appear that it takes longer than 10 minutes before novel word recognition to show performance decrements, which suggests that the memory trace had not faded completely in this period.

Gesture production and comprehension probes. For gesture production, it was found that children 5 to 6 years of age and 7 to 8 years of age actually performed significantly better in the delayed probes than in the immediate probes. Similarly, for the gesture comprehension probe, participants demonstrated better gesture comprehension after a delay than in the immediate probes, but in this case, only in the no gesture condition. In the gesture condition, there was no significant effect of time.

This was contrary to what was expected and can possibly be explained by how the probes were administered. In the immediate gesture comprehension probe, participants viewed the iconic gesture and were asked to identify the referent object. This meant that participants received an exposure to the gesture through the administration of the probe that seems to have resulted in additional incidental learning of the gesture resulting in greater gesture production performance after the delay. Interestingly, participants also received another exposure to the novel word during the immediate word comprehension probe. However, this did not lead novel word production to improve over time. This may suggest that these children were able to benefit more from the incidental exposure to iconic gestures than words in the probe task, potentially because words are arbitrary.

For the no gesture condition specifically, the similarity between the iconic gesture and the action performed upon the object as demonstrated during the comprehension probe could have increased the saliency of the gesture over time. In addition, exposure to the iconic gesture incidentally through the administration of the probe, could have led to fast-mapping of the iconic gesture and therefore improved participants accurate comprehension of the iconic gesture in the delayed probe.

Objective 5: How does performance differ between production and comprehension?

It was hypothesized that children would have better comprehension than production of words and gestures. Results from this study confirmed this hypothesis. Generally, both children 5 to 6 and 7 to 8 years of age could better comprehend both words and gestures than they could produce them. These findings are consistent with previous research, which demonstrated greater word comprehension over word production in fast-mapping tasks involving co-speech gestures (e.g., Hodges et al., 2015; Luke & Ritterfeld, 2014; Tolar et al., 2008), but extends the findings to gestures. Most studies of fast-mapping in a co-speech gesture context have not investigated both comprehension and production ability so are unable to compare performance across these processes. As discussed previously, information processing models would predict this result.

Limitations

Originally, this study sought to investigate the impact of co-speech iconic gestures on the fast-mapping performance of children with DLD compared to TD children. However, during recruitment, only three children who were identified with language impairment. These children also had the additional diagnosis of Autism Spectrum Disorder and were thus excluded from the study.

A design limitation of the study was that in the comprehension probes, participants were shown all three objects and asked to identify a picture of the target object when presented with either the word or the gesture. In this design, participants could potentially use the process of elimination to correctly identify target objects, possibly enhancing their comprehension performance. A possible way to eliminate the use of this strategy would be to add object foils to the pictures. Alternatively, the researcher could demonstrate the manipulation of more than one object in the exposure task, but only label one of them.

Another possible limitation was the fact that the study was transferred to an online forum due to COVID-19. Nonetheless, online testing proved to be a viable option in the COVID-19 context. It allowed families to participate in the research from their homes and allowed the study to include participants from across Canada rather than only those participants near Halifax, Nova Scotia. In addition, it resulted in greater standardization of how children were exposed to the toys and for how long since each participant viewed the same videos. However, online testing did have some difficulties. Results could have been negatively impacted by the online format, including glitches in audio or video (reported by 2/23 participants), delays in videos due to screen sharing (reported by 3/23 participants), and internet that was not ideal to support videoconferencing (reported by 5/23 participants who had to leave and come back into Zoom, or restart their internet). In addition, although all caregivers were asked to put their child in a quiet environment, this often did not happen. In most sessions, there was background noise, interruptions from siblings or family pets, or other siblings who were doing online learning nearby. These distractions may have also negatively impacted the fast-mapping performance of the participants. Regardless, participants were still able to demonstrate comprehension and production of words and gestures in a way that could be accurately recorded by the examiner using recorded videos.

Finally, the sample size may have been a limitation of the study. However, many significant effects were obtained, and effect sizes were generally high, which suggests sample size did not seriously impact findings.

Future Research

Future research should consider investigating the impact of co-speech iconic gestures on the fast-mapping performance of children with DLD. Vocabulary acquisition is more difficult for children with DLD compared to their age-matched TD peers (Kan & Windsor, 2010; Alt, 2011). One possible method to enhance word learning in children with DLD might be use of co-speech iconic gestures. Currently there is very little work on the effects of co-speech gestures on fast-mapping tasks in children with DLD. Specifically, there are only three known studies (Weismer & Hesketh, 1993; Luke & Rtterfeld, 2014, Vogt & Kauschke, 2017). Further investigation into the use of gestures to support fast-mapping in children with DLD is warranted.

In the current study, a word with a gesture was compared to a word with no gesture. In future studies, including a gesture and no word condition would allow investigation into whether the gesture paired with a word helped learn the gesture, or if the gesture-only is sufficient to see benefits in gesture production and comprehension. Previous research has compared gesture-only, verb-only and gesture-verb combination on the verb comprehension of 3- and 5-year-old children

(Sekine et al., 2015), but there is no previous research comparing gesture-only and gesture-word combinations on the learning of gestures. This study design would allow investigations into whether there are any facilitative effects of gestures-only in supporting the development of semantic representations for a referent object in comparison to gesture-word combinations. In addition, it could have implications for how gestures may provide augmentative support for TD children and children with language impairment.

Future research should modify the presentation of the immediate probes. As outlined in the discussion of objective 4, the lack of significant effects in the word production condition may be due to the fact that participants had to hold three novel words in their short-term memory and wait one minute prior to the immediate probes. The task could be changed to require children to recall and produce the target word immediately after every exposure, or immediately after all three exposures, rather than after a one-minute delay.

Future research should also consider replication of this study in-person to investigate the impact of conducting the fast-mapping study in an online format. Given the current context of COVID-19 and the influx of online learning and therapy, investigating the impacts of online learning would be both relevant and impactful.

Conclusion

In conclusion, the findings of the current study did not find that gestures improved the fast-mapping of novel words in these TD children 5 to 6 and 7 to 8 years of age. This may be due to the task and stimuli used (Clark & Paivio, 1991). Alternatively, it could be that co-speech iconic gestures do not benefit older children as they do in younger children. Future studies with 5- to 8-year-olds are needed to resolve this issue. As the current study was conducted on-line, it may also be that interacting with the object and face-to-face communication was needed for any facilitative effect of gesture to be observed in word learning. However, this was the first study to examine both gesture and word production and comprehension after the fast-mapping of co-speech iconic gestures. In doing so, it provided insights into what children learn in a fast-mapping context. Continuing to explore the role of co-speech iconic gestures in fast-mapping in TD children will help us to interpret the difficulties children with language impairments have in learning new words.

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APPENDIX A

Recommendations for use of Videoconferencing

For online testing, additional measures will be taken to ensure privacy and confidentiality while using video conferencing. Listed below are recommendations for you regarding the use of videoconferencing (e.g., Skype, Zoom):

- Don’t discuss, chat, or screen share personal/sensitive information while on a call.
- Use a background image or blank wall behind you.
- Do not use Facebook to create an account or log-in to Zoom.
- Clear cookies and blocking trackers after every call.

APPENDIX B

Required materials for study

Prior to the beginning of the study, please have the following items completed and/or available:

- ☐ Completed and returned consent form (filled pdf, scanned copy, or picture of completed consent)
- ☐ Completed and returned questionnaire (filled pdf, scanned copy, or picture of completed questionnaire)
- ☐ Review the 'Recommendations for use of Videoconferencing' document
- ☐ Have the following items available to your child during the session:
  - Scissors (child safe if available)
  - Pencil or other writing utensil
  - A piece of blank or lined paper (scrap paper is fine)

If you have any questions, please feel free to email me at k.boyce@dal.ca. Alternatively, we can set up a time to call.

APPENDIX C

Eligibility Screening Questionnaire

For researcher:

Eligible (Y/N):________________________________
Participant #:_________________________________
Proposed Group: ______________________________

General Information

1. Grade: _________
2. Gender Identification: ____________________
3. Birth Date:

Y	Y	Y	Y	M	M	D	D

   Chronological age (Y;M): _______________

Language and Communication

4. Does your child have a diagnosis of Development Language Disorder/Specific Language Impairment?
   - ☐ Yes
   - ☐ No
5. If you answered no to (6), do you have any concerns about your child's speech and language or has your child ever been diagnosed with a speech or language problem or received special services for speech or language problems?
   - ☐ Yes - explain: ____
     ____
   - ☐ No
6. Do you have any concerns about your child's learning abilities or has your child ever been diagnosed with a learning problem or received special service for learning problems?
   - ☐ Yes - explain: ____
     ____
   - ☐ No
7. Is your child's first language English? If no, please explain.
   - ☐ Yes
   - ☐ No – explain: ____

8. Has your child ever been exposed regularly to any languages, other than English? If yes, please explain.

☐ Yes – explain: ____

____

☐ No

9. Has your child ever been exposed to sign language? If yes, please explain.

☐ Yes – explain: ____

____

☐ No

Hearing and Cognition

10. Does your child have any other diagnoses such as autism or? If yes, please explain.

☐ Yes – explain: ____

____

☐ No

11. Do you have any concerns about your child's hearing or has your child ever been diagnosed with a hearing loss or problem?

☐ Yes – explain: ____

____

☐ No

Therapy and Services

12. Has your child ever participated in speech therapy services (e.g., public, private, within school, etc.)?

☐ Yes, currently in speech therapy.
  - Indicate age and duration:______________________________

☐ Yes, in the past
  - Indicate age and duration______________________________

☐ No

13. If you answered yes to #14, please indicate whether or not the speech therapy included training on gestural communication.

☐ Therapy included training on gestural communication

☐ Therapy <u>did not</u> include training on gestural communication

APPENDIX D

Background Questionnaire

For researcher:

Participant #:________________________________

Proposed Group: ____________________________

Demographic Information

1. What is the highest level of education that you and any other parent/guardian has completed?

Parent/Guardian A

- ☐ Some high school
- ☐ High school or equivalent
- ☐ Vocational/technical school
- ☐ Some college
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctoral degree
- ☐ Professional degree (e.g., MD)
- ☐ N/A, other, prefer not to say
- ☐ Additional information: ___________

____

Parent/Guardian B

- ☐ Some high school
- ☐ High school or equivalent
- ☐ Vocational/technical school
- ☐ Some college
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ Doctoral degree
- ☐ Professional degree (e.g., MD)
- ☐ N/A, other, prefer not to say
- ☐ Additional information: ___________

____

2. Your family income is:

☐ less than $30,000	☐ Between $30,000 and $60,000	☐ Between $60,000 and $80,000	☐ Between $80,000 and $125,000	☐ More than $125,000

☐ N/A, I don't know, or prefer not to say

THANK YOU FOR FILLING OUT THIS QUESTIONNAIRE!

APPENDIX E

Sounds in Words – Artic Screener

Target Word	**Prompts**	**Response**	**IPA transcription**		
Pig	What is this? This is a pig. It says oink. What is this?		p		g
Boy	She is a girl and is he a ______ He is a boy. He is not a girl. What is he?		b		
Duck	What is this? This is a duck. It swims in the water. What is this?		d		k
Quack	What sound does it make? A duck says quack. It’s a funny sound. What does a duck say?		k		k
Spider	What is this? This is a spider. It has eight legs. What is this?		s		
Web	What is this? This is a web. It is made of sticky thread. What is this				b
Knife	What is this? This is a knife. You use it to cut food. What is this?				f
Slide	What is this? This is a slide. You can go down it. What is this?		s		d
Guitar	What is this? This is a guitar. It has strings and you play it. What is this?			t	
Lion	What is this? This is a lion. It roars very loudly. What is this?		l		
Smile	What is this?		sm		

	This is a smile. We do this when we are happy. What is this?				
Soap	What is this? This is soap. You wash your hands with it. What is this?		s		
Puzzle	What is this? This is a puzzle. It is fun to put together. What is this?		p		
Vacuum	What is this? This is a vacuum. It is used to clean floors. What is this?		v		
Vegetable	An apple is a fruit. A carrot is a _____ A carrot is a vegetable. It is a healthy food. What is this?		v	t	
Blue	This crayon is red, and this crayon is _____ This crayon is blue. It's the same colour as the sky. What colour is it?		b		
Frog	What is this? This is a frog. It hops and says ribbit. What is this?				g
Leaf	What is this? This is a leaf. It is part of a tree. What is this?		l		f
Cookie	What is this? This is a cookie. It is a sweet treat. What is this?		k		
Princess	He is the king. She is the queen, and she is the _______ She is the princess. She lives in a castle with the king and queen. Who is she?		p	n	
Red	What colour is the truck? The truck is red. It is the same colour as a strawberry. What colour is it?				d
Clock	What is this? This is a clock. It shows us the time. What is this?		kl		

APPENDIX F

Manual Dexterity – Descriptive Measure

5 years (+):

- ☐ His movements seem shaky or stiff
- ☐ Her arms and hands seem very weak
- ☐ He is not able to cut along a straight line
- ☐ She is not holding her crayons or pencils with her thumb and fingers
- ☐ He is not able to draw a circle, square and cross (+)

Tasks

1. **Thumbs and Fingers**
    a. Twiddling Thumbs:
       0 1
    b. Touching Fingers to Thumb:
       0 = no success
       1 = one hand in order
       2 = both hands in order

2. **Cutting**
   0 = cannot cut along straight line or across paper
   1= error, but can cut along straight line
   2 = cut out perfectly

3. **Copying**
    a. Cross
    b. Circle
    c. Square

4. **Writing Name**

APPENDIX G

Unusual Toys

Please circle *YES* if your child is familiar with this toy. Please circle *NO* if they are not familiar with the toy.

 Yes No

 Yes No

 Yes No

 Yes No

 Yes No

 Yes No

APPENDIX H

Effects and interactions for word production probe

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	gesture	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
gesture	Linear		.049	1	.049	.943	.342	.043
gesture * Age	Linear		.035	1	.035	.670	.422	.031
Error(gesture)	Linear		1.098	21	.052			
time		Linear	.260	1	.260	13.541	.001	.392
time * Age		Linear	.182	1	.182	9.499	.006	.311
Error(time)		Linear	.403	21	.019			
gesture * time	Linear	Linear	.026	1	.026	.927	.347	.042
gesture * time * Age	Linear	Linear	.000	1	.000	.010	.923	.000
Error(gesture*time)	Linear	Linear	.595	21	.028			

Effects and interactions for word comprehension probe

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	gesture	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
gesture	Linear		.079	1	.079	.053	.820	.003
gesture * Age	Linear		2.818	1	2.818	1.901	.183	.083
Error(gesture)	Linear		31.138	21	1.483			
time		Linear	.415	1	.415	.427	.521	.020
time * Age		Linear	.198	1	.198	.203	.657	.010
Error(time)		Linear	20.411	21	.972			
gesture * time	Linear	Linear	.743	1	.743	1.984	.174	.086
gesture * time * Age	Linear	Linear	.439	1	.439	1.172	.291	.053
Error(gesture*time)	Linear	Linear	7.866	21	.375			

Effects and interactions for gesture production probe

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	gesture	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
gesture	Linear		31.551	1	31.551	4.561	.045	.178
gesture * Age	Linear		24.638	1	24.638	3.562	.073	.145
Error(gesture)	Linear		145.275	21	6.918			
time		Linear	12.461	1	12.461	11.700	.003	.358
time * Age		Linear	.069	1	.069	.065	.801	.003
Error(time)		Linear	22.366	21	1.065			
gesture * time	Linear	Linear	.167	1	.167	.197	.662	.009
gesture * time * Age	Linear	Linear	.036	1	.036	.043	.838	.002
Error(gesture*time)	Linear	Linear	17.790	21	.847			

Effects and interactions for gestures comprehension probe

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	gesture	time	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
gesture	Linear		1.413	1	1.413	1.653	.213	.073
gesture * Age	Linear		.978	1	.978	1.144	.297	.052
Error(gesture)	Linear		17.956	21	.855			
time		Linear	.908	1	.908	2.062	.166	.089
time * Age		Linear	.125	1	.125	.285	.599	.013
Error(time)		Linear	9.244	21	.440			
gesture * time	Linear	Linear	2.580	1	2.580	4.236	.052	.168
gesture * time * Age	Linear	Linear	1.015	1	1.015	1.666	.211	.073
Error(gesture*time)	Linear	Linear	12.790	21	.609			