Cognitive Development 40 (2016) 68–81

Contents lists available at ScienceDirect

Cognitive Development

Listening and watching: The effects of observing gesture on preschoolers' narrative comprehension

Alice Macoun, Naomi Sweller*

Department of Psychology, Macquarie University, North Ryde, NSW 2109, Australia

ARTICLE INFO

Article history:
Received 28 July 2016
Accepted 19 August 2016

Keywords:
Gesture
Narrative
Comprehension
Teaching
Communication

ABSTRACT

Observing gesture can have a beneficial effect on learning, however research into the role of gesture in preschoolers' narrative comprehension is scarce. The present study compared different forms of gesture and their associated communicative value. Preschool-aged children viewed a short videotaped narrative with either accompanying iconic, deictic, or beat gestures, or no gesture. Half of the gestures presented provided additional information beyond that presented in speech, while the other half depicted no additional information. Observing gesture was found to facilitate narrative comprehension, with iconic and deictic gesture providing the greatest benefit to recall. These differences between conditions were found only for gesture which presented additional information to that found in speech. The results suggest that iconic and deictic gestures may be used as an additional teaching tool for assisting children in understanding narratives.

1. Introduction

Gesture is a ubiquitous feature of communication in both children and adults, and often occurs simultaneously with speech (Kirk, Pine, & Ryder, 2011). An extensive line of research in nonverbal communication has pointed to the influence that gestures have in facilitating comprehension of a spoken message and performance on a wide range of tasks (Goldin-Meadow, 2000; Hostetter, 2011). Gesture's utility in communication is particularly apparent in the educational context. Educators employ gesture in teaching across a variety of domains, such as conservation tasks (Church, Ayman-Nolley, & Mahootian, 2004), mathematics (Goldin-Meadow, Kim, & Singer, 1999) and vocabulary acquisition (Capone & McGregor, 2005), and children indeed benefit from observing their teachers' gestures.

Although teachers spontaneously produce gesture in the classroom, it is unclear whether teachers appreciate the importance of gesture and employ gestures in the most efficacious way (Hostetter, Bieda, Alibali, Nathan, & Knuth, 2006). To harness the full potential of gestures in teaching sessions, it may be necessary to provide teachers with explicit instruction in relation to gesture usage. In order to do so, an understanding of the most effective form of gestural learning support is necessary. The present study aims to address the role of gesture in learning in the under-examined area of narrative comprehension. Understanding narratives is a crucial area to explore, as narrative comprehension is closely related to many developmental accomplishments and children learn from narrative from a young age (Egan, 1993). We begin by examining the function of gesture before discussing the different types of gesture, and how they may be beneficial for learning.

* Corresponding author.
E-mail addresses: alice.macoun@students.mq.edu.au (A. Macoun), naomi.sweller@mq.edu.au (N. Sweller).

http://dx.doi.org/10.1016/j.cogdev.2016.08.005
0885-2014/

1.1. The function of gesture

Although agreement exists about the natural occurrence of gesture and its intimate relationship with speech, there are two, perhaps non-mutually exclusive proposals in the gesture literature surrounding the exact function of gesture (Cassell, McNeill, & McCullough, 1999). Two primary hypotheses have been proposed to offer explanation for gesture usage: that gesture has benefits for a speaker, and that gesture has benefits for a listener. The first hypothesis proposes that gesture serves a speech production function. That is, the act of gesturing has an internal function for the producer. This internal function may be in the form of facilitating lexical access for the speaker (Krauss, 1998), reducing cognitive load for the speaker (Goldin-Meadow, Nusbaum, Kelly & Wagner, 2001; Ping & Goldin-Meadow, 2010) or in providing a simulation of actions (Gesture as Simulated Action framework, see Hostetter & Alibali, 2008; Hostetter & Alibali, 2010). It does appear that gestures have benefits for the speaker themselves, as individuals gesture despite the absence of an observant partner, for example when conversing on the telephone (de Ruiter, 1995) or in face-to-face conversation with a listener known to be blind (Iverson & Goldin-Meadow, 1998). In addition, restricting hand gesture has been found to impair speech production in both children (Pine, Bird, & Kirk, 2007) and adults (Rauscher, Krauss, & Chen, 1996), suggesting that gesture does indeed have beneficial effects for the speaker themselves.

The second hypothesis proposes that gesture serves an external, communicative function and is primarily produced to aid the receiver's comprehension (Kendon, 1994). In this way, the act of gesturing is socially motivated. This hypothesis is supported by studies such as that conducted by Beattie and Shovelton (1999), who found that more information could be detected when addressees viewed a speaker using accompanying gesture, in comparison with receiving audio information alone. Such results demonstrate that listeners attend to information expressed in both speech and gesture and use the mediums collectively to decode communication. In related work, researchers have found that both children (Alibali & Don, 2001) and adults (Alibali, Heath, & Myers, 2001) produce gesture at significantly higher rates when interacting with their listeners face-to-face than when deprived of reciprocal visibility via screens. Özyürek (2002) provides further support for the communicative hypothesis, in a study which found that speakers changed their gestures depending upon the spatial position of the addressee, thus implying that gestures are produced for the benefit of the listener. Furthermore, children are capable of detecting gestures produced by other children, even when the information conveyed through the gestures differs from that conveyed through speech (Kelly & Church, 1997).

These two theoretical positions may not be mutually exclusive. Indeed, gesture may be multifunctional, providing benefits for both speakers and listeners. For the purpose of understanding gesture's role in learning however, the present study focuses on the communicative function of gesture, specifically, how gesture can aid listeners' comprehension. "Gesture" is not a singular construct however, with different forms of gesture regularly produced by speakers. We now outline the various forms of gesture, before discussing the domains in which gesture has been found to benefit a listener.

1.2. Gesture classification

Numerous subsets of gestures have been identified. Cassell and McNeill (1991) found speakers produced four different forms of gesture when narrating a story and during social conversation: iconic, deictic, beat, and metaphoric gestures. Iconic gestures depict concrete referents or actions described in the speech; such as "book" accompanied by a mimetic enactment of the opening and closing of a book with two hands held out with palms opening and closing inward. This form of gesture is thought to be particularly communicative, due to offering a visuomotor representation of an object, action or affective cue, which serves not only to magnify the semantic meaning of the message, but also to tap into the viewer's motor representation of a concept (Kirk et al., 2011). Deictic gestures, another gestural form, are hand movements relating to spatial information. Such gestures are used to motion the relative position of the items being referred to in the accompanying speech and include pointing movements, for example "book" accompanied by the speaker pointing to a book. Metaphoric gestures convey abstract information and represent concepts with no physical form; such as "the story went on and on" accompanied by the speaker's hands mimicking a rolling motion.

These three forms of gesture all convey conceptual information. That is, they embody semantic meaning related to the speech. Such gestures are thought to assist communication by disambiguating and enhancing a spoken message (McNeill, 1992). As abstract concepts may be too cognitively challenging for the age group of interest, metaphoric gestures are not under investigation in the present study.

Unlike iconic and deictic gestures, beat gestures are baton like movements of a rhythmic nature, which contain no obvious semantic information. An example is "book" accompanied by the speaker's hands moving in a flicking motion. Such gestures can also be referred to as emphatic gestures and are thought to hold a meta-narrative function, reflecting the structure of the discourse (McNeill, 1992).

To our knowledge, no research to date has investigated the benefit of observing gesture through a direct comparison of different forms of gesture, namely iconic, deictic, and beat gesture. Although various studies have investigated the beneficial effects of different forms of gesture, they have often done so by examining one of the various forms in isolation. No direct comparison between the three has been made. Thus, the most effective form of gesture to employ when communicating a spoken message remains unknown. We now introduce different domains in which a listener can benefit from gesture.

1.3. Gestures as non-verbal learning supports

One particular communicative situation in which gesture holds significant importance is the interaction between a teacher and his or her student. A growing body of research demonstrates that teachers routinely gesture when giving lessons, both in the classroom (Flevares & Perry, 2001) and during individualized tutorials (Goldin-Meadow et al., 1999), and children indeed benefit from their teachers' gesture usage. Moreover, the information that teachers convey and emphasize through gesture appears to influence learning across various domains. For example, a study involving preschool students investigated whether teachers' use of deictic gesture influenced children's learning about the concept of symmetry (Valenzeno, Alibali, & Klatzky, 2003). Children who viewed the verbal plus gesture lesson displayed a greater understanding of symmetry on a post-test than children who viewed the verbal only lesson. Thus, deictic gestures may have the potential to facilitate learning by directing children's attention to the important elements of a problem. Studies indicate that teachers most frequently use deictic gesture, specifically pointing and tracing gestures, in the classroom (Alibali, Nathan & Fujimori, 2011; Fujimori, 1997).

However, it has also been reported that teachers produce iconic gesture when explaining concepts and children similarly profit from instruction accompanied by such gestures. A study by Church et al. (2004) found that understanding of Piagetian conservation increased two-fold for first graders who viewed a conservation lesson accompanied by iconic gesture in comparison with a lesson taught through speech alone. Here, the iconic gesture may have served as a second, non-verbal modality through which to process the instruction. Similarly, Ping and Goldin-Meadow (2008) likewise taught children Piagetian conservation tasks, with or without iconic gestures, as well as with or without the objects used in the task being present during explanation. Children learned more when the speech was accompanied by gestures, whether or not the gestures corresponded to concrete objects that were visually available.

In the aforementioned studies, the gesture conveyed the same semantic information as the spoken message, meaning the degree of redundancy between the two modalities was high. We refer to this as redundant gesture. Teachers' gesture does not always convey information corresponding to that presented in their speech, however. Often additional information is presented, offering learners a second approach to a problem. Singer and Goldin-Meadow (2005) presented children aged 8–10 years with instruction in mathematical equivalence. Children were taught problem solving strategies through speech with no accompanying gesture, speech with gesture conveying the same strategy, or speech with gesture conveying an alternative strategy. The gesture that conveyed an alternative strategy, that is, information not available in the instructor's speech, lead to significantly higher performance in the post-test in comparison with the other two conditions. Children have similarly been shown to learn from gestures produced by adults when the information conveyed through the gestures was misleading (Broaders & Goldin-Meadow, 2010), and when deictic gestures (both pointing and eye gaze) provided additional information only implicitly suggested through an ambiguous speech phrase (Kelly, 2001). These results suggest that non-redundant gestures – those gestures that provide listeners with unique information beyond that contained in speech – may also be effective in advancing learning.

The previously discussed studies, and much of the gesture literature, have primarily focused on iconic and deictic gestures. Much less attention has been given to beat gesture, and whether this non-semantic form of hand movement may play a role in children's learning. Although such gesture does not provide listeners with semantic information, some researchers have speculated that beat gesture may have the capacity to enhance recall (e.g., Nicoladis, 2007; Ravizza, 2003). For example, Krahmer and Swerts (2007) found that individuals perceived words accompanied by beat gesture to be more prominent than words merely spoken. Similarly, So, Chen-Hui & Wei-Shan (2012) found that when learning lists of words, beat gestures enhanced recall for adults but not children. In a study using event-related potential (ERP) data, Wang and Chu (2013) suggested that beat gestures can aid in semantic processing of individual words when hearing a single sentence. McNeill (1992) suggested that beat gesture serves a metacognitive function by directing listeners' attention to certain elements of the verbal message, thereby facilitating speech comprehension. McNeill also noted that the temporal connection beat gestures share with speech may have the capacity to draw attention to and emphasize new and important information. Thus, although not previously investigated with children, beat gesture may have the capacity to facilitate children's learning merely through an ability to capture and tune listeners' attention.

It is clear therefore that observing a speaker's gesture has the potential to enhance children's learning and understanding in a variety of domains. This relation between gesture and learning suggests that gesture may serve as a non-verbal learning support in another important educational domain: children's narrative comprehension.

1.4. Gesture and narrative

Children are surrounded by narrative from their earliest language experiences (Stein & Albro, 1996). Children as young as 2 and 3 years of age develop a rich repertoire of knowledge about narrative (Paris & Paris, 2003). It is uncontentious that narratives hold a considerable power to engage young children and that children learn from, comprehend and remember narrative content quite readily (Egan, 1993). According to Lyle (2000), narrative understanding is an important, if not the most important, cognitive tool through which all humans across cultures make sense of the world. Narratives are a key component in early childhood curricula (Dickinson & Tabors, 2001) and continue to have prominence in children's education throughout their schooling years (Taylor, Frye, & Maruyama, 1990). In fact, storytelling is becoming increasingly recognized by educators as a viable classroom technique, with emerging theoretical frameworks being proposed for classroom learning that are grounded in narrative – often referred to as narrative-centred learning environments (Egan, 1993; Hamilton, 2007). Narrative

comprehension is closely related to many concurrent developmental accomplishments of young children in domains such as reading, memory, language, listening, storytelling, socialisation and play (Paris & Paris, 2003). It reveals important cognitive accomplishments and encourages the use of skills such as the integration and elaboration of information, inferential thinking, and auditory processing (Frisk & Milner, 1990; Mar, 2004). Given the extensive research reviewed above establishing a relationship between gesture and learning, and the importance of narrative in young children's development, it is surprising that the role of gesture as a teaching aid in narrative comprehension has not been investigated. The current study is designed to fill that void.

1.5. The present study

In summary, gesture's facilitative effect on learning is well documented (Hostetter, 2011). Yet, the questions of which type of gesture is most facilitative and whether such benefits apply to narrative comprehension remain. Through an investigation of different forms of gestural support (iconic, deictic, and beat), and their associated communicative value (redundant and non-redundant), it may be possible to come to a conclusion on the most effective form of gesture to employ in teaching through narrative.

As young children learn from narrative (Egan, 1993) and readily attend to gesture (Thompson & Massaro, 1994), the present study used a sample of preschool students. This age group was particularly appropriate for the present study for three primary reasons. First, teachers' gesture usage is greater in classrooms with young learners and/or beginners (Tellier, 2008). Second, narrative understanding in preschool has been found to predict later reading comprehension and school achievement (Dickinson & McCabe, 2001; Paris & Paris, 2003). Third, at this early point in development, wide variation may exist in children's language ability and in their ability to comprehend speech alone compared with comprehending speech combined with gestural support (McNeil, Alibali, & Evans, 2000).

The role of gesture in narrative comprehension was investigated by way of a videotaped narrative. Children viewed the verbal narrative with, depending on the assigned condition, accompanying iconic, deictic, or beat gesture, or in the case of the control condition, no gesture. Present in each narrative was an accompanying visual display containing items both redundant and non-redundant to the narrative content. Phrases in the narrative that were accompanied by gesture were referred to as "gesture items", half of which were redundant and half of which were non-redundant. In line with prior research into comprehension of spoken language, preschoolers' narrative comprehension was assessed through recall (Kirk et al., 2011; McNeil et al., 2000) and compared between gesture conditions.

1.6. Hypotheses

It has been demonstrated that children display greater understanding of a concept when observing iconic or deictic gesture with accompanying speech than when presented with speech alone (Church et al., 2004; Valenzeno et al., 2003). It has also been demonstrated that beat gesture makes words more prominent, and thus easier to recall (Krahmer & Swerts, 2007). To that end, it is expected that children in conditions in which gesture accompanies speech (iconic, deictic, and beat) will recall more correct information about the narrative than children in the condition in which gesture does not accompany speech (the control).

It has been suggested that due to embodying semantic meaning, iconic and deictic gestures are of greater benefit to listeners than beat gesture (Woodall & Folger, 1985). As such, it is expected that children in the iconic and deictic gesture conditions will recall more correct information about the narrative than children in the beat gesture condition. On the other hand if, as suggested by McNeill (1992), beat gestures serve a metacognitive function, drawing attention to key words, then at least for gestures which do not provide any additional information beyond the spoken content, there may be no difference in recall between children in the iconic and deictic conditions and children in the beat gesture condition. All three types of gestures should serve to highlight key words or phrases.

A direct comparison of iconic and deictic gestures has yet to be made in the literature, and there is no theoretical justification for predicting that one form of gesture would provide greater support for narrative recall than the other. No directional hypotheses can be made therefore for the comparison between iconic and deictic gestures.

It has been demonstrated that children can detect information that is contained uniquely in a speaker's gesture (Thompson & Massaro, 1994). As such, it is expected that, although children in the control and beat conditions will report some information non-redundant to the verbal narrative due to the presence of the items in the visual display, children in the iconic and deictic conditions will report more non-redundant information. Providing non-redundant information will aid recall through the gesture itself in the iconic condition, or by making direct reference to the non-redundant information from the display through pointing in the deictic condition.

2. Methods

2.1. Experimental design

Participants were randomly allocated to one of the four gesture conditions: no gesture/control ($n = 25$), iconic gestures ($n = 25$), deictic gestures ($n = 25$) and beat gestures ($n = 26$). The dependent variable of interest was correct narrative recall,

Fig. 1. Visual display depicting park and home.

with higher scores indicating greater comprehension. Recall was assessed through both free recall and specific questions relating to the story content, as outlined below.

2.2. Participants

One hundred and two children, aged 3.25–5.58 years ($M = 4.651$, $SD = 0.47$), were recruited from independent preschools in the Sydney region through contact with centre directors. One child was omitted from the data set due to failure to complete all tasks, resulting in a total sample size of 101 participants. Of the final sample, 44 of the children were male ($M = 4.70$ years, $SD = 0.57$) and 57 were female ($M = 4.62$ years, $SD = 0.40$). Both parental written consent and verbal consent from children were obtained prior to each child's participation. Children were required to be fluent in the English language to participate in the study.

2.3. Materials

2.3.1. Stimulus video

The primary stimulus was a narrative about a girl's afternoon at the park with her family, narrated by an adult male unknown to participants. The narrative was 2 min in length and filmed with a video camera (both audio and visual). To maintain consistency across conditions, the narrator appeared in each video seated in front of a white wall, wearing a white t-shirt. Furthermore, the narrator was instructed to keep prosody constant across conditions, with vocal pitch and speed of narration constant across conditions. On the table before the narrator was a visual display depicting a park and a family home, which contained items both redundant and non-redundant to the narrative (see Fig. 1). The purpose of the visual display was primarily for reference during the deictic condition, however, it was present in every condition. Each condition was filmed separately and each child was exposed to one video only. In the control condition, the narrator told the story with his hands placed still on the table. In the iconic condition, the narrator told the story also producing representative hand movements indicating the shape or action of the object being described in the speech. In the deictic gesture condition, the narrator told the story also producing pointing movements, indicating the relative position of the items being referred to in the speech. In the beat condition, the narrator told the story also producing rhythmic hand movements bearing no representational meaning. The gestures only occurred at 10 places in the narrative, referred to here as gesture items. Five of the gesture items were redundant in nature and five were non-redundant. In each condition, the gestures were performed on the same words in the narrative and held for a duration of 4 s each. A copy of the story script and accompanying gestures can be found in Appendix A.

2.3.2. Filler task

A join-the-dots task was provided to the children to complete. This task lasted for approximately 5 min and children were offered help in its completion. By allowing for a break between viewing of the narrative and questioning, this task was included to reduce the probability of the child recalling any particular part of the narrative with greater accuracy than any other part due to primacy or recency effects at recall.

2.3.3. Response items

Each participant was asked a single free recall question followed by 15 specific questions relating to the content of the narrative. Five of these questions concerned general story content (non-gesture items), another five concerned the gesture items that provided no additional information beyond the speech content (redundant gesture items) and the remaining five concerned the gesture items that provided additional information beyond the speech content (non-redundant gesture items).

If a child answered a specific question correctly the experimenter moved onto the next question. If a child was unable to answer a specific question or answered the question incorrectly, a forced choice option was presented. For example, if a child incorrectly answered "chicken" to the question "What did the family have for dinner?", then the forced choice option "spaghetti or vegetables?" was presented. The order of the forced choice options given was counterbalanced between participants. Scoring and coding of the responses is described below.

To further eliminate potential order effects, the order in which the questions were presented to each participant was randomized. This was done using an online random number generator (http://www.randomizer.org/form.htm), with the order of questions pre-determined for each participant.

As the presence of visual stimuli in the video may impact upon a child's response to a question, half of the gesture questions contained visual stimuli in the video for both the forced choice options and half contained visual stimuli in only one of the forced choice options. For example, the visual display contains both a bath and a book. For the question "While Daisy's mum was cooking dinner, what were the children doing?", the forced choice options are "having a bath" or "reading a book". Therefore, both options had visual stimuli in the video. On the other hand, for the question "What type of animal did the family see on the way home?" with the forced choice options "a dog" or "a bird", the video only displays a visual for bird not dog. Following a pilot study, it was not deemed possible to have both forced choice options present for all questions, as the display became too crowded, making it difficult to isolate individual elements. Similarly, it was not possible to have no forced choice options present, as the items were required to be present for the deictic condition. The compromise outlined here was therefore decided upon, with half the questions having both options present, and half only one. It should be noted that the visual display was only present while children viewed the narrative, not during recall. See Appendix B for the complete interview protocol.

2.3.4. Recording devices

In order for the experimenter to maintain her attention on the child and to retain an accurate record of children's verbal responses for later analysis, children's responses to the interview questions were audio-recorded. Prior to turning on the device children were asked for consent. All children gave consent.

2.3.5. Peabody picture vocabulary test

The Peabody Picture Vocabulary Test-4 Form A (PPVT-4, Dunn & Dunn, 2007) was administered to each child as a measure of receptive vocabulary. Including a vocabulary assessment was necessary because knowledge of word meanings is crucial for comprehending a story (Becker, 1977). Children who displayed a receptive language ability of below the age of 3 years were to be eliminated from the study, since it could not be certain that they had sufficiently understood the narrative and the tasks required of them. One child displayed a receptive language ability below the age of 3 years but did not perform at floor level in the comprehension tasks. On this basis the child was retained in the sample. The PPVT-4 has been used with children in prior studies (e.g., Borovsky, Elman, & Fernald, 2012; Ouellette, 2010) with a reported internal consistency of 0.94, a test-retest reliability of 0.93, a parallel-forms reliability of 0.89 and convergent validity in the range of 0.68–.82 (Dunn & Dunn, 2007).

2.4. Procedure

Before commencing the study, ethics approval was obtained from the Macquarie University Faculty of Human Sciences Research Ethics Sub-Committee (Reference Code: 5201400154). Preschool directors were provided with information documents explaining the study in detail and requirements from the participating preschool. Information and consent forms were distributed to parents. Only children whose parents returned signed forms were permitted to participate.

Each participant was tested individually and each session ran on average for 25 min. The experimenter and child sat side by side at a table in a quiet location away from the usual proceedings of the classroom. The experimenter instructed the child to pay close attention to the video, as they would later be asking questions about the story. Each child viewed one of the four videos depending on his or her random allocation to a gesture condition. Following presentation of the narrative, the child completed a join-the-dots filler task.

The experimenter then presented the audio-recorder and obtained verbal consent to record the child's responses. The free recall question was then asked, "First, please tell me everything you remember about the story you saw told on the computer" followed by the 15 specific questions. Praise and non-directional, positive encouragement only was given throughout the interview procedure (e.g., "You are doing really well!"). Upon completion of the interview, the audio-recorder was switched off and the child completed the PPVT-4. Children were offered stickers throughout as thanks for completing each task.

2.5. Coding

All speech during delivery of the interview procedure was transcribed and responses to questions were coded. The free recall question was coded such that a score of 1 was given for accurate recall of a phrase from the story. There was no negative scoring for incorrect recall. Higher scores indicated greater comprehension of the narrative. The maximum score possible was 35.

Table 1
Mean and Standard Deviation Scores for Overall Recall, Gesture Questions and Non-Gesture Questions Across Conditions.

Measure	Gesture Condition							
	Control		Iconic		Deictic		Beat	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall Recall	2.44	2.31	4.92	2.71	5.76	2.74	3.96	3.17
Gesture Questions	0.57	0.21	0.73	0.13	0.70	0.15	0.56	0.18
Non-Gesture Questions	0.53	0.23	0.60	0.19	0.58	0.17	0.47	0.20

Each of the 15 specific questions had a weighting out of 2. If the child gave a correct response to an open-ended question, they were given a score of 2 and the forced choice option was not asked. If the forced choice option was presented and answered correctly, the participant received a score of 1. A non-response or incorrect response to the forced choice option resulted in a score of 0 for that question. The scores were summed into three groups: non-gesture item question score, redundant gesture item question score, and non-redundant gesture item question score. Each participant received a score out of 10 for each question group, with higher scores indicating greater narrative comprehension.

2.6. Reliability

Inter-rater reliability was assessed by having an independent rater who was blind to the purpose of the study code 20% of the transcripts. Reliability was evaluated by obtaining single-rater intraclass correlations (*ICC*s) assessed through an absolute agreement model. Intraclass correlations were highly significant for all dependent variables; overall free recall ($ICC = 0.998$, $p < 0.0005$), non gesture item questions ($ICC = 0.996$, $p < 0.0005$), redundant gesture item questions ($ICC = 0.995$, $p < 0.0005$), non-redundant gesture item questions ($ICC = 1.00$).

3. Results

Hypotheses examining the effects of gesture on narrative comprehension were assessed through: (1) performance on the free recall task; and (2) performance on the specific questions. Performance on the specific questions was in turn split into: (1) non-gesture items; and (2) gesture items. Performance on the gesture items was then split into (1) redundant gesture items; and (2) non-redundant gesture items.

3.1. The effect of condition on free recall

The effect of gesture condition on free recall was examined using a one-way between groups ANOVA. There was a highly significant main effect of gesture condition on free recall, $F(3, 97) = 6.69$, $p < 0.0005$, *partial* $\eta^2 = 0.17$. Post hoc pairwise comparisons using the Tukey HSD test revealed that observing iconic ($F(1, 97) = 10.14$, $p = 0.010$, *partial* $\eta^2 = 0.09$) or deictic ($F(1, 97) = 18.17$, $p < 0.0005$, *partial* $\eta^2 = 0.16$) gesture, significantly increased free recall compared with not observing gesture (control condition) (see Table 1). No other pairwise comparisons were significant (all $p > 0.10$).

An equivalent pattern of results is seen when analysing recall of information that was available only through gestures, but that was not present in the verbal speech content of the narrative. Due to problematic positive skew in responses, with nearly 60% of participants receiving a score of 0, responses were recoded as either did not recall any information available only through gesture, or did recall one or more pieces of information available only through gesture. A binary logistic regression was carried out, with did not report any information vs. did report information as the dependent variable. The overall model was significant, $\chi^2(3) = 14.33$, $p = 0.002$. Follow up pairwise comparisons indicated that the odds of reporting such information was significantly higher for the deictic (B = 2.23, Wald = 10.59, $p = 0.001$, odds ratio = 9.33) and iconic (B = 1.74, Wald = 6.60, $p = 0.01$, odds ratio = 5.69) gesture conditions than for the control condition; the beat condition did not differ from the control condition (B = 1.02, Wald = 2.24, $p = 0.14$, odds ratio = 2.78).

3.2. The effect of condition on gesture item questions

The effect of gesture condition on performance for gesture item questions (non-redundant gesture questions and redundant gesture questions combined) was examined using a one-way between groups ANOVA. A highly significant main effect of gesture condition on gesture item questions was found, $F(3, 97) = 6.45$, $p < 0.0005$, *partial* $\eta^2 = 0.17$. Mirroring the free recall results, post hoc comparisons using the Tukey HSD test revealed that observing iconic ($F(1, 97) = 10.37$, $p = 0.009$, *partial* $\eta^2 = 0.10$) and deictic ($F(1, 97) = 6.98$, $p = 0.047$, *partial* $\eta^2 = 0.07$) gesture significantly increased performance on gesture item questions compared to observing no gesture (control) (see Table 1). Unlike for free recall however, the test also indicated that observing iconic ($F(1, 97) = 12.34$, $p = 0.004$, *partial* $\eta^2 = 0.11$) and deictic ($F(1, 97) = 8.58$, $p = 0.022$, *partial* $\eta^2 = 0.08$) gesture, significantly increased performance on gesture item questions compared with observing beat gesture. However, there were

Table 2
Mean and Standard Deviation Scores for Redundant and Non-redundant Gesture Questions Across Conditions.

Gesture Question	Gesture Condition							
	Control		Iconic		Deictic		Beat	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Redundant	0.69	0.27	0.81	0.15	0.77	0.17	0.67	0.24
Non-redundant	0.46	0.17	0.65	0.17	0.63	0.23	0.46	0.17

no statistically significant differences between the beat gesture condition and the no gesture control condition ($p = 0.994$), or between the iconic and deictic gesture conditions ($p = 0.938$).

3.3. The effect of condition on non-gesture item questions

A one-way between groups ANOVA testing the effect of gesture condition on non-gesture item questions found no significant difference between conditions in participants' performance, $F(3, 97) = 2.19$, $p = 0.093$, *partial* $\eta^2 = 0.06$ (see Table 1).

3.4. The effect of condition on non-redundant gesture item questions

The effect of gesture condition on non-redundant gesture item question scores was examined using a one-way between groups ANOVA. There was a highly significant main effect for gesture condition on non-redundant gesture item question scores $F(3, 97) = 8.13$, $p < 0.0005$, *partial* $\eta^2 = 0.20$. Post hoc comparisons using the Tukey HSD test revealed a significant difference between the iconic ($F(1, 97) = 13.22$, $p = 0.002$, *partial* $\eta^2 = 0.12$) and deictic ($F(1, 97) = 11.11$, $p = 0.007$, *partial* $\eta^2 = 0.10$) gesture conditions compared with the no gesture control condition, such that children who observed iconic and deictic gesture outperformed participants in the control condition on non-redundant gesture item questions (see Table 2). Similarly, a significant difference between the iconic ($F(1, 97) = 13.20$, $p = 0.002$, *partial* $\eta^2 = 0.12$) and the deictic ($F(1, 97) = 11.07$, $p = 0.007$, *partial* $\eta^2 = 0.10$) gesture conditions compared with the beat gesture condition was found, such that children who observed iconic and deictic gesture outperformed participants in the beat gesture condition on unique gesture item questions. There were no statistically significant differences between the beat condition and the no gesture control condition ($p = 1.000$) or between the iconic and deictic gesture conditions ($p = 0.990$).

3.5. The effect of condition on redundant gesture item questions

A one-way between groups ANOVA testing the effect of gesture condition on redundant gesture item questions found no significant difference between conditions, $F(3, 97) = 2.59$, $p = 0.06$, *partial* $\eta^2 = 0.07$ (see Table 2).

4. Discussion

This study was designed to investigate the role of gesture in preschoolers' narrative comprehension. Observing iconic and deictic gesture was found to enhance narrative comprehension above the no-gesture control and beat conditions, while beat gesture provided no greater benefit beyond hearing the story without gesture. This effect held for both free recall as well as follow-up questions. Furthermore, children who viewed iconic and deictic gesture reported more non-redundant information than those who did not. Taken together, these results suggest that gesture does have an effect on preschoolers' ability to recall story content. However, iconic and deictic gestures provided a greater beneficial effect on recall than did beat gestures. The results are discussed with implications for future research and practical application.

4.1. The role of gesture in narrative comprehension

The primary objective of the present study was to assess whether gesture facilitates narrative comprehension and if so, which form of gestural support is most facilitative. Children who observed gesture recalled more correct story content during free recall and performed better on the gesture questions (but not the non-gesture questions) in the subsequent question task than children who did not observe gesture. This increase in recall was only true for the iconic and deictic gesture conditions however. Those in the beat gesture condition did not recall more correct information about the narrative in the free recall or the follow up question task than those in the control condition. These results are consistent with those of Church et al. (2004) and Valenzeno et al. (2003), who likewise found that the use of iconic and deictic gesture increased children's understanding in lessons on conservation and symmetry respectively, as compared with observing a lesson with no gesture.

The results have bearing on our understanding of the role of gestures in attention. As noted above, it has been proposed that beat gestures draw attention to key words (see e.g., McNeill, 1992). Beat gestures did not serve to increase children's recall for the corresponding key words or phrases however. Although this null result is not definitive evidence that beat

gestures do *not* draw attention to key words, it does suggest that if they are performing such a function, this function is at the very least lesser in importance to that served by iconic and deictic gestures. It must be noted that other reasons behind the lack of a difference in performance between the beat gesture and control conditions are possible.

A possible explanation for the present study's finding that beat gesture was not effective in facilitating comprehension to the extent that deictic and iconic gestures were is that children found the beat gestures distracting. Children may have granted attentive resources to observing the beat gesture, but in doing so missed crucial narrative content. If children attended to the iconic or deictic gesture in the same manner, they would still have the opportunity to process the information via the gestural modality, and thus their comprehension would not be hindered. It should be noted however that performance in the beat gesture condition was never worse than in the control condition, so it is unlikely that these gestures were overly distracting to the children.

Alternately, it is possible that the beat gestures were simply ignored by the children, thereby having no impact on recall. Preschool aged children may not be sensitive to the meta-cognitive functions of beat gesture (e.g., to emphasize speech) and thus do not make use of such gesture to perceive prominence of spoken words (McNeill, 1992). In fact, McNeill has proposed that gestures reflecting meta-cognitive aspects do not develop until children are seven years of age. If the children in the present study were not sensitive to the metacognitive aspects of beat gesture then the children's attention would not have been drawn to the important words of the narrative – the role the beat gesture was designed to serve.

Lastly, it is possible that beat gestures may be more effective when presented alongside ambiguous speech content. Holle et al. (2012) used beat gestures to disambiguate ambiguous spoken German sentences with adult participants. Results indicated that when a beat gesture was used to emphasise the subject of a sentence, the complex and previously difficult to understand sentence was easier to process. Although such ambiguous sentences are likely to be too complex for preschool-aged children to comprehend, future research should attempt to directly compare iconic, deictic and beat gestures with age-appropriate ambiguous sentences.

The finding that children in the iconic and deictic gesture conditions performed better on the gesture item questions in the follow up task than children in the beat condition is consistent with the suggestion made by Woodall and Folger (1985) that the semantic meaning carried in these types of gestures make these gestures more useful for facilitating speech, as they provide a more elaborate memory trace than beat gesture void of semantic information. However, it is important to note that in Woodall & Folger's (1985) study, speech phrases were accompanied by gesture at encoding and cued by gesture at retrieval. In the present study, the children did not receive any gestural cues at retrieval.

Further, narrative comprehension is a complex task involving processes such as memory encoding, retrieval and integration (Mar, 2004). Memory and integration have been found to improve with information considered to be of high importance for an individual, as this information is processed on a deeper level than information deemed to be unimportant, which may in turn be filtered out as unnecessary noise (Badzinski, 1991). The cues associated with important information can trigger additional processing by activating concepts related to the narrative content in memory (Bower, 1981). This process may result in a richer mental representation of the narrative content than if the related concepts had not been activated. Due to its emphatic rather than representational nature, beat gesture did not convey information that was important for children's understanding of the narrative, thus it is likely that children did not assign importance to or attend to the beat gesture to the same extent as they did for the iconic and beat gesture. In sum, the finding of the present study suggests that iconic and deictic gesture carrying semantic meaning is of greater value than beat gesture when recalling information for a question task, but not when freely recalling a story.

There was no significant difference found on any of the recall measures between the iconic and deictic gesture conditions. Although no prior study to our knowledge has isolated and compared the effects of these two forms of gesture, this lack of a difference suggests that the two forms of gesture are equally efficacious in conveying narrative information. In the present study, iconic gesture resembled the action or shape of the referent, and deictic gesture indicated the position of the referent in the visual display. Due to the design of the study, the majority of the gesture items referred to simple concrete nouns, which could be easily conveyed by the two forms of gesture. As deictic gesture is particularly adept at communicating information regarding spatial topics (Driskell & Radtke, 2003) and iconic gesture regarding motor events (Hostetter, 2011), the communicate effectiveness of these two forms of gesture may be better compared across motor and spatial topics of speech.

Lastly, children who observed iconic or deictic gesture recalled more non-redundant gestural information than children in the beat and control conditions, as measured by greater performance on the non-redundant gesture questions. This finding implies that the non-redundant gestural information was detected and integrated with the accompanying speech by children in the iconic and deictic conditions to build a unified representation of the narrative. Children in the beat and control conditions were given no non-redundant information through gesture and so would not be expected to recall such information unless they perceived it in the visual display. The fact that children in the iconic and deictic conditions reported more non-redundant information than children in the beat and control conditions implies that the gestures themselves provided information beyond that provided by the visual display. This finding may be seen to concur with a previous study by Thompson and Massaro (1994), whereby children detected information contained uniquely in a speaker's gesture when encoding lists of words. This current finding demonstrates that children of preschool age are skilled in processing gestural information non-redundant to that contained in speakers' verbal messages when listening to narratives, even when gesture processing was not explicitly requested. It further suggests that children are likely to integrate this additional

information with the accompanying speech, thereby generating a more comprehensive view of the narrative and enhancing understanding.

More broadly, consistent with research that children make use of implicit information in narratives (Badzinski, 1991), this result of the present study suggests that the way children process narratives involves a multitude of mediums, not only the verbal one. For example, children in the control and beat conditions, who did not receive the additional information through gesture or speech, were able to recall some of the non-redundant information, indicating that they made use of the visual display to some extent to supplement their understanding of the narrative. Moreover, children in the iconic and deictic conditions recalled more non-redundant information than children in the beat and control conditions, indicating that they made use of the gestures alone or in conjunction with the visual display to supplement their understanding of the verbal narrative. Further research should assess the differential and/or additive effect of different forms of non-verbal learning supports on narrative comprehension. For example, one video stimulus may include a narrator telling a story whilst showing the children non-redundant pictures; another may include the narrator telling a story whilst gesturing non-redundant iconic or deictic information; and a third may include a combination of the two mediums in addition to the verbal narrative. Furthermore, future research could manipulate additional information presented through gesture as a between-subjects factor, rather than within subjects, with the aim to compare the effects of gestures on redundant vs. non-redundant points in a narrative with no concern regarding the possibility of unequal question difficulty.

It should be noted that the actual form of the gestures differed between the redundant and non-redundant points, while the verbal narrative remained static. Replication of the current study, in which the verbal narrative was altered between redundant and non-redundant points, thereby allowing the form of the gestures to remain identical between conditions is required. Lastly, it should also be noted that although the narrated text was constant across conditions, it is possible that unwanted differences in prosody occurred between conditions. To be confident that any differences in performance between conditions is due to the gesture manipulation rather than unintended differences in prosody, future research could use a single audio recording, to which the narrator lip-synced while performing the differing gestures.

4.2. Practical implications

The findings presented have important implications for both psychological and educational research, as well as for teachers. Gesture research is a growing field. The present study contributed to this field by providing further confirmation of gesture's facilitative effect on learning, as previously demonstrated in a variety of teaching domains (e.g., Church et al., 2004; Valenzeno et al., 2003), and by extending these findings to provide evidence for a beneficial effect of observing specific types of gesture in narrative comprehension. It has previously been demonstrated that teachers use deictic gestures in mathematics lessons to link their speech to its referents (see Alibali & Nathan, 2012 for a review). In addition, teachers may use representational gesture, for example when discussing actions on mathematical objects (Alibali & Nathan, 2012). The current study extends these findings to narrative comprehension, indicating that such deictic and iconic gestures may be beneficial for learners in domains beyond mathematical reasoning.

Although teachers have been reported to spontaneously produce gesture to assist their lessons, it is unclear whether teachers appreciate the importance of their gesture usage and use gesture in the most efficacious ways (Flevares & Perry, 2001). It has been suggested that in order to completely harness the potential of teachers' gesture usage, it may be necessary to provide explicit instruction regarding gesture usage (Hostetter et al., 2006). The present study can offer such instruction. The present study's findings suggest that the strategic use of iconic and deictic gesture when telling narratives can aid preschoolers' narrative comprehension. Specifically, it would be valuable for teachers to communicate important semantic information through the two types of gesture.

5. Conclusions

The present study aimed to determine the most effective form of gesture to employ in teaching children through narrative. Both iconic and deictic gestures were found to facilitate children's narrative comprehension. Further, it was found that children did encode information that is only communicated through gesture and this information aids their comprehension of the story content.

The present study contributes to the growing body of gesture literature by extending research into the effects of gestures on narrative comprehension. The study suggests that iconic and deictic gesture should be used as an additional teaching tool in assisting children to understand narratives. When children listen to a narrative, they are also watching.

Acknowledgements

Warmest thanks to the children, parents, directors and teachers of Pinjarra Preschool, Ku-ring-gai Kindergarten, Jack and Jill Kindergarten, Arden Preschool, Hornsby Central Preschool, Waitara Explore and Develop, Beecroft Buddies, Artarmon Explore and Develop, Shellytots Preschool, Riverside Preschool and East Lindfield Community Preschool, for your involvement in my study.

Thanks also to Wendy Macoun and Chanelle Tarabay for double coding the data and to Yianni Gertos for narration of the task.

Appendix A. Narrative Text with Gesture Items

An Afternoon at the Park

There was once a girl called Daisy. One afternoon Daisy went to the park with her mum, her dad and her little brother Joey (NGI). First, Daisy played on the swings *(*RGI. *Deictic: Point to swing set. Iconic: Mime swinging back and forth with hands. Beat: Unmeaningful hand movements)*, going back and forth, back and forth. Second, she went super fast down the slide *(*RGI. *Deictic: Point to the slide. Iconic: Tilt arm on a diagonal, other hand traces down)*. Woosh! Suddenly, Daisy's mum realized it was really quite sunny so she called Daisy over to her to give her something to protect her from the sun (NRGI. *Deictic: Point to hat. Iconic: Mime putting on a hat with two hand – one at front of head and other at back)*, and then Daisy went off to play again. Later, her mum found a ball in her bag for Daisy and her brother to play with together. Daisy's brother threw the ball *(*RGI. *Deictic: Point to a ball. Iconic: Shape circular ball with hands)* to Daisy and she caught it with two hands. Her mother and father were so happy with their two children for playing with the ball so well (NGI) they clapped their hands! The two children then played on Daisy's favourite piece of equipment. They went up and down, up and down (NRGI. *Deictic: Point to see saw. Iconic: Tilt arm on diagonal and move up and down)*. Daisy could spend hours playing on this – she loves it that much! But after all of these activities at the park the two children were feeling hungry and sleepy (NGI), so Daisy and her family went home (NRGI. *Deictic: Point to car. Iconic: Make steering wheel with hands – move left to right)*. On the way home they were lucky enough to see a colourful animal (NRGI. *Deictic: Point to bird. Iconic: Thumbs joined – make flapping motion with hands)*! Daisy asked her mum if she could have one as a pet and her mum said "maybe for your birthday". This excited Daisy. Back at home; Daisy's mum cooked (RGI. *Deictic: Point to stove in kitchen. Iconic: Arm curled as if holding a pot and other hand makes stirring motion*) some delicious dinner in her brand new kitchen (pause) while the children were busy (NRGI. *Deictic: Point to book. Iconic: Mime reading book, palms open folding inwards and out)*. Then the family sat down to eat a beautiful meal together. Spaghetti, (NGI) yum! After dinner Daisy's dad (NGI) carried her into her bedroom and tucked her into bed (RGI. *Deictic: Point to bed. Iconic: Mime sleeping with head on hands)*, where she fell fast asleep. What a big afternoon!

*RGI = Redundant gesture item
*NRGI = Non-redundant gesture item
*NGI = non-gesture item

Appendix B. Interview Protocol

Now I am going to ask you some questions about the story you saw told on the computer. If you don't know the answers you can just guess, okay?

Free recall question: First, please tell me everything you remember about the story you saw on the computer.

Now I am going to ask you some more questions.

1. What was the name of the girl's brother?
If unable to answer:

a Nicholas
b Joey

2. Why were Daisy's mother and father so happy with Daisy and her brother at the park?
If unable to answer:

a Because they played with the ball together so well
b Because they did not run away

3. Why did Daisy and her family leave the park
If unable to answer:

a Because they wanted to get home before it got dark
b Because the children were feeling hungry and sleepy

4. What did the family have for dinner?
If unable to answer:

a Spaghetti
b Vegetables

5. Who tucked Daisy into bed?
If unable to answer:

a Her Mum
b Her Dad

6. What piece of equipment did Daisy go on at the park that went back and forth?
If unable to answer:

a Swings
b Flying fox

7. What piece of equipment did Daisy go down super fast on?
If unable to answer:

a Fireman's Pole
b Slide

8. What did Daisy's brother throw to Daisy?
If unable to answer:

a Ball
b Stick

9. What did Daisy's mum do when the family arrived home?
If unable to answer:

a Go upstairs
b Cook dinner

10. After Daisy's dad carried her to her room what did he do?
If unable to answer:

a Tuck her into bed
b Play with her and her soft toys

11. What was Daisy's favourite piece of equipment?
If unable to answer:

a Ladder
b See saw

12. What did Daisy's mum do to protect Daisy from the sun at the park?
If unable to answer:
Did she. . .

a Give her a hat
b Get Daisy to play under the shade of the tree

13. How did the family get home?
If unable to answer:

a By walking
b By car

14. What type of animal did the family see on the way home?
If unable to answer:

a A bird
b A dog

15. While Daisy's mum was cooking dinner what were the children busy doing?
If unable to answer:

a Having a bath
b Reading a book

References

Alibali, M. W., & Don, L. S. (2001). Children's gestures are meant to be seen. *Gesture*, *1*, 113–127. http://dx.doi.org/10.1075/gest.1.2.02ali

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences*, *21*, 247–286. http://dx.doi.org/10.1080/10508406.2011.611446

Alibali, M. W., Heath, D. C., & Myers, H. J. (2001). Effects of visibility between speaker and listener on gesture production: Some gestures are meant to be seen. *Journal of Memory and Language*, *44*, 169–188. http://dx.doi.org/10.1006/jmla.2000.2752

Alibali, M. W., Nathan, M. J., & Fujimori, Y. (2011). Gestures in the mathematics classroom: What's the point? In N. L. Stein, & S. W. Raudenbush (Eds.), *Developmental cognitive science goes to school* (pp. 219–234). New York: Routledge, Taylor & Francis.

Badzinski, D. M. (1991). Vocal cues and children's mental representations of narratives: Effects of incongruent cues on story comprehension. *Western Journal of Communication*, *55*, 198–214. http://dx.doi.org/10.1080/10570319109374379

Beattie, G., & Shovelton, H. (1999). Do iconic hand gestures really contribute anything to the semantic information conveyed by speech? An experimental investigation. *Semiotica*, *123*, 1–30. http://dx.doi.org/10.1515/semi.1999.123, 1–2.1

Becker, W. (1977). Teaching reading and language to the disadvantaged—What we have learned from field research. *Harvard Educational Review*, *47*, 518–543.

Borovsky, A., Elman, J. L., & Fernald, A. (2012). Knowing a lot for one's age: Vocabulary skill and not age is associated with anticipatory incremental sentence interpretation in children and adults. *Journal of Experimental Child Psychology*, *112*, 417–436. http://dx.doi.org/10.1016/j.jecp.2012.01.005

Bower, G. H. (1981). Mood and memory. *American Psychologist*, *36*, 129–148. http://dx.doi.org/10.1037/0003-066X.36.2.129

Broaders, S. C., & Goldin-Meadow, S. (2010). Truth is at hand: How gesture adds information during investigative interviews. *Psychological Science*, *21*, 623–628. http://dx.doi.org/10.1177/0956797610366082

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

Cassell, J., & McNeill, D. (1991). Gesture and the poetics of prose. *Poetics Today*, *12*, 375–404. http://dx.doi.org/10.2307/1772644

Cassell, J., McNeill, D., & McCullough, K.-E. (1999). Speech-gesture mismatches: Evidence for one underlying representation of linguistic and nonlinguistic information. *Pragmatics & Cognition*, *7*, 1–34. http://dx.doi.org/10.1075/pc.7.1.03cas

Church, R. B., Ayman-Nolley, S., & Mahootian, S. (2004). The role of gesture in bilingual education: Does gesture enhance learning? *International Journal of Bilingual Education and Bilingualism*, *7*, 303–319. http://dx.doi.org/10.1080/13670050408667815

de Ruiter, J. (1995). Why do people gesture at the telephone. In M. Biemans, & M. Woutersen (Eds.), *Proceedings of the CLS opening academic year 1995–1996* (pp. 49–56).

Dickinson, D. K., & McCabe, A. (2001). Bringing it all together: The multiple origins, skills, and environmental supports of early literacy. *Learning Disabilities Research and Practice*, *16*, 186–202. http://dx.doi.org/10.1111/0938-8982.00019

Dickinson, D. K., & Tabors, P. O. (2001). *Beginning literacy with language: Young children learning at home and school*. Baltimore, MD: Paul H Brookes Publishing.

Driskell, J. E., & Radtke, P. H. (2003). The effect of gesture on speech production and comprehension. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *45*, 445–454. http://dx.doi.org/10.1518/hfes.45.3.445.27258

Egan, K. (1993). Narrative and learning: A voyage of implications. *Linguistics and Education*, *5*, 119–126. http://dx.doi.org/10.1016/0898-5898(93)90028-9

Flevares, L. M., & Perry, M. (2001). How many do you see? The use of nonspoken representations in first-grade mathematics lessons. *Journal of Educational Psychology*, *93*, 330–345. http://dx.doi.org/10.1037/0022-0663.93.2.330

Frisk, V., & Milner, B. (1990). The role of the left hippocampal region in the acquisition and retention of story content. *Neuropsychologia*, *28*, 349–359. http://dx.doi.org/10.1016/0028- 3932(90)90061-R

Fujimori, Y. (1997). *Gestures in the classroom in Japan and the United States*. Pittsburgh, PA: Carnegie Mellon University [Unpublished Senior Honors Thesis].

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. http://dx.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*, 516–522. http://dx.doi.org/10.1111/1467-9280.00395

Goldin-Meadow, S. (2000). Beyond words: The importance of gesture to researchers and learners. *Child Development*, *71*, 231–239. http://dx.doi.org/10.1111/1467-8624.00138

Hamilton, W. (2007). Constructing classroom learning environments that are interactive and authentic and aim for learner empowerment. In E. W. L. Norman, & D. Spendlove (Eds.), *The design and technology association international research conference 2007* (pp. 27–36).

Holle, H., Obermeier, C., Schmidt-Kassow, M., Friederici, A. D., Ward, J., & Gunter, T. C. (2012). Gesture facilitates the syntactic analysis of speech. *Frontiers in Psychology*, *3*, 1–12. http://dx.doi.org/10.3389/fpsyg.2012.00074

Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulletin & Review*, *15*, 495–514. http://dx.doi.org/10.3758/pbr.15.3.495

Hostetter, A. B., & Alibali, M. W. (2010). Language, gesture, action! A test of the Gesture as Simulated Action framework. *Journal of Memory and Language*, *63*, 245–257. http://dx.doi.org/10.1016/j.jml.2010.04.003

Hostetter, A. B., Bieda, K., Alibali, M. W., Nathan, M. J., & Knuth, E. J. (2006). Don't just tell them, show them! Teachers can intentionally alter their instructional gestures. In R. Sun (Ed.), *Proceedings of the 28th Annual conference of the cognitive science society* (pp. 1523–1528). Mahwah, NJ: Erlbaum.

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

Iverson, J. M., & Goldin-Meadow, S. (1998). Why people gesture when they speak. *Nature*, *396*, 228. http://dx.doi.org/10.1038/24300

Kelly, S. D., & Church, R. B. (1997). Can children detect conceptual information conveyed through other children's nonverbal behaviors. *Cognition and Instruction*, *15*, 107–134. http://dx.doi.org/10.1207/s1532690xci1501_4

Kelly, S. D. (2001). Broadening the units of analysis in communication: Speech and nonverbal behaviours in pragmatic comprehension. *Journal of Child Language*, *28*, 325–349. http://dx.doi.org/10.1017/S0305000901004664

Kendon, A. (1994). Do gestures communicate? A review. *Research on Language and Social Interaction*, *27*, 175–200. http://dx.doi.org/10.1207/s15327973rlsi2703_2

Kirk, E., Pine, K. J., & Ryder, N. (2011). I hear what you say but I see what you mean: The role of gestures in children's pragmatic comprehension. *Language and Cognitive Processes*, *26*, 149–170. http://dx.doi.org/10.1080/01690961003752348

Krahmer, E., & Swerts, M. (2007). The effects of visual beats on prosodic prominence: Acoustic analyses, auditory perception and visual perception. *Journal of Memory and Language*, *57*, 396–414. http://dx.doi.org/10.1016/j.jml.2007.06.005

Krauss, R. M. (1998). Why do we gesture when we speak? *Current Directions in Psychological Science*, *7*, 54–60. http://dx.doi.org/10.1111/1467-8721.ep13175642

Lyle, S. (2000). Narrative understanding: Developing a theoretical context for understanding how children make meaning in classroom settings. *Journal of Curriculum Studies*, *32*, 45–63. http://dx.doi.org/10.1080/002202700182844

Mar, R. A. (2004). The neuropsychology of narrative: Story comprehension, story production and their interrelation. *Neuropsychologia*, *42*, 1414–1434. http://dx.doi.org/10.1016/j.neuropsychologia.2003.12.016

McNeil, N. M., Alibali, M. W., & Evans, J. L. (2000). The role of gesture in children's comprehension of spoken language: Now they need it, now they don't. *Journal of Nonverbal Behavior*, *24*, 131–150. http://dx.doi.org/10.1023/A:1006657929803

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. Chicago, IL: University of Chicago Press.

Nicoladis, E. (2007). The effect of bilingualism on the use of manual gestures. *Applied Psycholinguistics*, *28*, 441–454. http://dx.doi.org/10.1017/S0142716407070245
Ouellette, G. (2010). Orthographic learning in learning to spell: The roles of semantics and type of practice. *Journal of Experimental Child Psychology*, *107*, 50–58. http://dx.doi.org/10.1016/j.jecp.2010.04.009
Özyürek, A. (2002). Do speakers design their cospeech gestures for their addressees? The effects of addressee location on representational gestures. *Journal of Memory and Language*, *46*, 688–704. http://dx.doi.org/10.1006/jmla.2001.2826
Paris, A. H., & Paris, S. G. (2003). Assessing narrative comprehension in young children. *Reading Research Quarterly*, *38*, 36–76. http://dx.doi.org/10.1598/RRQ.38.1.3
Pine, K. J., Bird, H., & Kirk, E. (2007). The effects of prohibiting gestures on children's lexical retrieval ability. *Developmental Science*, *10*, 747–754. http://dx.doi.org/10.1111/j.1467-7687.2007.00610.x
Ping, R. M., & Goldin-Meadow, S. (2008). Hands in the air: Using ungrounded iconic gestures to teach children conservation of quantity. *Developmental Psychology*, *44*, 1277–1287. http://dx.doi.org/10.1037/0012-1649.44.5.1277
Ping, R., & Goldin-Meadow, S. (2010). Gesturing saves cognitive resources when talking about nonpresent objects. *Cognitive Science*, *34*, 602–619. http://dx.doi.org/10.1111/j.1551-6709.2010.01102.x
Rauscher, F. H., Krauss, R. M., & Chen, Y. (1996). Gesture, speech, and lexical access: The role of lexical movements in speech production. *Psychological Science*, *7*, 226–231. http://dx.doi.org/10.1111/j.1467-9280.1996.tb00364.x
Ravizza, S. (2003). Movement and lexical access: Do noniconic gestures aid in retrieval? *Psychonomic Bulletin & Review*, *10*, 610–615. http://dx.doi.org/10.3758/BF03196522
Singer, M. A., & Goldin-Meadow, S. (2005). Children learn when their teacher's gestures and speech differ. *Psychological Science*, *16*, 85–89. http://dx.doi.org/10.1111/j.0956-7976.2005.00786.x
So, W. C., Sim Chen-Hui, C., & Low Wei-Shan, J. (2012). Mnemonic effect of iconic gesture and beat gesture in adults and children: Is meaning in gesture important for memory recall? *Language and Cognitive Processes*, *27*, 665–681. http://dx.doi.org/10.1080/01690965.2011.573220
Stein, N., & Albro, E. (1996). Building complexite and coherence: Children's use of goal-structured knowledge in telling good stories. In M. Bamberg (Ed.), *Learning how to narrate: New directions in child development* (pp. 5–44). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
Taylor, B. M., Frye, B. J., & Maruyama, G. M. (1990). Time spent reading and reading growth. *American Educational Research Journal*, *27*, 351–362. http://dx.doi.org/10.3102/00028312027002351
Tellier, M. (2008). The effect of gestures on second language memorisation by young children. *Gesture*, *8*, 219–235. http://dx.doi.org/10.1075/gest.8.2.06tel
Thompson, L. A., & Massaro, D. W. (1994). Children's integration of speech and pointing gestures in comprehension. *Journal of Experimental Child Psychology*, *57*, 327–354. http://dx.doi.org/10.1006/jecp.1994.1016
Valenzeno, L., Alibali, M. W., & Klatzky, R. (2003). Teachers' gestures facilitate students' learning: A lesson in symmetry. *Contemporary Educational Psychology*, *28*, 187–204. http://dx.doi.org/10.1016/S0361-476X(02)00007-3
Wang, L., & Chu, M. (2013). The role of beat gesture and pitch accent in semantic processing: An ERP study. *Neuropsychologia*, *51*, 2847–2855. http://dx.doi.org/10.1016/j.neuropsychologia.2013.09.027
Woodall, W. G., & Folger, J. P. (1985). Nonverbal cue context and episodic memory: On the availability and endurance of nonverbal behaviors as retrieval cues. *Communications Monographs*, *52*, 319–333. http://dx.doi.org/10.1080/03637758509376115