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Can gesture input support toddlers' fast mapping?

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Abstract

Forty-eight toddlers participated in a word-learning task to assess gesture input on mapping nonce words to unfamiliar objects. Receptive fast mapping and expressive naming for target object-word pairs were tested in three conditions – with a point, with a shape gesture, and in a no-gesture, word-only condition. No statistically significant effect of gesture for receptive fast-mapping was found but age was a factor. Two year olds outperformed one year olds for both measures. Only one girl in the one-year-old group correctly named any items. There was a significant interaction between gesture and gender for expressive naming. Two-year-old girls were six times more likely than two-year-old boys to correctly name items given point and shape gestures; whereas, boys named more items taught with the word only than with a point or shape gesture. The role of gesture input remains unclear, particularly for children under two years and for toddler boys.

Keywords: gesture; language development; fast mapping; iconic; toddlers

Introduction

Gesture and language development are "tightly coupled." (Iverson & Thelen, 1999, p. 20), and the parallel unfolding of gesture development and spoken language development may lie in their shared symbolism (Capone & McGregor, 2004). Gesture initially grounds spoken language through sensorimotor experiences (Perniss & Vigliocco, 2014). The emergence of specific gesture types in later infancy and early toddlerhood precedes children's language production milestones including the onset of single words and two-word combinations (e.g., Crais, Watson & Baranek, 2009; Iverson & Goldin-Meadow, 2005). This is a developmental period during which children move from saying their first words to rapid vocabulary growth. After age 12 months and the onset of first words, children gradually add new words at a rate of about one to two new words weekly, and after 24 months of age, word learning accelerates with children producing 10 new words within a 14-day period (e.g., Hirsh-Pasek, Golinkoff & Hollich, 2000; Mervis & Bertrand, 1994).

One explanation for children's rapidly accelerating word production is fast mapping, the process whereby children encode beginning, incomplete word representations from brief exposures and incidental mappings of novel words to referents (Carey & Bartlett,

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1978; Dollaghan, 1987; Gershkoff-Stowe & Hahn, 2007; Swingley, 2010). Children as young as 13 months show fast mapping, and there is substantial evidence indicating that typically developing toddlers are fast mapping successfully by age 2 years (Hiebeck & Markman, 1987; Spiegel & Halberda, 2011). Fast mapping, however, is just one step in a word learning process that may not involve the same mechanisms needed for children's development of full lexical representations (Bion, Borovsky & Fernald, 2013; Carey, 2010; Horst & Samuelson, 2008). Word learning can be considered a continuum starting with a person's initial exposures and building to well-established understanding and use of words for effective communication. Fast mapping occurs early in word learning and can result from a single exposure to a word and referent incidentally. Following limited exposure, often in experimental tasks, fast mapping is usually assessed by immediate, forced-choice recognition or receptive identification. Next steps in word learning can be termed slow mapping. Slow mapping is defined by repeated linkages between a referent's semantic information and the word form. Slow mapping or extended word learning may be assessed in recognition tasks following a time delay varying from minutes to days or weeks. Likewise, expressive naming can be viewed as evidence of slow mapping because it requires activating and speaking a stored representation (Capone & McGregor, 2005).

Our aim in this investigation was to test the role of gesture input in support of young children's word learning. Early gestures in the baby's environment, showing and pointing, can provide a foundation for first words. Caregivers engage in showing by shaking an object or moving an object up and down in front of the infant's face while synchronously naming the object (Matatyaho & Gogate, 2008), and researchers have reported a type of gestural motherese consisting of pointing gestures paired with talking (Iverson, Capirci, Longobardi & Caselli, 1999; Zammit & Schafer, 2010). By 13 months of age, typically developing infants demonstrate understanding that the deictic, point gestures produced by adults reference objects in the environment (Gliga & Csibra, 2009). Pointing can harness an infant's joint attention with the adult and an object, supporting the child's mapping of the word spoken by the parent to the object that has been ostensively indicated. In this sense, point gestures are considered a type of social/pragmatic cue, indicating the pointer's intended referent (Capone Singleton, 2012). Pointing by Italian mothers when interacting with their children aged 1;4 was positively correlated with their children's vocabulary skills at 1;8 (Iverson et al., 1999).

In addition to deictic gestures such as showing and pointing, gestures can be iconic. Iconic gestures reflect a characteristic of a concrete referent. Iconic gestures manually represent some element of meaning – the shape, action, or function features of the referent (Capone Singleton & Saks, 2015; Goldin-Meadow & Alibali, 2013). An example is when a caregiver moves his hand to his mouth to represent eat when asking a toddler, "Do you want to eat?" Gestures most often co-occur with speech, and the meaning conveyed by the gesture is often redundant with speech (Capone Singleton & Saks, 2015; Hostetter & Mainela-Arnold, 2015; Iverson et al., 1999). Zammit and Schafer (2010) reported an association between children's comprehension of target words (aged 11 months) and their mothers' verbal labeling of the items paired with iconic gestures at a time when the children (aged 9 months) had not yet acquired the words. In a meta-analysis of gesture studies, Hostetter (2011) concluded that listeners had better comprehension of speech when accompanied by gestures, but age was one of several moderating factors. Children benefitted more from gesture than adolescents or adults, and individuals who were considered less verbally proficient (i.e., listeners with Down syndrome or autism) were more likely to benefit from gestures than unimpaired learners. Also, the

positive effects of an iconic gesture were measured when motoric or spatial information was being conveyed but not for abstract information (Hostetter, 2011).

There is widespread belief in popular culture as well as some research support that children benefit from baby sign language or gesture instruction in the environment (Goodwyn, Acredolo & Brown, 2000; Lederer & Battaglia, 2015), and this has led to the development and marketing of Baby Signs® (see http://www.babysignstoo.com/), one of now several similar programs that encourage use of manual signs with typically developing infants and toddlers to increase their expressive communication abilities with caregivers as their speech skills develop. Founders of Baby Signs®, Goodwyn et al. (2000) reported that children whose parents were trained to combine words with iconic gestures outperformed a control group with no training for expressive and receptive language measures. No differences in language development were found for a no-training control group compared with a verbal training group whose parents were trained to increase speech-only labeling. Studies by Goodwyn and Acredolo (1993, 1998) using the same cohort as Goodwyn et al. (2000) were critiqued by Johnston, Durieux-Smith, and Bloom (2005), who conducted a systematic review of the baby sign language research literature. Johnston et al. (2005) pointed out that Goodwyn et al. did not test and report comparisons between the sign-training group and the verbal-training group. Additionally, Goodwyn et al.'s finding of differences was statistically significant at only ages 15 and 24 months of age, not at 19, 30, or 36 months. Based on their review of this study and others, Johnston et al. (2005) concluded that there were no advantages in adding gestural communication to parental input beyond 24 months. Kirk, Howlett, Pine, and Fletcher (2013) reported no language development differences for children followed from ages 8 to 20 months whose mothers used baby sign language compared to control groups consisting of symbolic gesture, verbal training or no intervention. Authors cautiously reported that there were three boys with relatively low ability whose expressive language learning appeared facilitated by participation in a group with sign language or symbolic gestures. Clearly, not all research has supported the premise that gesture enhances word learning. In a looking-paradigm study examining the fast-mapping abilities of infants, Puccini and Liszkowski (2012) found that children (aged 1;3) did not map words to referents accurately in the word-plus-gesture and gesture-alone conditions. The only statistically significant effect was found for the word-only condition. Authors concluded that spoken words alone are the optimal input for hearing children.

Differences among studies led us to conclude that any benefits derived by adding gesture to speech input may depend on the age and skills of the children as well as the type of gesture and its relationship to the referent. For example, in addition to the young age of their participants, Puccini and Liszkowski (2012) included American Sign Language gestures for *yes* and *no*. These gestures are arbitrary, not iconic, because there were no recognizable associations between the gestures and the study referents. Iconic gestures, as opposed to arbitrary gestures, are assumed to support word learning because they map semantic elements that can facilitate children's representation of the referent. Several studies, however, have indicated that children under the ages of 3;6 to 4 years cannot easily engage iconic information (Lüke & Ritterfeld, 2014; Namy, 2008; Tolar, Lederberg, Gokhale & Tomasello, 2008). Lüke and Ritterfeld (2014) found no significant differences in typically developing preschoolers' receptive fast mapping of novel cartoon character labels paired with iconic gestures versus arbitrary gestures, but word learning was supported by both gesture conditions when compared to a no-gesture condition. Namy (2008) found that children at 14, 18, and 22 months did not consistently recognize iconic action gestures when selecting target objects in target trials, and at 14 months, the children

did not choose target objects more often than expected by chance. Only one age group, children who were 26 months, showed consistent selection of target objects above chance levels when the stimulus was an action gesture that matched conventional actions performed on objects (e.g., spinning a top-like novel object or scooping with a familiar object, a spoon). Namy concluded that gesture iconicity was fragile and fluctuating for children under age 2 years.

Tolar et al. (2008) also concluded that iconicity recognition was fragile for children age 3 years and younger. They studied the recognition of iconicity for sign language signs with hearing children ages 2;6 to 4;6 years. Only in the age groups 3;6, 4;0 and 4;6 did 50% of the children successfully identify pictures based on iconic signs. Children at ages 2;6 and 3;0 did not correctly associate iconic signs with pictures. Stimuli in their study varied iconicity such that some signs were considered pantomime or actions associated with the referent (e.g., "baby," "write") versus perceptual aspects (e.g., "house," "tornado"). Perniss and Vigliocco (2014) argued that the type of iconicity – action-based signs such as for the word "push" versus a perception-based sign for "deer" – is a factor in language development and language processing.

Capone and McGregor (2005) compared iconic shape gestures versus iconic function gestures in a fast-mapping investigation with typically developing children 2;3 to 2;6 years. They hypothesized that an early visual or perceptual aspect such as the shape of a referent might be easily recognized and improve fast mapping compared to an action or function gesture that could require additional representational learning. Their hypothesis drew from literature proposing a shape bias as a mechanism supporting young children in learning words (Landau, Smith & Jones, 1988; Smith, 2000). Diesendruck and Bloom (2003) proposed that children's attention to perceptual aspects such as the shape of objects is not a specific linguistic mechanism but rather a more general means of concept creation for a category or kind. Toddlers' attention and selectivity to the perceptual feature of shape increases between 2;0 to 3;1 for generalizing novel object labels and shape continues to be a significant factor for word learning beyond age 4 years (Davidson, Rainey, Vanegas & Hilvert, 2018; Diesendruck & Bloom, 2003; Landau et al., 1988; Landau, Smith & Jones, 1988; Smith, 2000). To test iconic shape gestures, Capone and McGregor (2005) contrasted three fast-mapping conditions: nonce words paired with shape gestures; nonce words paired with function gestures; and nonce words only as a no-gesture control condition. Results indicated that children fast mapped at levels above chance when the word was paired with a shape gesture: 68% of the novel item/nonce word pairs were fast mapped. In the function gesture and no-gesture conditions, performance was at chance. Retrieval for the labels for the novel items trained in both gesture conditions, shape or function iconic gestures, required fewer cues than for labels trained in the no-gesture condition. Capone Singleton (2012) extended these findings regarding shape cues to children who were two and three years old. When three novel words were taught in three gesture conditions – with a shape gesture, with a function gesture, and with a point – children's naming of words taught with shape gestures was significantly more frequent compared to the other conditions and resulted in better categorization and naming of untaught exemplars. It was iconic shape gestures, not deictic gestures such as pointing, that enhanced semantic representations underlying fast mapping and slow mapping processes for object naming.

Despite the evidence of gesture influences on language learning in typically developing toddlers, several unknowns remain. Given the conflicting findings of studies, one unknown is the extent to which an iconic gesture versus a deictic gesture might aid toddlers in fast mapping. A second unknown is whether fast mapping by children younger

than 2;3 would be improved given adult input that combines spoken word labels with gesture aids. A clearer understanding of these factors is needed when advising parents of typically developing children regarding the use of gestural techniques to promote language learning. Of greater importance are implications for the use of gesture-speech input for language development and word learning in clinical populations with limited expressive language, including children with autism, Down syndrome, and even late talkers (Capone & McGregor, 2004; Capone Singleton & Anderson, 2020; Capone Singleton & Saks, 2015; Caselli, Vicari, Longobardi, Lami, Pizzoli & Stella, 1998; Özçalişkan, Adamson, Dimitrova, Bailey & Schmuck, 2016; Thal & Tobias, 1992; Vogt & Kauschke, 2017; Wang, Bernas & Eberhard, 2001; Ellis Weismer & Hesketh, 1993).

Research questions

Our purpose was to determine whether gesture input combined with speech facilitated toddlers' fast mapping nonce words to unfamiliar objects. We examined how participants from two age groups, children aged 1;4-1;8 and children aged 2;0-2;4, responded in three input conditions – an iconic shape gesture combined with speech, a deictic point gesture combined with speech, and a speech-only, no gesture control condition. The following research questions and hypotheses were posed:

1. Is there a significant effect of gesture input on receptive fast mapping of unfamiliar target objects by toddlers? We hypothesized that participants would demonstrate more correct responses in the gesture conditions than in the speech-only control condition. We also hypothesized that the iconic shape gesture condition would have a greater proportion of accurate responses than the point gesture condition.
2. Is there a significant effect of participant demographic variables on the receptive fast mapping skills in toddlers? We expected that the older toddler groups would have more accurate responses than the younger toddler groups.
3. Is there a significant effect of gesture condition on expressive naming of unfamiliar objects following a brief word learning task? We hypothesized that gesture input would support successfully naming newly learned objects. In particular, we expected that the shape gesture would support mapping some semantic information thereby increasing the likelihood of successful encoding and retrieval for the newly learned name.
4. Is there a significant effect of participant demographic variables on toddlers' accurate expressive naming of nonce words paired with unfamiliar objects immediately following a brief word learning task? As with the receptive task, we anticipated that older toddlers would show more accurate naming than younger toddlers.

Method

Participants

Recruitment and enrollment proceeded after Institutional Review Board human-subjects approval. Participants were 48 children from the northern Gulf Coast region of the United States who met eligibility criteria: $\geq 10^{th}$ percentile on the MacArthur-Bates Communicative Development Inventories (MBCDI; Fenson, Marchman, Thal, Dale & Reznick,

2007); a reported gestation age of ≥ 37 weeks; monolingual English-speaking parents/ caregivers; and no known hearing impairments. Sixty-one toddlers were initially seen, but 13 (21%) were not enrolled. Nine had MBCDI percentile scores <10th percentile; three did not complete the experimental task; and one was not included due to investigator error.

Two participant groups were formed: 24 toddlers (14 boys, 10 girls) ages 1;4 to 1;8 in the Younger Toddler group and 24 toddlers (10 boys, 14 girls) ages 2;0 to 2;4 years in the Older Toddler group. See Table 1 for group demographic information. A one-way analysis of variance (ANOVA) was performed and a significant difference for MBCDI Words Produced was revealed for Gender and Age (F [3, 48] = 41.98, p < .001). Post hoc

Table 1. Participant Characteristics for Total Sample and by Age Group

	Total Sample	Younger Toddlers	Older Toddlers
Age (Months)			
M (*SD*)	21.90 (4.66)	17.50 (1.47)	26.29 (1.42)
Min. to Max. Range	16-28	16-20	24-28
MBCDI *M* (*SD*)			
Words Produced Raw	273.44 (215.56)	102.83 (111.46)	444.04 (147.60)
Words Produced %ile	53.23 (26.12)	47.04 (26.02)	59.42 (25.26)
%ile Min. to Max. Range	12th to 98th	12th to 97th	20th to 98th
Utterance Length	3.53 (2.48)	1.71 (0.82)	5.35 (2.23)
Race % (n)			
Caucasian	90% (43)	88% (21)	92% (22)
African American	4% (2)	4% (1)	4% (1)
Hispanic	2% (1)	4% (1)	0
Biracial	4% (2)	4% (1)	4% (1)
Daily Environment % (n)			
Home	42% (20)	46% (11)	38% (9)
Daycare	58% (28)	54% (13)	62% (15)
Exposed to Symbolic			
Gesture % (n)	54% (26)	58% (14)	50% (12)
Birth Order % (n)			
1st born	63% (30)	54% (13)	71% (17)
2nd	31% (15)	38% (9)	25% (6)
3rd	6% (3)	8% (2)	4% (1)
Years Maternal Education			
M (*SD*)	16.96 (2.00)	17.17 (1.79)	16.75 (2.21)
Min. to Max. Range	12-21	12-20	12-20

Note. MBCDI = MacArthur-Bates Communicative Developmental Inventories – Words and Sentences (Fenson et al., 2007).

analyses using Bonferroni procedures indicated that the mean raw score for Older Toddler girls ($M = 515.36$, $SD = 113.14$) was significantly higher than for Older Toddler boys ($M = 344.20$, $SD = 134.90$) which was significantly higher than for Younger Toddler boys ($M = 64.07$, $SD = 60.65$) and Younger Toddler girls ($M = 157.10$, $SD = 144.319$). Differences between Younger Toddler boys and girls were nonsignificant. Because gender differences were significant, gender was added as a participant demographic factor to our analyses. A one-way ANOVA revealed no significant differences for maternal education for the age groups or for gender.

Stimuli creation

Nine white objects (see Table 2) – six unfamiliar objects and three familiar objects – were selected to be perceptually similar in color and general size except for their distinctive shapes. The six unfamiliar objects were divided into two subsets. Three unfamiliar objects were targets paired with iconic shape gestures: a triangular holder, an over-the-door hanger, and part of an onion blossom maker. To provide names for the unfamiliar target objects, investigators studied monosyllabic, consonant-vowel-consonant nonce words from prior studies of word learning and fast mapping. Three nonce words, "tull" /tʌl/, "fim" /fɪm/, and "sep" /sɛp/, were selected because they had no phonemes in common with the familiar object names and they had high phonotactic probability (Vitevitch & Luce, 2004). Each word was randomly assigned to one unfamiliar target object (see Table 3).
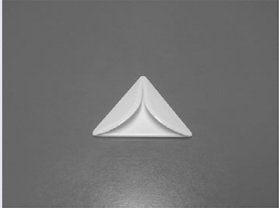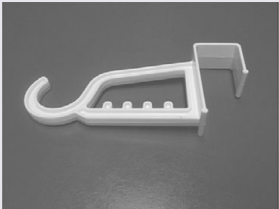
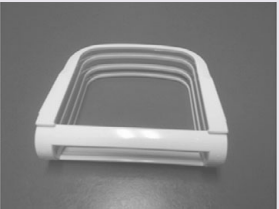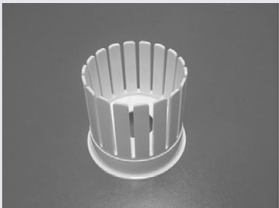Iconic shape gestures for each unfamiliar target object (see Table 3) were created with two hands making contact and presented statically in similar gesture spaces. Three unfamiliar objects served as foils: a pastry blender, a plastic ridged tube, and a cable T-fitting.

Five of our six unfamiliar objects were previously established as unfamiliar – that is, un-nameable objects (i.e., Beverly & Estis, 2003). Pilot testing of the shape gesture to object mapping occurred prior to object selection. Specifically, 20 consented adults were asked to identify an object when presented with its associated shape gesture in an array of seven unfamiliar objects. The three items selected as the unfamiliar target objects were the only three items of the seven selected by 100% of the participants: the triangular holder, the over-the-door hanger, and the onion blossom maker part. Unfamiliar foil objects and the familiar objects – keys, a cup, and a sock – were white and sized to be similar to the target unfamiliar objects. Also, familiar objects were selected using a word frequency program based on lexical development data, the Lex2005 Database (Dale & Fenson, 1996), that generated proportion ratings indicating that >80% of toddlers are reported to comprehend these.

Experimental design and procedures

The within-subjects design consisted of three word-learning conditions: Point, Shape, and Control. In the Point condition, the investigator (first author) pointed to the unfamiliar target object while saying the associated nonce word. The investigator pointed with the index finger of the right hand extended within approximately six inches of the object. In the Shape condition, the investigator produced the iconic shape gesture next to and within six inches of the unfamiliar target object while saying the nonce word. In the Control condition, the investigator said the nonce word for the unfamiliar target
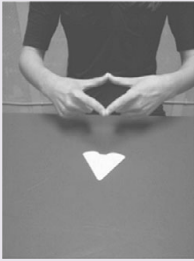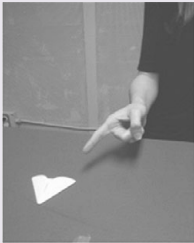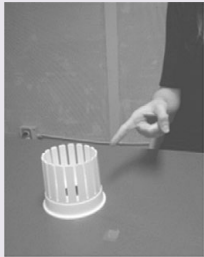
Table 2. Familiar objects, unfamiliar target objects, and unfamiliar foils

Familiar Objects	Unfamiliar Target Objects	Unfamiliar Foils
Keys	Triangular holder	Plastic ridged tube
Cup	Over-the-door hanger	Pastry blender
Sock	Onion blossom maker	Cable T-fitting

object but with no gesture. Objects were grouped and presented in a consistent order – the familiar object, the unfamiliar target object, and then the unfamiliar foil (see Figure 1). The administration of conditions (i.e., A = Point, B = Shape, and C = Control) associated with the unfamiliar target word-object pairing was systematically varied across participants using six unique sequences to attain complete counterbalancing: ABC, BCA, CAB, CBA, BAC, and ACB. The nonce words – tull, sep, and fim – each labeling an unfamiliar object were presented in the same order but the six presentation lists resulted in nine word-gesture condition pairings: "tull" + Point; "tull" + Shape; "tull" Control; "sep" + Point; "sep" + Shape; "sep" Control; "fim" + Point; "fim" + Shape; and "fim" Control. In this manner, gesture condition differences would not be due to unexpected item effects.

Experimental sessions were scripted (see Figure 1) and conducted live by the first author in one of three settings (i.e., 65% in participants' homes; 23% in a preschool/ daycare; and 13% in the university-based lab setting) with a familiar adult present in the

Table 3. Unfamiliar target objects paired with nonce word labels, shape gestures, and point gestures

	Triangular holder	Over-the-door hanger	Onion blossom maker
Nonce word label	/tʌl/	/sɛp/	/fɪm/
Shape Gesture			
Point Gesture			

room. Participants were seated in a highchair, a booster seat, or in their mother's lap (See Figure 2). A brief 2- to 5-minute play period was used to establish rapport and to determine participants' ability to follow simple commands.

The experimental procedure consisted of two phases, the fast-mapping phase and the testing phase, repeated for each of the three conditions. Within each fast-mapping phase, the investigator's utterances were scripted (see Figure 1) and included producing the object name – familiar or unfamiliar target – a total of four times. The fast-mapping script was designed to initially call attention to the novel object. Then, the participant manipulated each object for approximately 10 seconds before dropping it in a bucket. Once in the bucket, the investigator pretended to look for the object and then quickly found it, supporting one additional exposure.

A testing phase immediately followed each fast-mapping phase. During testing, the three objects were arranged in a line on a red mat placed on the high-chair tray, the table, or the floor in front of the participant (See Figure 1). Object position was pre-determined and counterbalanced, such that the unfamiliar target object position varied in the three testing phases. First, the investigator instructed the participant to get the familiar object, and for this trial the investigator provided training to participants who did not correctly select the familiar object. Training consisted of repetition and scaffolded cues: holding one of the participant's hands to promote a single-object selection, moving the familiar object closer to the participant, manipulating the familiar object while naming it, and hand-over-hand assistance to select the familiar object. Once the familiar object was removed,
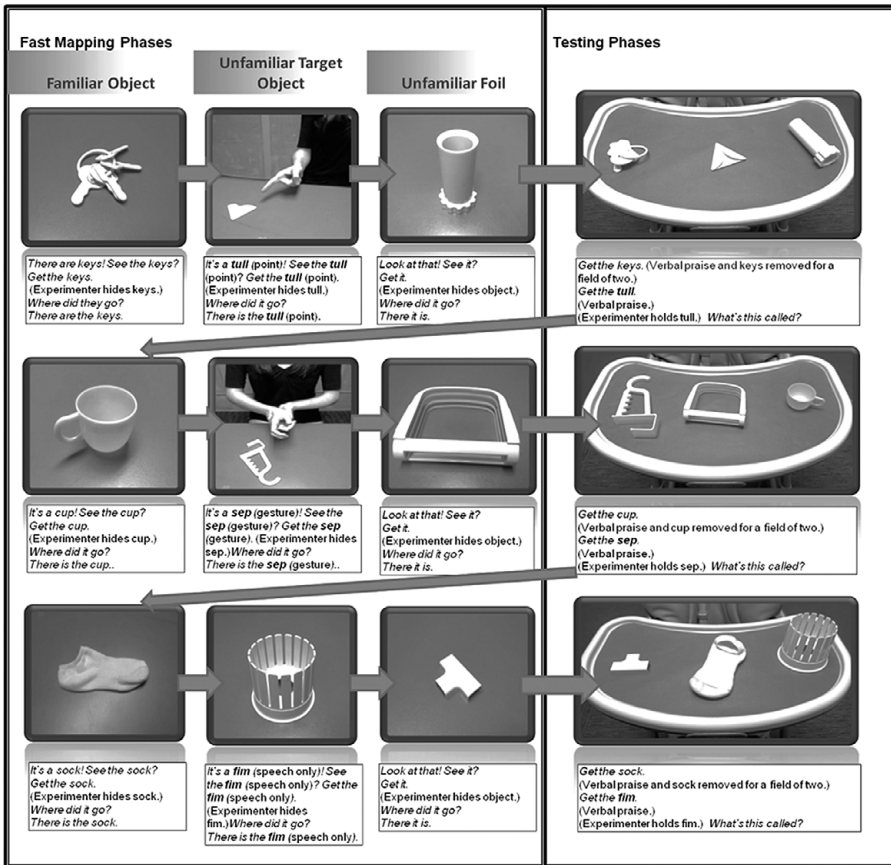
Figure 1. One example sequence is shown depicting the experimental procedure, including the three fast-mapping phases (one for each condition), the three testing phases (one for each condition), and the corresponding scripted input.

testing proceeded from a field of two unfamiliar objects (the target and the foil). Receptive assessment for the unfamiliar target object consisted of the name only, no point or gesture. Noncontingent positive reinforcement was provided following each selection to promote continued participation. Lastly, an opportunity for naming was provided: the investigator held up the unfamiliar target object and asked, "What's this?" Upon completion of the testing phase, the next fast-mapping phase for the second condition in the counterbalanced sequence was conducted, followed by the associated testing phase. The third fast-mapping and testing phases completed the experimental procedure, which lasted approximately 8 minutes.

Receptive trials were scored as correct if the participant accurately selected the target object given the unfamiliar object name without prompting. Receptive trials were scored via the video recording, and reliability checks for 50% of the data revealed 100% inter-judge agreement and 100% intra-judge agreement. Expressive trials were scored as correct if the participant said the correct nonce word for the unfamiliar target objects. This was

> Object location on the table with two-handed shape gesture beside the object.

Figure 2. Experimental task arrangement depicting the unfamiliar object and shape gesture. Note the gesture presented near the object to support visual attention to the iconic relationship between the gesture and the object. The investigator's eye gaze remained predominantly on the child throughout the exposure and testing interactions.

completed live and the participant's responses were transcribed if needed. Reliability using the video recordings was 97% (35 of 36 reviewed decisions) for the inter-judge agreement and 97% for the intra-judge agreement.

Statistical analyses

The dependent variables were the fast-mapping responses – receptive fast mapping and expressive naming. These were dichotomous, categorical variables with correct responses coded as 1 and incorrect responses coded as 0. Participants contributed one receptive fast-mapping score and one expressive naming score for each of the three conditions: Point, Shape, and Control. Mean proportions and standard deviations were computed for the number of participants responding correctly in each gesture condition for each measure, receptive fast mapping and expressive naming.

To address the research questions, the factors of gesture input, age, and gender were examined. The generalized estimating equation (GEE; Liang & Zeger, 1986) approach in IBM SPSS (IBM Corp, 2021, Version 28) was used. GEE is subsumed under generalized linear mixed models and offers a framework for examining repeated categorical outcome variables that are nested within participants who are selected at random (Heck, Thomas & Tabata, 2012). A two-level data hierarchy was constructed in which receptive and expressive responses for three repeated gesture conditions (Level 1) were nested within each of the 48 toddlers (Level 2). Toddler participants were from a random sample of the population, and, therefore, are considered as random effects for the model. The intercept of the random effect was allowed to vary freely.

Table 4. QIC Statistics for Six Models and Fixed Effects for Receptive Fast Mapping and Expressive Naming

	Fixed Effects	QIC Statistics	
		Receptive Fast Mapping	Expressive Naming
Model 1	Gesture condition only	196.824	150.865
Model 2	Gesture condition, age, gender	192.256	113.143
Model 3	Full factorial	199.589	Failed
Model 4	Gesture condition, age, gender & condition*age interaction	194.690	111.825
Model 5	Gesture condition, age, gender & condition*gender interaction	193.703	111.740
Model 6	Gesture condition, age, gender & age*gender interaction	193.125	Failed

Note. QIC statistics were labeled as Failed when statistical analysis procedures did not execute. This was due to one participant group, the younger male toddlers, all having 0 values (i.e., no correct responses) for expressive naming in all gesture conditions.

Several models were constructed with main effect and interaction terms, including a full factorial framework. The models were compared using the quasilikelihood under independence model criterion (QIC) to determine which model had the best quality of fit. QIC statistics with smaller values indicate a more superior model fit than higher values; therefore, we used the statistical models that demonstrated the lowest QIC for each analysis. Six models were specified for the two dependent variables, receptive fast mapping and expressive naming. Table 4 displays the models, the fixed effects, and the QIC statistics for each.

Results

Receptive fast mapping

In a repeated fashion, the 48 participants contributed one receptive fast-mapping score for each of the three conditions: Point, Shape, and Control. This resulted in a total of 144 receptive fast-mapping responses, 1 or 0 for correct and incorrect, respectively. In addition to the planned investigation of gesture conditions and participant age groups, data are depicted with age groups divided by gender because of a significant gender difference for the participant groups on the eligibility language assessment, the MBCDI. Figure 3 displays the mean proportions of correct fast mapping responses over the gesture conditions, age groups, and genders. Group means and standard deviations indicated that Older Toddler girls were accurate for receptive fast mapping, and Older Toddler boys' receptive fast mapping was greatest for objects exposed in the Shape condition.

To test for statistically significant differences, GEE was conducted. Model 2 (see Table 4) demonstrated the lowest QIC indicating the best quality of fit. Using GEE, the effects of gesture condition, age, and gender on receptive fast mapping were evaluated. Age was a significant main effect, Wald χ^2 (1) = 5.551, p = .018, β = 1.047 (SE= .4446).
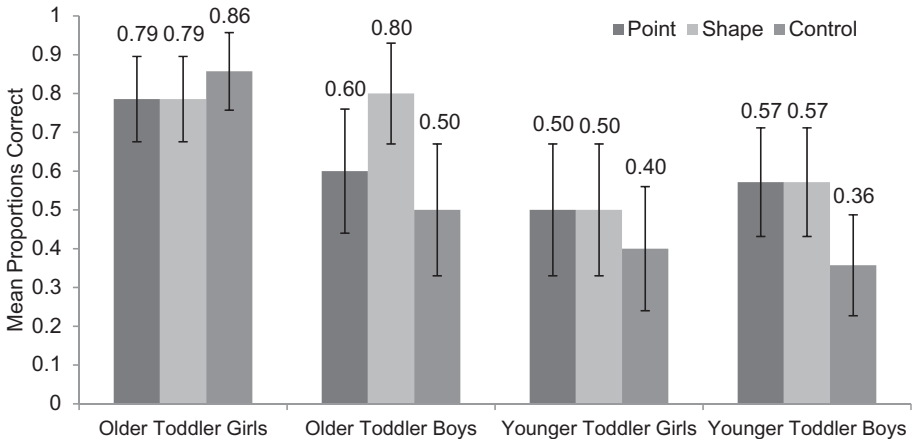
Figure 3. The mean proportions of correct fast mapping responses over the gesture conditions, age groups, and genders.

The mean proportions of correct receptive fast-mapping responses in Older and Younger Toddlers were .74 ($SD = .05$) and .49 ($SD = .10$) respectively. When other factors were held constant, Older Toddlers were 1.5 times more likely to receptively fast map correctly than Younger Toddlers. The main effects of gesture input condition and gender were not statistically significant. The model was also repeated with the predictor factor of Presentation List to test for item effects. Presentation List was nonsignificant and the significant main effect for age was unchanged.

During each testing phase, toddlers were first asked to select a familiar object. This task consisted of a forced-choice field of two. Means and standard deviations for groups' selection of familiar objects is shown in Table 5 and compared with their means and standard deviations for correct selection of the unfamiliar target objects. Group differences were statistically significant based on independent *t* tests (p values < .01). Older Toddlers had more correct selections of familiar and unfamiliar objects than the Younger Toddlers did.

Expressive naming

Of the 48 total participants who were asked to expressively name newly learned unfamiliar object labels in three gesture input conditions, 8 responses were not collected, either

Table 5. Familiar and Unfamiliar Object Selections by Older and Younger Toddler Groups

	Familiar Object Selections		Unfamiliar Object Selections	
Participants	*M*	*SD*	*M*	*SD*
Younger Toddlers	1.63	.92	1.46	1.02
Older Toddlers	2.63	.65	2.21	.98

Note. Means represent the group averages for correct object selection in three opportunities.
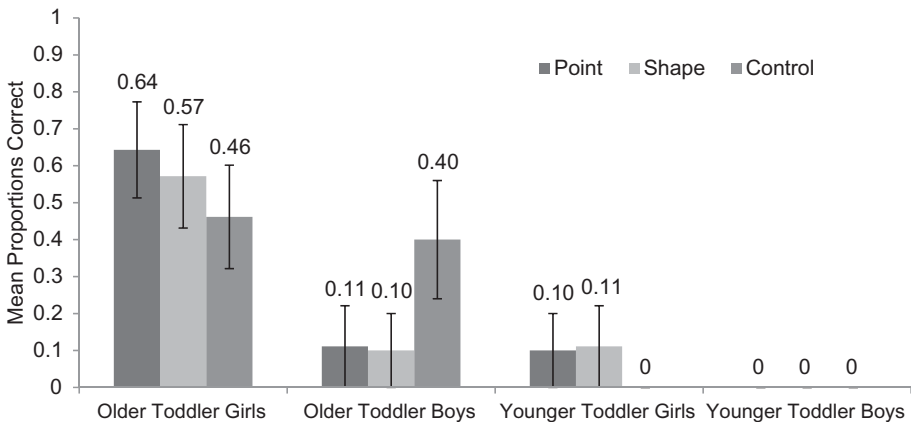
Figure 4. The mean proportions of correct expressive naming responses over the gesture conditions, age groups, and genders.

due to toddler fatigue or investigator error. Older Toddler girls contributed 41 responses with 1 missing response in the Control condition. Older Toddler boys contributed 29 responses with 1 missing response in the Point condition. Younger Toddler girls contributed 27 responses with 1 missing response in Shape and 2 missing responses in Control. Younger Toddler boys contributed 37 responses with 2 missing responses in the Point condition, 1 missing in the Shape condition, and 2 missing Control responses. This resulted in a total of 134 expressive naming responses, 0 or 1 for correct and incorrect, available for analysis. Figure 4 displays the proportions of correct expressive naming responses over the gesture conditions, age groups, and genders. Similar to the receptive fast-mapping responses, Older Toddler girls outperformed the other groups. The Older Toddler boys had a higher proportion of correctly named objects in the Control condition.

To test for statistical significance of hypothesized factors on toddlers' expressive naming, Model 5 demonstrated the best quality of fit based on the lowest QIC (See Table 4). In the GEE approach, the 10 missing data points are assumed to be random. Despite this limitation that can impact model efficiency and parameter estimates (Heck et al., 2012), the selected GEE model adequately accommodated the available expressive fast mapping data and imputations were unnecessary. To address our research questions, main effects of gesture condition, age, and gender as well as the interaction of gesture condition and gender were evaluated. To rule out any item effects, the model was repeated with Presentation List tested. Results indicated two statistically significant main effects: age, Wald χ^2 (1) = 9.369, p = .002, β = 3.145 (SE = 1.0276), and gender, Wald χ^2 (1) = 7.761, p = .005, β = 2.683 (SE = 1.1605). A main effect of gesture condition was not statistically significant; however, an interaction between gesture condition and gender was statistically significant, Wald χ^2 (1) = 9.822, p = .007, β = 2.388 (SE = 1.1857). Compared to boys, girls were nine times more likely to expressively name newly learned words in the Point and Shape conditions. While girls and boys performed similarly in the Control condition in which speech with no accompanying gestures was used to teach the new words, boys expressively named more words in the Control condition than in the two gesture conditions. In contrast, girls expressively named fewer words in the Control condition than in the two gesture conditions.

Because of the homogeneity in responding by the younger toddler boys (i.e., no younger toddler boys named any items correctly), a separate analysis of the expressive naming by the Older Toddlers only was conducted. There were two instances of missing data resulting in 70 expressive naming responses from 24 participants available for analysis. A GEE approach (QIC = 93.556) was used to test the main effects of gesture condition and gender as well as an interaction between gesture condition and gender. Results revealed a statistically significant main effect of gender: Wald χ^2 (1) = 6.286, p = .012, β = 2.485 (SE = 1.1844). A main effect of gesture condition was not statistically significant; however, the interaction between gesture condition and gender was statistically significant, Wald χ^2 (1) = 8.142, p = .017, β = 2.234 (SE = 1.2320). These findings mirrored those in the previous analysis: Older Toddler girls were six times more likely to expressively name newly learned words in the Point and Shape gesture conditions than the Older Toddler boys. The boys' and girls' performances were similar in the Control condition, but Older Toddler boys expressively named more words in the Control condition than in the two gesture conditions.

Demographic factors

Additional demographic factors were tested using the GEE approach. Analyses for the receptive fast-mapping responses and expressive naming (Models 2 and 5, respectively) were repeated with exposure to gesture communication (i.e., baby signs) and language skill (measured by MBCDI percentile score for words produced) added as covariates. Neither factor was statistically significant in the models, and the significant findings of main effects and interactions for hypothesized predictors remained constant.

Discussion

In this experimental study of fast mapping by young toddlers, we systematically manipulated gestures provided with the linguistic input. A group of typically developing one year olds was compared with a group of young typically developing two year olds for mapping object names to novel referents given brief interactions with an unfamiliar adult. Our research questions addressed the effect of gesture combined with speech on the word learning skills of the toddlers.

The first dependent measure was receptive fast mapping, and all participants contributed three data points for each unfamiliar object selection given the nonce words and paired gesture conditions. There was no statistically significant effect of gesture condition for the two toddler groups' recognition of the target objects. We had hypothesized that participants would demonstrate more correct responses in the gesture conditions than the word-only, no gesture condition, and we proposed that the shape gesture would have the greatest proportion of correct fast mapping. This hypothesized pattern for the shape condition emerged for the two-year-old boys, but this was not a significant finding. Only a main effect of age was found to be a significant predictor of the receptive fast-mapping selections.

Our second dependent measure was expressive naming of the target unfamiliar objects. Again, we hypothesized that gesture input would support successful naming. In particular, we expected that the shape gesture would support this mapping through at least partial encoding of some semantic information, the shape of the novel object. Assuming mapping of the salient shape feature would occur, then the likelihood of

successful encoding and retrieval for the newly learned name might increase. Again, there was no significant main effect of gesture input. Instead, age and gender were both significant predictors. There was a gesture-gender interaction primarily characterized by more correct naming by two-year-old boys in the word-only, no gesture condition.

Toddler age and fast mapping

Age was a significant predictor of both receptive fast mapping and expressive naming. The two year olds outperformed the one year olds for both measures. The older toddlers were 1.5 times more likely to correctly select the target object receptively, and 12 of the 24 older toddlers receptively identified all three novel referents correctly regardless of the gesture condition. Like other researchers who report that typically developing toddlers fast map successfully by age two (Hiebeck & Markman, 1987; Spiegel & Halberda, 2011), our results did not uncover fast mapping by children under 20 months.

The nature of our fast-mapping task and the testing phases may be factors impacting our findings. The linguistic context was ostensive (e.g., "It's a X; "See the X") with words and phrases that serve a deictic function, and each nonce word and unfamiliar object pairing included four explicit labels, not just one or two exposures. The task also was multimodal in several ways. In addition to hearing the name and seeing the object, the investigator moved the target object to several locations (table, tray and bucket) and allowed the child to briefly handle each object. Any benefits from this ostensive teaching and engaging interaction, however, may have been off set by the total number of targets presented in a sequence of brief exposures. That is, the fast-mapping task exposed the young toddlers to nine white objects (three named familiar objects, three target objects paired with nonce words and gesture conditions, and three foil objects labeled "it"). For each of the objects, the investigator engaged in a scripted interaction during which she said the labels for the nine objects four times resulting in 36 labels total in the approximately eight-minute interaction. Given the very young age of the toddlers, this could be considered a challenging task compared to fast mapping studies with fewer targets.

The first of our two measures, the receptive fast-mapping measure, was a forced-choice, recognition task from a field of two that took place immediately after the brief interactive exposures for three objects. Naturalistic behavioral methods that relied on toddlers' object selections may have limited our findings. Specifically, the group of younger toddlers, aged 1;4 to 1;8, showed inconsistent skills for this assessment even when asked to select familiar objects with known names. Only 21% of the one year olds accurately selected all three familiar objects. As a group, the younger toddlers averaged less than two correct selections out of three opportunities, which was significantly fewer correct selections of familiar objects than the toddlers in the older group. Namy (2008) also found that toddlers at 14, 18, and 20 months of age demonstrated inconsistent performance compared to toddlers at 26 months of age in a gesture recognition study using direct, manual object selection. Studies that implement looking paradigms may be more effective than behavioral studies when it comes to assessing fast mapping in toddlers younger than 2;0 (Gliga & Csibra, 2009; Puccini & Liszkowski, 2012). Bion et al. (2013) suggested that the forced-choice paradigm is truly a disambiguation task that may not be indicative of word learning. They reported looking-paradigm data differentiating the development of skills for disambiguation separate from word-object learning and retention for children from 1;6 to 2;6. Bion and colleagues concluded that recognition of

familiar words as well as disambiguating and learning new words are skills that develop gradually.

Our second measure, expressive naming, was expected to be more challenging than the receptive fast-mapping task, because toddlers had to encode and retrieve the phonological elements of the nonce word to correctly name the object. This was still an immediate assessment, not a test of retention with any time delay. Across gesture conditions, older toddlers named more of the newly learned nonce words than younger toddlers. Only one toddler in the younger group ($n = 24$) named the nonce label when presented with the associated object, and she named two out of three of the objects. None of the one-year-old boys correctly named any target objects.

Interestingly, several older toddlers named the unfamiliar object, the folder holder, a "triangle," during the fast-mapping phase and again during the expressive naming test. This was despite their correct selection of the object named "tull" during the receptive fast-mapping test. If children already had a name for this object, "triangle," then a mutual exclusivity assumption could interfere with mapping a new name to the object. Mutual exclusivity, the idea that an object has only one label, is one process hypothesized to support fast mapping new names to novel objects (Beverly & Estis, 2003).

Gender and word learning

Gender was found to be a significant predictor for toddlers' expressive naming of the newly learned object labels. Sex differences for early language development with girls outpacing boys is not an uncommon research finding, despite boys meeting age-level language expectations. Female toddlers achieve language milestones such as vocabulary and syntax use at earlier ages than males (Fenson, Dale, Reznick, Bates, Thal, Pethick, Tomasello, Mervis & Stiles, 1994), and Özçalişkan and Goldin-Meadow (2010) reported that girls' gesture productions, like their spoken language skills, emerged ahead of boys' gesture use. This was despite no significant differences in the gesture input by mothers of the children (Özçalişkan & Goldin-Meadow, 2010). Our findings suggested that female toddlers have a referent mapping advantage that promotes word learning. Female toddlers over the age of two are geared to learn new words. They are flexible fast mappers whose performance may have been enhanced by, but was not dependent upon, gestural cues combined with linguistic input. Girls' and boys' vocabulary sizes become more similar in the preschool years; and yet, the fast-mapping advantage of female toddlers may be a factor that undergirds female language skills through adolescence and into adulthood (Özçalişkan & Goldin-Meadow, 2010).

In addition to a main effect of gender with girls outperforming boys, there was a significant interaction between gender and gesture condition for the older toddlers. Two-year-old girls were six times more likely than the boys to correctly name objects that were paired with point and shape gestures in the exposure task; however, naming by the boys and girls for the word-only, no gesture condition was similar. The boys were more accurate namers in the word-only, no-gesture condition. In fact, the gesture input appeared to interfere with the boys' naming.

Puccini and Liszkowski (2012) concluded that multimodal input in the form of an arbitrary gesture paired with a spoken word is unnecessary for word learning and potentially disruptive for their participants who were 1;3. They questioned whether children under the age of 2;2 to 2;6 can benefit from multimodal input for word learning, particularly when the gesture is not a deictic point that can support joint attention

processes. Puccini and Liszkowski hypothesized that mapping gesture-speech input with a novel referent is more complex than mapping speech to a referent. The multimodal input results in a word plus gesture plus object or three-way mapping compared with the word plus object, a simpler two-term mapping. Furthermore, encoding a representational gesture with an object requires coordinating competing visual information, whereas the spoken word in the auditory modality can be mapped synchronously to the visual referent in the environment.

The nature of iconic gesture

Iconicity is only one semantic feature that could support referent representation during fast mapping and word learning, but iconicity varies for gestures and signs such that some require understanding of the word and its referent (e.g., sign for "cat" that refers to a cat's whiskers) to understand the iconic relationship. The shape gesture, however, is an iconic cue consistent with research suggesting that young toddlers attend to the shape of objects in the process of rapidly learning new words (Landau et al., 1988; Namy, 2008; Smith, 2000) including some studies supporting the facilitative effect of a shape gesture for word learning (Capone & McGregor, 2005; Capone Singleton, 2012). Our results did not show a clear benefit for these toddlers from the co-occurring shape gesture. In addition to the younger ages of our participants, there were several study differences. Perhaps the most important one was the extended word learning or slow mapping nature of the Capone Singleton investigations. If, rather than being all-or-nothing, recognition of iconicity is developmental requiring repeated associations, then a fast-mapping task might not capture its impact on semantic encoding.

In language, iconicity is contrasted with arbitrariness, a critical aspect of language symbolism (Nielsen & Dingemanse, 2021). And yet, words that have more iconic sounds (e.g., roar, choo-choo) are often learned earlier by young children than words with sounds that have no relationship to the referent. Iconicity is assumed to provide some perceptual-motor grounding or imagistic information (Nielsen & Dingemanse, 2021). In this sense, we hypothesized that iconicity depicted by hand shapes that mimicked object shapes would be facilitative for very young children. Hodges, Özçalişkan, and Williamson (2018), however, found that toddlers (mean age of 2;8) did not match one subtype of iconic gestures, attribute gestures, to object photos, but three year olds did recognize iconic attribute gestures significantly more often than predicted by chance. Hearing three year olds who participated in a study by Magid and Pyers (2017) of iconic shape gestures did not reliably map shape gestures to referents. Children who were Deaf learners of sign language recognized shape gestures matched to referents at age three. Novack, Filippi, Golding-Meadow, and Woodward (2018) conducted a series of studies investigating interpretation of iconic gestures by two year olds. They found that the toddlers correctly interpreted different handshape gestures in a reach gesture but not when the same handshapes were gestured without the extended arm in a reach toward the object referents. Investigators concluded that children have difficulty interpreting shape gestures as representational of objects.

Gesture and language learning

Multimodal motherese has been described in natural and experimental contexts for parents from several cultures (Cheung, Hartley & Monaghan, 2021; Gogate, Bahrick &

Watson, 2000; Gogate, Maganti & Bahrick, 2015). This multimodal input, however, is characterized by gestures paired with showing, shaking, and moving unfamiliar objects including sometimes touching the child with the object and the use of deictic gestures for scaffolding joint attention in the environment. This synchronized movement has been proposed to reduce cognitive load for preverbal children particularly when there is referent ambiguity; however, these studies have not assessed the benefits of the multi-modal motherese. After all, typically developing children effectively learn language when their parents do not specifically use gesture to enhance the spoken input.

What is the role of gesture? A question often raised by parents and professionals is whether gesture programs, such as Baby Signs® and others, should be used to enhance word learning for typically developing toddlers. For spoken language learners, we know that gesture cannot be wholly sufficient for mapping words to referents. Children need linguistic input to hear and then learn vocabulary. We had anticipated that gesture in the form of a deictic point would direct attention to the object for mapping, and that the shape gesture would encode some representational information supporting mapping words to target objects. Our results, however, did not support a facilitative effect of gesture input for very young toddlers. Gesture input appeared beneficial to the two-year-old girls; however, these female toddlers were generally better at word learning than their male counterparts. So, although they were significantly more likely to successfully name the novel objects in the gesture conditions compared to the boys, their performance in the control condition was not significantly different. Instead, the two-year-old boys named more items taught in the word-only condition than in the gesture conditions. These findings are indicative of disrupted word learning for the multimodal input. As suggested in a body of work by Goldin-Meadow and colleagues (e.g., Breckinridge Church & Goldin-Meadow, 1986; Goldin-Meadow & Alibali, 2013; Goldin-Meadow, Kim & Singer, 1999; Goldin-Meadow, Nusbaum, Kelly & Wagner, 2001), gesture appears to lessen the cognitive burden when children are in the process of acquiring language. Our results, however, indicate that the role of gesture is mitigated by children's age-related language development and gender. Gesture is not necessary or sufficient; and very young language learners may not be able to capitalize on gesture cues in fast-mapping paradigms.

Limitations and implications

Primary limitations were the sample size based on the number of total participants from a relatively homogenous background and the few binomial data points evoked by our study design. Additionally, an experimental word learning study such as this is limited by the nature of the experimental tasks and assessments that differ from naturally occurring exposures and interactions. During our study, participants were seated in a child chair with a tray that restricted their movement, and the investigator introduced the objects and associated language in a highly scripted manner. Any effect of the object position to the side of the face-to-face interaction is unknown. Similarly, the shape gesture was produced next to the object rather than directly between the child and adult or closer to the adult's body as typically produced in sign languages. Another limitation was the lack of a familiarization phase. That is, participants' first exposures to novel objects were during the experimental task. This lack of hands-on exposure to the objects could have interfered with participants' attention to the added gesture.

The question of clinical importance that remains is whether word learning by young children at-risk for or exhibiting language disorders could be aided by spoken language

combined with gesture. Ellis Weismer and Hesketh (1993) reported that manual gestures representing spatial concepts supported nonce word learning by kindergartners with specific language impairment. Vogt and Kauschke (2017) found that preschool children with specific language impairment performed similarly to typically developing children who were matched for age when novel words presented in a storybook were accompanied by gesture. In a single-subject intervention with four toddlers who were late talkers, Capone Singleton and Anderson (2020) showed that shape gestures paired with taught words increased learning for these words and supported generalization to untaught exemplars compared to words taught with deictic gestures of touching, showing or eye gaze. These studies provide an emerging evidence base needing larger, well-designed investigations of gesture treatments for children with language disorders.

Conclusion

Results suggested that the role of gesture input was circumscribed. There was no statistically significant effect of gesture input when toddlers' receptive fast-mapping responses were measured. Only an effect of age emerged, such that the older toddlers outperformed the younger toddlers for identification of novel objects taught with nonce labels. When expressive naming was assessed, only one girl and no boys in the younger toddler group named any target objects. Gesture input significantly interacted with gender. Gesture was facilitative for the two-year old girls but conversely appeared to interfere with naming for two-year-old boys. There was not a statistically significant unique effect of the iconic shape gesture compared to a deictic point for the older toddler girls, and the boys demonstrated more naming for the labels taught in the speech-only condition than in the two gesture-speech combined conditions. There remain unlimited opportunities for further investigation into the complex nature of language development in conjunction with child development factors, learning contexts, and the role of gesture input.

References

Beverly, B. L., & Estis, J. M. (2003). Fast mapping deficits during disambiguation in children with specific language impairment. *Canadian Journal of Speech-Language Pathology and Audiology*, **27**(3), 162–169. http://cjslpa.ca/files/2003_JSLPA_Vol_27/No_03_141-184/Beverly_Estis_JSLPA_2003.pdf

Bion, R. A. H., Borovsky, A., & Fernald, A. (2013). Fast mapping, slow learning: Disambiguation of novel word–object mappings in relation to vocabulary learning at 18, 24, and 30 months. *Cognition*, **126**, 39–53. https://doi.org/10.1016/j.cognition.2012.08.008

Breckinridge Church, R., & Goldin-Meadow, S. (1986). The mismatch between gesture and speech as an index of transitional knowledge. *Cognition*, **23**(1), 43–71. https://doi.org/10.1016/0010-0277(86)90053-3

Capone, N. C., & McGregor, K. K. (2004). Gesture development: A review for clinical and research practices. *Journal of Speech, Language, and Hearing Research*, **47**(1), 173–186. https://doi.org/10.1044/1092-4388(2004/015)

Capone, N. C., & McGregor, K. K. (2005). The effect of semantic representation on toddlers' word retrieval. *Journal of Speech, Language, and Hearing Research*, **48**(6), 1468–1480. https://doi.org/10.1044/1092-4388(2005/102)

Capone Singleton, N. (2012). Can semantic enrichment lead to naming in a word extension task? *American Journal of Speech-Language Pathology*, **21**, 279–292. https://doi.org/10.1044/1058-0360(2012/11-0019)

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

Capone Singleton, N. C., & **Saks, J.** (2015). Co-speech gesture input as a support for language learning in children with and without early language delay. *Perspectives on Language Learning and Education*, **22**, 61–71. https://doi.org/10.1044/lle22.2.61

Carey, S. (2010). Beyond fast mapping. *Language Learning and Development*, **6**(3), 184–205. https://doi.org/10.1080/15475441.2010.484379

Carey, S., & **Bartlett, E.** (1978). Acquiring a single new word. *Papers and Reports on Child Language Development (Stanford University)*, **15**, 17–29.

Caselli, M. C., **Vicari, S.**, **Longobardi, E.**, **Lami, L.**, **Pizzoli, C.**, & **Stella, G.** (1998). Gestures and words in early development of children with Down syndrome. *Journal of Speech, Language, and Hearing Research*, **41**(5), 1125–1135. https://doi.org/10.1044/jslhr.4105.1125

Cheung, R. W., **Hartley, C.**, & **Monaghan, P.** (2021). Caregivers use gesture contingently to support word learning. *Developmental Science*, **00**:e13098, 1–15. https://doi.org/10.1111/desc.13098

Crais, E. R., **Watson, L. R.**, & **Baranek, G. T.** (2009). Use of gesture development in profiling children's prelinguistic communication skills. *American Journal of Speech-Language Pathology*, **18**, 95–108. https://doi.org/10.1044/1058-0360(2008/07-0041)

Dale, P. S., & **Fenson, L.** (1996). Lexical developmental norms for young children. *Behavioral Research Methods, Instruments, and Computers*, **28**, 125–127. https://doi.org/10.3758/bf03203646

Davidson, D., **Rainey, V. R.**, **Vanegas, S. B.**, & **Hilvert, E.** (2018). The effects of type of instruction, animacy cues, and dimensionality of objects on the shape bias in 3- to 6-year-old children. *Infant and Child Development*, **27**, e2044. https://doi.org/10.1002/icd.2044

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

Dollaghan, C. A. (1987). Fast mapping in normal and language-impaired children. *Journal of Speech and Hearing Disorders*, **52**(3), 218–222. https://doi.org/10.1044/jshd.5203.218

Ellis Weismer, S. E., & **Hesketh, L. J.** (1993). The influence of prosodic and gestural cues on novel word acquisition by children with specific language impairment. *Journal of Speech and Hearing Research*, **36**(5), 1013–1025. https://doi.org/10.1044/jshr.3605.1013

Fenson, L., **Dale, P.**, **Reznick, J.**, **Bates, E.**, **Thal, D.**, **Pethick, S.**, **Tomasello, M.**, **Mervis, C.**, & **Stiles, J.** (1994). Variability in early communication development. *Monographs of the Society for Research in Child Development*, **59**. https://doi.org/10.2307/1166093

Fenson, L., **Marchman, V. A.**, **Thal, D. J.**, **Dale, P. S.**, & **Reznick, J. S.** (2007). MacArthur-Bates communicative development inventories. *User's Guide and Technical Manual*. https://doi.org/10.1037/t11538-000

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

Gliga, T., & **Csibra, G.** (2009). One-year-old infants appreciate the referential nature of deictic gestures and words. *Psychological Science*, **20**(3), 347–353. https://doi.org/10.1111/j.1467-9280.2009.02295.x

Gogate, L. J., **Bahrick, L. E.**, & **Watson, J. D.** (2000). A study of multimodal motherese: The role of temporal synchrony between verbal labels and gestures. *Child Development*, **71**, 878–894.

Gogate, L. J., **Maganti, M.**, & **Bahrick, L. E.** (2015). Cross-cultural evidence for multimodal motherese: Asian Indian mothers' adaptive use of synchronous words and gestures. *Journal of Experimental Child Psychology*, **129**, 110–126. https://doi.org/10.1016/j.jecp.2014.09.002

Goldin-Meadow, S., & **Alibali, M. W.** (2013). Gesture's role in speaking, learning, and creating language. *Annual Review of Psychology*, **64**, 257–283. https://doi.org/10.1146/annurev-psych- 13011–143802

Goldin-Meadow, S., **Kim, S.**, & **Singer, M.** (1999). What the teacher's hands tell the student's mind about math. *Journal of Educational Psychology*, **91**, 720–730. https://doi.org/10.1037/0022-0663.91.4.720

Goldin-Meadow, S., **Nusbaum, H.**, **Kelly, S. D.**, & **Wagner, S.** (2001). Explaining math: Gesturing lightens the load. *Psychological Science*, **12**(6), 516–522. https://doi.org/10.1111/1467-9280.00395

Goodwyn, S. W., & **Acredolo, L. P.** (1993). Symbolic gesture versus word: Is there a modality advantage for onset of symbol use? *Child Development*, **64**(3), 688–701. https://doi.org/10.2307/1131211

Goodwyn, S. W., & Acredolo, L. P. (1998). Encouraging symbolic gestures: A new perspective on the relationship between gesture and speech. *New Directions for Child Development*, **79**, 61–73. https://doi.org/10.1002/cd.23219987905

Goodwyn, S. W., Acredolo, L. P., & Brown, C. A. (2000). Impact of symbolic gesturing on early language development. *Journal of Nonverbal Behavior*, **24**(2), 81–103. https://doi.org/10.1023/A:1006653828895

Heck, R. H., Thomas, S., & Tabata, L. (2012). *Multilevel modeling of categorical outcomes using IBM SPSS*. Abingdon, Oxfordshire, UK: Routledge.

Hiebeck, T., & Markman, E. (1987). Word learning in children: An examination of fast mapping. *Child Development*, **58**, 1021–1034. https://doi.org/10.2307/1130543

Hirsh-Pasek, K., Golinkoff, R. M., & Hollich, G. (2000). An emergentist coalition model for word learning. *Becoming a word learner: A debate on lexical acquisition*, pp. 136–164. New York, NY: Oxford University Press.

Hodges, L. E., Özçalışkan, S., & Williamson, R. (2018). Type of iconicity influences children's comprehension of gesture. *Journal of Experimental Child Psychology*, **166**, 327–339. https://doi.org/10.1016/j.jecp.2017.08.009

Horst, J. S., & Samuelson, L. K. (2008). Fast mapping but poor retention by 24-month-old infants. *Infancy*, **13**(2), 128–157. https://doi.org/10.1080/1525O(xH)70179559

Hostetter, A. (2011). When do gestures communicate? A meta-analysis. *Psychological Bulletin*, **137**(2), 297–315. https://doi.org/10.1037/a0022128

Hostetter, A., & Mainela-Arnold, E. (2015). Gestures occur with spatial and motoric knowledge: It's more than just coincidence. *Perspectives on Language Learning and Education*, **22**, 42–49. https://doi.org/10.1044/lle22.2.42

IBM Corp. (2021). IBM SPSS Statistics for Windows, Version 28.0 [Computer Software]. Armonk, NY: IBM Corp.

Iverson, J. M., Capirci, O., Longobardi, E., & Caselli, M. C. (1999). Gesturing in mother-child interactions. *Cognitive Development*, **14**(1), 57–75. https://doi.org/10.1016/S0885-2014(99)80018-5

Iverson, J. M., & Goldin-Meadow, S. (2005). Gesture paves the way for language development. *Psychological Science*, **16**(5), 367–371. https://doi.org/10.1111/j.0956-7976.2005.01542.x

Iverson, J. M., & Thelen, E. (1999). Hand, mouth and brain. The dynamic emergence of speech and gesture. *Journal of Consciousness Studies*, **6**, 11(12), 19–40.

Johnston, J. C., Durieux-Smith, A., & Bloom, K. (2005). Teaching gestural signs to infants to advance child development: A review of the evidence. *First Language*, **25**(2), 235–251. https://doi.org/10.1177/0142723705050340

Kirk, E., Howlett, N., Pine, K. J., & Fletcher, B. C. (2013). To sign or not to sign? The impact of encouraging infants to gesture on infant language and maternal mind-mindedness. *Child Development*, **84**(2), 574–590. https://doi.org/10.1111/j.1467-8624.2012.01874.x

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

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

Lederer, S. H., & Battaglia, D. (2015). Using signs to facilitate vocabulary in children with language delays. *Infants & Young Children*, **28**(1), 18–31. https://doi.org/10.1097/IYC.0000000000000025

Liang, K. Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika*, **73**(1), 13–22. https://doi.org/10.1093/biomet/73.1.13

Lüke, C., & Ritterfeld, U. (2014). The influence of iconic and arbitrary gestures on novel word learning in children with and without SLI. *Gesture*, **14**(2), 203–224. https://doi.org/10.1075/gest.14.2.04luk

Magid, R. W., & Pyers, J. E. (2017). "I use it when I see it": The role of development and experience in Deaf and hearing children's understanding of iconic gesture. *Cognition*, **162**, 73–86. https://doi.org/10.1016/j.cognition.2017.01.015

Matatyaho, D. J., & Gogate, L. J. (2008). Type of maternal object motion during synchronous naming predicts preverbal infants' learning of word–object relations. *Infancy*, **13**(2), 172–184. https://doi.org/10.1080/15250000701795655

Mervis, C., & Bertrand, J. (1994). Acquisition of the novel name-nameless category (N3C) principle. *Child Development*, **65**, 1646–1662. https://doi.org/10.2307/1131285

Namy, L. L. (2008). Recognition of iconicity doesn't come for free. *Developmental Science*, **11**(6), 841–846. https://doi.org/10.1111/j.1467-7687.2008.00732.x

Nielsen, A. K. S., & Dingemanse, M. (2021). Iconicity in word learning and beyond: A critical review. *Language and Speech*, **64**(1), 52–72. https://doi.org/10.1177/0023830920914339

Novack, M. A., Filippi, C. A., Golding-Meadow, S., & Woodward, A. (2018). Actions speak louder than gestures when you are 2 years old. *Developmental Psychology*, **54**(10). 1809–1821. https://doi.org/10.1037/dev0000553

Özçalişkan, S., Adamson, L. B., Dimitrova, N., Bailey, J., & Schmuck, L. (2016). Baby sign but not spontaneous gesture predicts later vocabulary in children with Down Syndrome. *Journal of Child Language*, **43**(4), 948–963. https://doi.org/10.1017/S030500091500029X

Özçalişkan, S., & Goldin-Meadow, S. (2010). Sex differences in language first appear in gesture. *Developmental science*, **13**(5), 752–760. https://doi.org/10.1080/01690960801956911

Perniss, P., & Vigliocco, G. (2014). The bridge of iconicity: From a world of experience to the experience of language. *Philosophical Transactions of the Royal Society, Series B: Biological Sciences*, **369**, 20130300. http://doi.org/10.1098/rstb.2013.0300

Puccini, D., & Liszkowski, U. (2012). 15-month-old infants fast map words but not representational gestures of multimodal labels. *Frontiers in Psychology*, **3**, 1–8. https://doi.org/10.3389/fpsyg.2012.00101

Smith, L. B. (2000). Learning how to learn words: An associative crane. In M. Marschark (Ed.), *Becoming a word learner: a debate on lexical acquisition*, (pp. 51–80). New York, NY: Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195130324.003.003

Spiegel, C., & Halberda, J. (2011). Rapid fast-mapping abilities in 2-year-olds. *Journal of Experimental Child Psychology*, **109**, 132–140. https://doi.org/10.1016/j.jecp.2010.10.013

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

Thal, D. J., & Tobias, S. (1992). Communicative gestures in children with delayed onset of oral expressive vocabulary. *Journal of Speech and Hearing Research*, **35**(6), 1281–1289. https://doi.org/10.1044/jshr.3506.1289

Tolar, T. D., Lederberg, A. R., Gokhale, S., & Tomasello, M. (2008). The development of the ability to recognize the meaning of iconic signs. *Journal of Deaf Studies and Deaf Education*, **13**(2), 225–240. https://doi.org/10.1093/deafed/enm045

Vitevitch, M. S., & Luce, P. A. (2004). A web-based interface to calculate phonotactic probability for words and nonwords in English. *Behavior Research Methods*, **36**(3), 481–487. https://doi.org/10.3758/BF03195594

Vogt, S., & Kauschke, C. (2017). Observing iconic gestures enhances word learning in typically developing children and children with specific language impairment. *Journal of Child Language*, **60**, 1458–1484. https://doi.org/10.1017/S0305000916000647

Wang, X. L., Bernas, R., & Eberhard, P. (2001). Effects of teachers' verbal and non-verbal scaffolding on everyday classroom performances of students with down syndrome. *International Journal of Early Years Education*, **9**(1), 71–80. https://doi.org/10.1080/09669760125651

Zammit, M., & Schafer, G. (2010). Maternal label and gesture use affects acquisition of specific object names. *Journal of Child Language*, **38**(1), 1–21. https://doi.org/10.1017/S0305000909990328