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The effects of observing different gestures during storytelling on the recall of path and event information in 5-year-olds and adults

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ABSTRACT

This study examined (a) how observing different types of gestures while listening to a story affected the recall of path and event information in 5-year-old children ($n = 71$) and adults ($n = 55$) and (b) whether the effects of gesture type on children's recall of information were related to individual differences such as working memory, language abilities, spontaneous gesture use, and gesture production during the recall task. Participants were asked four questions to measure their spontaneous gesture frequency. They then listened to a story that included different path and event information. Depending on the assigned condition, participants listened to the story with the narrator producing iconic gestures (gestures having semantic meaning), beat gestures (rhythmic hand movements), or no gesture. We then asked participants to relate what happened in the story and administered a recognition task about the story. Children were given standardized tests to assess their language and working memory skills. Children and adults best recalled the story after observing iconic gestures as compared with children and adults presented with beat gestures or no gestures. Children who were exposed to iconic gestures during encoding better recalled event information than children in the other conditions. Children's language abilities, but not working memory, were related to their recall performance. More important, children with better expressive language abilities benefitted more from seeing iconic gestures. These results suggest that observing iconic

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gestures at encoding facilitates recall and that children's language skills could play a role in encoding and using specific information provided by gestures.

Introduction

Speakers in all languages gesture when they speak (Goldin-Meadow & Alibali, 2013). Gesture and speech form an integrated system during the processes of speech production (e.g., de Ruiter, 2006; Kita, 2000; Kita & Özyürek, 2003) and comprehension (e.g., Özyürek, Willems, Kita, & Hagoort, 2007), but they express information differently. Speech represents highly structured and symbolic information, whereas gesture displays visual and motor information (McNeill, 1992). Therefore, gestures can enhance the comprehension of a spoken message (Goldin-Meadow & Alibali, 2013; Krauss, Dushay, Chen, & Rauscher, 1995; Macoun & Sweller, 2016) and improve recall of target information (Austin & Sweller, 2014; Church, Garber, & Rogalski, 2007; So, Chen-Hui, & Wei-Shan, 2012; Thompson, Driscoll, & Markson, 1998; Woodall & Folger, 1985) in both adults and children. Although observing gestures during encoding is related to listeners' comprehension, memory, and learning, there are contradictory findings regarding the effect of different types of gestures on these cognitive processes (e.g., Austin & Sweller, 2014; Feyereisen, 2006; Igualada, Esteve-Gibert, & Prieto, 2017; So et al., 2012).

McNeill (1992) classified gestures into four different dimensions: deictic, beat, iconic, and metaphoric. Deictic gestures involve a speaker pointing to an object or a location in the environment, whereas beat gestures are rhythmic hand movements without any semantic content. Iconic gestures illustrate the aspects of actions or visuospatial features of an action or object. Finally, metaphoric gestures are similar to iconic gestures in their form in that they present abstract ideas rather than concrete objects or actions (see also McNeill, 2005). Some research indicates that observing iconic gestures during encoding benefits both adults' and children's memory (Aussems & Kita, 2019; So et al., 2012), whereas beat gestures help only adults but not children (So et al., 2012). However, other research shows the benefit of presenting beat gestures during encoding for both adults' and children's memory (Austin & Sweller, 2014; Igualada et al., 2017; Kushch, Igualada, & Prieto, 2015; Llanes-Coromina, Vilà-Giménez, Kushch, Borràs-Comes, & Prieto, 2018). Because these gestures differ in content, they may assist listeners in different ways. Iconic gestures can aid encoding by providing a semantic cue (e.g., Aussems & Kita, 2019; Cohen & Otterbein, 1992), but beat gestures might be useful by drawing attention to the target information (Feyereisen, 2006; Kushch et al., 2015). It is also possible that both gesture types can draw attention to the message, but iconic gestures have an additional benefit of providing a semantic cue (Aussems & Kita, 2019).

In this study, we asked three questions about the effects of gestures on memory. First, does observing gestures at encoding affect children's and adults' recall of specific types of information (i.e., path and event information) in a story (e.g., Aussems & Kita, 2019; Austin & Sweller, 2014, 2017)? Second, does the type of gesture (iconic or beat) matter for children's and adults' recall of information (e.g., Austin & Sweller, 2014; So et al., 2012)? Third, are there individual differences in children's benefit from observing gestures during encoding?

Memory and multimodal encoding

Several studies have focused on understanding how exposure to different modalities (i.e., verbal, visual, or motor) affects memory processes (e.g., Clark & Paivio, 1991; Cohen, 1989; Engelkamp & Cohen, 1991). According to the dual coding theory (Clark & Paivio, 1991), memory is an entity that comprises both symbolic (verbal) and nonsymbolic (imageable) representations. Thus, individuals' memory traces of information are enriched when the information is encoded in both verbal and nonverbal modalities (Clark & Paivio, 1991). In line with the arguments of the dual coding theory, Moreno and Mayer (2002) showed that college students learned better when they were provided with verbal explanations with pictures rather than verbal descriptions or pictures alone.

In addition to visual imagery, the motor component of a message benefits memory, particularly for action sentences (Cohen, 1989). The enactment of actions accompanying sentences leads to better memory by adding a third representation to visual and verbal modalities and making the trace for the action phrases richer or more distinctive (Engelkamp & Zimmer, 1985). Some studies report a memory advantage from producing actions rather than just observing them (e.g., Hornstein & Mulligan, 2004). However, others have revealed enhancing effects of enactment when participants merely observe the gestures of the speaker (Bucciarelli, 2007; Cutica & Bucciarelli, 2008; Madan & Singhal, 2012). For instance, Cohen (1989) found that the free recall of action phrases was enhanced when participants performed the action with a gesture or when they observed the experimenter enacting the action compared with a condition in which participants only heard the phrases. In another study, both 9- and 10-year-old children and adults remembered sentences that were accompanied by representational (iconic and metaphoric) gestures better than sentences without gestures (Thompson et al., 1998).

In keeping with the enactment effect, the mental model theory (Johnson-Laird, 1983, 2006) proposed that the construction of an iconic, nondiscrete mental representation leads to stronger comprehension and memory of discourse. Supporting this theory, Cutica and Bucciarelli (2008) found that adult participants who observed a combination of different gestures (iconic, metaphorical, beat, and deictic) retained target information better than participants who did not see any gestures. The recollection of information can be achieved through enriched mental models (Bucciarelli, 2007). Listeners who observed a combination of gestures constructed a richer mental model of the discourse, allowing them to better recall the provided information (Cutica & Bucciarelli, 2008). Ianì and Bucciarelli (2017) argued that a mental model includes both declarative (knowing what) and procedural (knowing how) knowledge. Information presented by meaningful gestures is iconic and nondiscrete; thus, the message can quickly be involved in the construction of mental models. Because these gestures activate motoric information, they add procedural knowledge to the declarative knowledge of linguistic information. In their experiment, Iani and Bucciarelli asked what would happen if a listener observes gestures while the listener's motor system is engaged in another task. If observing gestures enhances memory via the motor systems of the listener, the effects of observing gestures should disappear when the listener's motor system is occupied. Supporting this hypothesis, they found that when listeners performed a motor task with their hands and arms, but not with their legs, the benefit of observing gestures disappeared. Therefore, Iani and Bucciarelli concluded that gesture improves memory through specific activation of the listener's motor system.

In addition to gesture's effect on memory, gesture theories support gesture's ability to affect listeners' cognitive processes more generally (de Ruiter, 2006; Goldin-Meadow & Alibali, 2013; Kita & Özyürek, 2003; McNeill, 1992). For example, the gesture as simulated action framework proposes that when we speak, activation occurs in the motor cortex and premotor cortex; if this activation passes a threshold, we produce gestures (Hostetter & Alibali, 2008, 2019). For instance, when a speaker talks about an action, mental representations of that action are activated; if they reach an activation threshold, this prompts the speaker to produce gestures imitating the action. Similar to the processes in producing gestures, observing gestures may activate cognitive processes by providing mental representations of the semantic information or by eliciting overt mimicry.

Previous research suggests that different types of gestures influence the recall of information in different ways. Woodall and Folger (1985) found that speech phrases accompanied by representational gestures (i.e., iconic and deictic gestures) were more likely to be recalled compared with speech phrases accompanied by emphasizing gestures (i.e., beat gestures). Because of their semantic content, representational cues provide more information than beat gestures and are more closely related to target information. Cohen and Otterbein (1992) demonstrated that adults recalled more sentences when they observed any gestures than when they did not see any gestures. In addition, adults who observed meaningful gestures recalled more sentences than adults who did not see any gestures or who saw non-meaningful gestures. Representational gestures provided a stronger memory trace for the sentences than the meaningless gestures. In line with these findings, Feyereisen (1998) investigated whether the beneficial effects of gestures on memory stem from the distinctive impact of observing gestures or from additional meaning in the visual modality, as the dual coding theory introduced. The results of the recall task after seeing sentences in one of the three conditions (iconic gestures that matched the meaning of the content, iconic gestures that did not match the meaning of the content, or no gesture) revealed that only iconic gestures that matched the content enhanced the subsequent performance (see also Feyereisen, 2006). The enhancing effects of gesture depend on the meaning and activation of visual modality rather than solely increasing attention to content.

Even though many findings have demonstrated the beneficial effects of representational gestures in the encoding processes, some studies have also reported encoding benefits from beat gestures (Igualada et al., 2017; Kushch & Prieto, 2016; Kushch et al., 2015). These studies criticized previous research for its unnatural use of beat gestures. For instance, Kushch and Prieto (2016) found that participants who observed beat gestures accompanied by prosodic prominence recollected more target words compared with participants who listened to the target words accompanied by prosodic prominence alone. They suggested that beat gestures can improve memory by functioning as focus markers and emphasizing target information. Moreover, neural evidence measured by event-related potentials showed that observing beat gestures activates language-related areas in the brain (Biau & Soto-Faraco, 2013; Holle et al., 2012). These studies discussed the highlighting effect of beat gestures in directing listeners' attention to a piece of information in speech (Biau & Soto-Faraco, 2013; Holle et al., 2012).

Overall, previous research highlights the beneficial effects of multimodal encoding of information on later recall of target information, although there remains disagreement on how different types of gestures influence adults' memory. Another critical question that needs to be addressed is whether similar mechanisms are observed in children's encoding and comprehension of information.

Effects of gestures on children's comprehension and memory

Gesture comprehension develops early in life. Children follow deictic gestures before their first birthdays and can comprehend iconic gestures at around 2 years of age (Bertenthal, Boyer, & Harding, 2014; Hodges, Özçalışkan, & Williamson, 2018; Namy, Campbell, & Tomasello, 2004; but see Namy, 2008). Studies demonstrated that observing gestures enhances children's comprehension and learning (e.g., Macoun & Sweller, 2016; McNeil, Alibali, & Evans, 2000; Valenzeno, Alibali, & Klatzky, 2003). For instance, preschool children learned more in a lesson about symmetry when instructions included pointing and tracing gestures (Valenzeno et al., 2003). Similarly, 6- and 7-year-olds learned the Piagetian conservation task better when their instructor used iconic gestures instead of showing the task without gestures even when the related object was not present in front of the children (Ping & Goldin-Meadow, 2008). Children in elementary school also benefitted from teachers' meaningful gestures in understanding mathematical concepts and problem-solving tasks (Cook, Duffy, & Fenn, 2013; Singer & Goldin-Meadow, 2005). In addition, 20- to 24-month-olds who were trained with a demonstration of iconic gestures better learned the concept of the spatial term "under" compared with children who were trained with pictures or who received the training without any visuals (McGregor, Rohlfing, Bean, & Marschner, 2009).

Related to our study, Wakefield, Hall, James, and Goldin-Meadow (2018) investigated 4- and 5-year-old children's ability to learn action verbs with objects either performing or seeing an *action* (e.g., squeezing an object) or performing or seeing a *gesture* (e.g., making a squeezing gesture in the air near the object). Children needed the same amount of exposure to learning novel verbs with actions or gestures. Nevertheless, children who learned the verbs with gestures were better at generalizing the novel verbs to new objects than children who learned the novel verbs with actions. In addition, when children produced the movements (via either action or gesture) rather than only observing them, they learned more quickly and remembered more verbs. However, no difference was found in the generalization task between children who observed movements (action or gesture) and those who produced them. Tellier (2008) demonstrated that the beneficial effects of observing iconic gestures go beyond learning in children's first language. Preschool-aged children who saw iconic gestures in a word-learning task in their second language showed better memory for the practiced words than children who only observed pictures of the words.

Parallel to findings with adults, there are contradictory results regarding the effect of gesture type on children's recall of information. For instance, Macoun and Sweller (2016) found that observing iconic and deictic gestures enhances narrative comprehension in preschool-aged children more than observing beat gestures or listening to a story without gestures. Furthermore, So et al. (2012) found that both adults and 4- and 5-year-old children had better recall of a list of verbs when iconic gestures accompanied the words. Beat gestures enhanced only adults' recall of verbs.

Only a few studies have investigated the effects of gesture on memory of events (Aussems & Kita, 2019; Broaders & Goldin-Meadow, 2010; Kirk, Gurney, Edwards, & Dodimead, 2015). Early findings demonstrated that an interviewer's gestures influence children's recall across different ages (Broaders & Goldin-Meadow, 2010; Kirk et al., 2015). In another study, 3-year-old children who saw action events with iconic gestures at the encoding phase remembered the actions and actors better in a memory recognition task than children who were in the interactive gesture condition (drawing children's attention to the action but irrelevant to the action itself) or in the no gesture condition (Aussems & Kita, 2019). Iconic gestures have the function of encoding the distinctive features of actions to help children encode specific information. These gestures improve retrieval of related information and provide additional cues rather than solely drawing attention to the message (Aussems & Kita, 2019). Thus, iconic gestures may aid in remembering specific aspects of target information.

Both So et al. (2012) and Aussems and Kita (2019) revealed that iconic gestures, but not meaningless gestures, enhance children's recall of verbs, actions, and actors. On the other hand, beat gestures can function as focus markers for adults (Jannedy & Mendoza-Denton, 2005; Loehr, 2012). Recently, similar beneficial effects of beat gestures on children's comprehension and memory were reported (Igualada et al., 2017; Llanes-Coromina et al., 2018). For example, observing beat gestures, which highlight a word to demonstrate that this word is the target, improved the recall performance of 3- to 5-year-old preschoolers. In addition, beat gestures did not cause an overall improvement in the recall of an adjacent word. Instead, a local effect on a highlighted word was detected (Igualada et al., 2017). Thus, beat gestures can highlight words in sentences and thereby help children to encode information if they are produced in natural and pragmatically relevant ways.

Do children encode specific types of information, such as route descriptions, similarly with and without gestures? Memory for route descriptions is unique because it requires the listener to mentally visualize a nonexperienced space (Austin & Sweller, 2014, 2017). Moreover, the listener needs to remember and follow the specific steps to reach the target location (Allen, 2000). In a live presentation, adults and 3- and 4-year-old children were provided with verbal descriptions of a target path on a small-scale spatial array. They encoded the route descriptions in one of the three conditions: combined gesture (verbal descriptions accompanied by deictic, iconic, beat, and metaphoric gestures), beat gesture, or no gesture. Children, but not adults, benefitted from observing gestures in recalling the route directions. Children in the combined gesture group recalled more information compared with the other groups, and children in the beat gesture condition performed better than children in the no gesture condition (Austin & Sweller, 2014). In a follow-up study using a larger scale spatial array, the researchers investigated the effect of observing different types of gestures at encoding (a combination of iconic and deictic gestures, beat gestures, and no gesture) on 3- to 5-year-olds' recall of route directions. Children in the iconic–deictic combination condition recalled more information than those in the beat gesture and no gesture conditions. There was no difference between the beat gesture condition and no gesture condition in free recall. However, in the physical navigation task, children who listened to the route directions with iconic–deictic or beat gestures navigated more accurately compared with those in the no gesture condition (Austin & Sweller, 2017). These findings suggest that observing gestures enhances children's memory for route descriptions that involve spatial information and particularly for recall of different paths. Even though children benefit from beat gestures, representational gestures improve children's recall the most.

Why would observing gestures be helpful for children's encoding of specific information? In addition to the benefits of elaborated encoding in multiple modalities, children may benefit from gestures for several other reasons (Austin & Sweller, 2017; McNeil et al., 2000). Because children are in the process of learning language, comprehending a spoken message may be demanding and gestures may serve to "scaffold" understanding of verbal messages (McNeil et al., 2000). The combination of speech and gesture aids children by providing additional cues and information by illustrating particular concepts (Sauter, Uttal, Alman, Goldin-Meadow, & Levine, 2012). That is, using gesture, children may be able to understand complex or ambiguous spoken messages that would otherwise exceed their level of language competence (Kelly, 2001). Consistent with this idea, research suggests that gestures are mostly useful when they accompany complex messages such as math instruction and communication of spatial information (Austin & Sweller, 2014, 2017; Cook et al., 2013). Although these experiments may help to explain how representational gestures lead to a stronger memory trace, they do not explain how beat gestures are useful for memory. As supported by different findings, beat gestures can also aid memory processes by emphasizing specific information and functioning as focus markers in a narrative (Austin & Sweller, 2014; Llanes-Coromina et al., 2018).

Individual differences in cognitive abilities and gesture production can also be related to encoding information from gestures. Research has mostly focused on gesture production and individual differences (Chu, Meyer, Foulkes, & Kita, 2014; Marstaller & Burianová, 2013; Wagner, Nusbaum, & Goldin-Meadow, 2004), suggesting that individuals' spatial and verbal abilities are related to gesture production (e.g., Hostetter & Alibali, 2007). For instance, in two different studies, Galati and colleagues reported that the effects of gesturing on route learning depend on the spatial abilities of the adult learners; gesture production aided route recall for individuals with lower spatial skills (Galati et al., 2018; Galati, Weisberg, Newcombe, & Avraamides, 2015). Working memory capacity has also been found to be related to gesture production; adults with lower verbal working memory capacities produce more gestures (Gillespie, James, Federmeier, & Watson, 2014). Frequent production of representational gestures is related to poor performance in visual and spatial working memory (Chu et al., 2014).

Even though the broad effects of gesture on memory have been outlined, individual differences in comprehending or integrating gestures with speech has been little addressed. A few studies have focused on individual differences among adults, mostly assessing spatial skills or working memory skills (Wu & Coulson, 2014a, 2014b). Because gesture is part of language processing and forms an integrated system with speech in both production (e.g., de Ruiter, 2006; Kita, 2000; Kita & Özyürek, 2003) and comprehension (e.g., Özyürek et al., 2007), it is plausible that individuals' verbal or language abilities can also affect how the individuals obtain information from gesture.

Another potential difference across individuals is individual gesture use and its relation to perception of gestures. Research shows that 6-year-old children produce fewer gestures than adults and 10-year-old children in a narrative telling task (Colletta, Pellenq, & Guidetti, 2010). Wakefield, James, and James (2013) suggested that this developmental pattern in gesture production may be echoed in the neural processing of gesture perception. They found that during gesture perception, the frontal motor system is activated in adults but not in 5-year-old children, suggesting that gesture perception can be affected by the experience of gesture production (see also Demir-Lira et al., 2018).

To our knowledge, previous research has not investigated whether the effects of gesture observation on memory depend on individual differences in children. Individuals vary in their spatial, verbal, and memory abilities and in how these abilities relate to gesture production and comprehension (Chu et al., 2014, ; Galati et al., 2015, 2018; Gillespie et al., 2014; Hostetter & Alibali, 2007; Wu & Coulson, 2014a, 2014b). Thus, some individuals might not benefit from gestural support of a message. Preschool-aged children particularly diverge in their language and working memory abilities. Children whose verbal skills and working memory abilities are good can easily integrate gestural information with verbal information and remember them better than children who have lower verbal skills and working memory capacities. The examination of multimodal encoding in preschoolers and the assessment of individual differences related to this process can fill a gap in the literature and inform both memory and gesture theories.

The current study

This study investigated the effects of observing different types of gestures (iconic or beat) on adults' and children's recall and recognition of path information (i.e., trajectories of actions) and event sequences in a story. Previous studies indicated that observing gestures aids both comprehension and recall of information for adults and children in different tasks (Aussems & Kita, 2019; Austin & Sweller, 2014, 2017; Cutica & Bucciarelli, 2008; Dargue & Sweller, 2018; Madan & Singhal, 2012). Here, we included adult participants as a comparison group to examine possible similarities and differences in gesture observation and benefit from different types of gesture. We predicted that both children and adults who observed gestures at encoding would remember more information than participants who did not observe any gestures. Regarding differences between adults and children, we expected that adults would recall more information (both path and event information) than children. Moreover, as supported by several studies, regardless of age, we predicted that the presence of iconic gestures at the encoding phase would lead to better memory compared with the presence of beat gestures (Austin & Sweller, 2014; Feyereisen, 2006; So et al., 2012). Considering the findings on the beneficial effects of beat gestures in some studies (Austin & Sweller, 2014; Kushch et al., 2015; Llanes-Coromina et al., 2018), again, regardless of age, we expected that observing beat gestures at encoding would lead to better recall performance than encoding information without seeing any gestures. However, seeing gestures should benefit recall of some types of information more than others. As shown in the previous studies, both children and adults can remember more path information than event information after seeing iconic gestures. Our story included several paths (e.g., across, over) that could be easily recalled with complementary information presented in gesture.

Second, because gesture use varies across individuals (Galati et al., 2018; Suppes, Tzeng, & Galguera, 2015), this variation may result in differences in how individuals are affected by observing gestures while listening to a story. To our knowledge, previous research has not compared the link between people's gesture use and their recall of information after seeing gestures (but see Wakefield et al., 2018, for children's novel verb learning). We explored whether differences in participants' gesture frequency (while talking about daily events or describing a route) were related to their performance in remembering a story. People who produce more gestures can be more aware of nonverbal cues and accumulate experience in both producing and perceiving gestures (Wakefield et al., 2013). As a result, they may detect gestures in conversations better. We asked whether individuals who produce more gestures in a spontaneous conversation better comprehend speech accompanied by gestures and, consequently, recall more information. We did not expect that gesture production would be more beneficial than gesture observation for memory but did expect that individuals who produce gestures would be more sensitive to gestural information provided by a speaker.

Another potential individual difference is variation in gesture use while recalling information. Previous research indicated that children who were instructed to use gestures during the recall phase reported information more correctly than children who only engaged in spontaneous gestures (Stevanoni & Salmon, 2005). Similarly, gesture production during recall can help both adults and children to recollect spatial information (Austin & Sweller, 2014). Based on these findings, regardless of age, we expected that participants who produced gestures at the recall phase would perform better in retrieving both path and event information from the story.

Finally, the current study was also designed to understand whether the effects of gestures on children's memory depend on individual differences in working memory capacity and language ability. Based on their skills, children may differ in how they extract information from their environment. We recruited adults as a comparison group for the information recall after observing different types of gestures. Thus, we only assessed individual differences in children. As in the case of gesture production, some children benefit more than others from seeing gestures. We expected that children with higher language abilities would recall more information regardless of how they listened to the story (i.e., with or without gestures). Alternatively, children with lower language abilities might use semantic cues provided by iconic gestures. Therefore, these children would benefit more from observing iconic gestures than children with higher language abilities. Moreover, studies with adults reported that lower working memory capacity increases gesture production (Chu et al., 2014; Galati et al., 2015). We explored whether working memory capacity was related to children's comprehension of messages presented with gestures. Children with higher working memory capacity were expected to perform better in recalling information regardless of condition. As in the case of language ability, children with lower working memory capacities might benefit more from observing gestures because gestures can provide additional cues to remember the story.

Method

Participants

The final sample included 71 children (36 girls) aged 54–73 months (M = 64.00 months, SD = 4.97). The children were native speakers of Turkish. The gender and age distributions of the children were similar across all three conditions, $\chi^2(2) = 0.21$, $p = .900$ and $F(2, 68) = 0.29$, $p = .803$, respectively. This age group was chosen for the current study for the following reasons. First, at this age, children can understand and express causal relations significantly better than younger children (Göksun, Hirsh-Pasek, & Golinkoff, 2010). Their level of causal understanding was important because our story consisted of causal sentences, and children needed to be able to comprehend the causal events in the narrative. Second, children at this age vary in their ability to comprehend speech alone and to comprehend it with gestures (Macoun & Sweller, 2016; McNeil et al., 2000). Data from 7 children were excluded because there were recording problems during their sessions ($n = 4$) or because children did not meet the criteria for the experiment (2 children were non-native Turkish speakers, and 1 child had atypical development). We recruited participants from various child-care centers and kindergartens in Istanbul, Turkey. As a comparison group, we collected data from 55 native Turkish-speaking adults (46 women; M = 21.50 years, SD = 1.95). The gender distribution of adult participants was similar across conditions, $\chi^2(2) = 0.02$, $p = .946$. The data from 1 adult participant were excluded from the final sample because that adult was not a native speaker of Turkish. Our adult participants were undergraduate students, and they received course credit for their participation.

Tasks

Measuring spontaneous gesture frequency

To test participants' overall gesture production and the rate of gesture use during their speech, we asked four questions. Two questions were related to participants' daily activities: "What do you do on weekends?" and "Can you explain how to play your favorite game?" Then, we asked two questions to observe participants' gesture use while talking about space (route descriptions): "Can you describe how you would go from the kitchen to the bathroom in your home?" and "How would you go from the entrance to your bedroom?"

Encoding path and event information

Participants listened to a story that included both path descriptions and event sequences. The story was about a character who followed different paths to find her friend's house (see Appendix B for the story). The story involved five paths with various details: "walked around the mountains," "passed through trees," "crossed over the bridge," "jumped over the fence to the garden," and "passed by the table." An event sentence followed each piece of path information: "rest on a bank," "picked flowers," "came across a friend on the road," "petted the cats in her friend's garden," or "hugged the friend who invited her." These event sentences did not include any spatial content. We piloted the story to 8 children (not included in the final sample) to ensure that both the story and instructions were appropriate for preschoolers.

All participants listened to the same narration, and the gender of the character was the same as the participant's gender. However, we manipulated the gestures produced during the narration. There were three conditions. In the first condition, participants listened to the narrative with accompanying iconic gestures. While saying "walked around the mountain," the experimenter moved her right hand in front of her chest with an open palm and fingers closed. Her palm faced her chest and made a clockwise half-circle. For "crossed over the bridge" and "jumped over the fence," the experimenter moved her right hand up and down slightly as she moved it forward from her chest. Her palm faced down, parallel to the floor. For "passed through trees," she moved both hands forward in parallel to trace the action on the road. Her palms were open, and the movement extended from her chest until her arms were outstretched. For "passed by the table," she moved her right hand to the left slightly to indicate an imaginary table while making a half circle with an open palm facing her chest.

For each event, we used the same number of gestures. While saying "rested on a bank," the experimenter represented "the bank" by using her right hand with an open palm facing up, and her left hand moved up and down parallel to her right hand, representing the sitting action in front of her chest. For "picked flowers," the experimenter moved her right hand as if plucking something with a closed palm. For the event "came across a friend on the road," she moved both hands toward each other. Her palms were open and parallel to each other with fingers straight. For the event "petted the cats in her friend's garden," she moved her hands as if there were a cat in her hands. Her right hand was facing up with no motion, and her left hand moved slightly above the right hand. Finally, when she said "hugged the friend who invited her," she performed an imaginary hug by using both arms, bonding her arms in front of her chest. Thus, in total, participants heard 10 sentences, each accompanied by one gesture.

In the second condition, the experimenter narrated the story with beat gestures. A random movement of the hand without any representational meaning appeared with the same path information and event sentences previously presented. For the one-hand gestures, the experimenter slightly moved her hand (with her palm open and facing her chest) up and down. For the two-hand gestures, the experimenter used the same movement with two hands (both palms open, facing her chest and moving together). The number of gestures was equal for both the iconic and beat gesture conditions, and the experimenter performed the gestures for the same parts of the sentences with the same hand (Fig. 1). In the third condition, participants heard the story without any gestures.

After encoding, participants were immediately asked to recall what happened in the story. Next, as a recognition task, we asked 10 binary-choice questions (5 for path information and 5 for event information) about the story (see Appendix C for the questions).

Testing individual differences in children

Children were given standardized tests to assess individual differences in language and working memory skills. We used the Turkish adaptation of the Test of Early Language Development (TELD-3; Güven & Topbaş, 2014) to measure children's language abilities. This test assesses both receptive and expressive language development of children aged 2–7 years, and the reliability scores for the subtests were .93 and .92, respectively (Güven & Topbaş, 2014). In this test, there is an evaluation form for the experimenter and a picture book for the child. The receptive language subtest contains 37 items. Of these, 24 items assess children's word knowledge and 13 measure grammatical knowledge. For example, in the receptive language test, children were asked to point to the picture that depicts the meaning of the word or phrase (e.g., "show me the girl who stands next to the chair"). The maximum score was 37 for the receptive language subtest. There were 39 items on the expressive language subtest. In this subtest, for example, the experimenter pointed to a picture of a woman who went shopping and asked the child to explain what is happening in the picture. The child obtained 1 point if she or he mentioned both the woman and the event. The maximum score was 39 for the expressive language subtest. The test ended when the child had three consecutive errors.

To test working memory abilities, we used forward and backward digit span tasks. These tasks are subtests of the Wechsler Intelligence Scale for Children–Revised (WISC-R). Turkish standardization,

Fig. 1. Example of the phrase "dağın etrafından dolanmak"/"walking around the mountain" accompanied by iconic gesture and beat gesture. The arrows present the direction of the motion.

validity, and reliability of these tests have been established (Savaşır & Şahin, 1995). In the forward digit span task, children heard sequences of numbers from three to nine digits and were asked to repeat the series in the correct order. Children were given two trials—two different sequences of numbers—for each digit series. The maximum score was 14 for the forward digit span task. In the backward digit span task, children were asked to repeat the sequences in the reverse order. In this test, children were given digit series from two to six, and the maximum score was 10. The test ended when the child did not recall the correct order in both trials.

Procedure

Children were tested individually in a quiet room of their kindergarten. The female experimenter and the participant sat face to face during the session. The order of tasks was the same for all participants. First, the experimenter asked the daily activity questions and route descriptions. Because we were interested in participants' spontaneous gesture use, no instruction was given about gesturing. Next, the experimenter said, "I am going to tell you a story. Please listen to me carefully because I am going to ask you questions about it." Then, participants listened to the story based on their assigned condition in a live presentation (see Appendix B). Participants were randomly assigned to one of the three conditions: the iconic gesture condition, the beat gesture condition, or the no gesture condition. As described above, in the iconic gesture condition, the experimenter performed an iconic gesture that depicted the described path or action. In the beat gesture condition, the experimenter produced beat gestures that accompanied speech with rhythmic hand movements. In the no gesture condition, the child heard the narrative without any gestures. When a participant seemed to be distracted during the encoding phase, the experimenter asked, "Are you listening?" After the encoding phase, participants were asked, "Can you tell me everything you remember from the story?" Children who failed to respond were encouraged to say anything that they remembered from the story. Participants were asked to tell the story out loud. After participants stopped responding, they were once again asked, "Do you remember anything else?" There was no restriction on recall time. Following free recall, children were asked 10 binary-choice questions about the story (see Appendix C). In the next step, children were given the forward and backward digit span tasks. There were practice trials for these tasks. The task was terminated when a participant failed to recall the correct order two consecutive times. Finally, the Turkish adaptation of the TELD-3 receptive and expressive language development subtests were administered. No feedback was provided about participants' accuracy in any of these tasks. Each session was videotaped for later transcription and coding. All participants completed the tasks in one session. The entire procedure took approximately 20 to 30 min per participant, depending on the length of the participant's responses.

The adult participants were also tested individually in a quiet room in the research laboratory at the university. Adult participants were asked the same four questions to measure their spontaneous gesture use. Then, they listened to the same story based on their assigned condition. After the encoding phase, participants were asked to recall what happened in the story. Finally, they were asked the same 10 binary-choice questions. Each session was videotaped for later transcription and coding. The sessions took approximately 10–15 min per participant.

Coding

Scoring for speech

With respect to path information, participants were expected to recall five locations (the mountain, the path with trees, the bridge, the fence/garden, and the table) and five directions (walking around the mountains, passing through the trees, crossing over the bridge, jumping over the fence, and passing by the table). With respect to event information, participants were expected to recall five objects/subjects (the bank, the flowers, the friend, the cats, and two friends) and five events (resting on the bank, picking the flowers, coming across a friend, petting the cats, and hugging the friend who invited her). Each piece of information (i.e., locations and directions, objects/subjects, and events) was scored out of 2 points. The maximum possible score was 40. If a participant correctly recalled the target information, a score of 2 was given. However, for partial recall of the target information, we gave a score of

1. For example, if a participant said “walked on the mountains,” we gave a score of 2 for location but a score of 1 for direction because the correct answer was “walked around the mountains.” A nonresponse or an incorrect response was scored as 0. For the binary-choice questions, each correct answer was counted as 1 point. The maximum possible score was 10.

Gesture coding

We used ELAN software Version 5.1 (https://tla.mpi.nl/tools/tla-tools/elan/) for gesture transcription and coding (Lausberg & Sloetjes, 2009). Participants’ gestures were categorized as iconic, deictic, iconic–deictic, or beat. *Iconic* gestures included hand movements depicting an object or action. *Deictic* gestures involved a whole hand or index finger pointing to refer to an object or a location. If participants simultaneously conveyed an object or action *and* a direction or location in a gesture, we coded it as an *iconic–deictic* gesture (Suppes et al., 2015). We categorized all other formless quick hand movements of participants as *beat* gestures. To calculate gesture frequency, we summed all types of gestures used by each participant.

Reliability

To assess the reliability of free recall scores, 20% of participants’ free recalls were coded by a second person. The intraclass correlation coefficient (ICC) was significant for free recall scores (ICC = .99, $p < .001$). To establish reliability in gesture coding, a second person independently coded 20% of participants’ gestures. Reliability was assessed by obtaining single rater ICCs through a consistency model. The ICCs were significant for both gesture production and gesture type, ICC = .99, $p < .001$ and ICC = .75, $p < .001$, respectively.

Results

Preliminary analyses

We first checked whether there were differences in age, working memory scores, and language abilities of children among three conditions (iconic, beat, and no gesture). Results indicated no

Table 1
Descriptive statistics (age, working memory scores, and language scores) for children in the three conditions.

		n	*M*	*SD*	Min	Max
Age	Iconic	24	64.43	5.089	56	72
	Beat	24	63.45	5.289	54	73
	No gesture	23	64.14	4.814	55	72
	Total	71	64.01	5.008	54	73
Forward digit span	Iconic	24	3.57	1.376	2	6
	Beat	24	3.61	1.469	0	7
	No gesture	23	3.55	1.224	2	6
	Total	71	3.57	1.342	0	7
Backward digit span	Iconic	24	0.57	0.945	0	3
	Beat	24	0.70	1.063	0	3
	No gesture	23	0.50	0.913	0	3
	Total	71	0.59	0.966	0	3
Receptive language	Iconic	24	28.48	3.475	23	35
	Beat	24	27.22	3.849	20	32
	No gesture	23	27.64	3.959	21	37
	Total	71	27.78	3.745	20	37
Expressive language	Iconic	23	30.82	2.538	28	37
	Beat	24	31.13	3.647	25	37
	No gesture	23	30.95	3.184	26	38
	Total	70	30.97	3.119	25	38

significant differences among the three conditions for any of these variables ($ps > .05$) (see Table 1 for the descriptive statistics).

To explore whether the sex of the participant affected recall of the story, two three-way analyses of variance (ANOVAs) with age group (adults or children), gesture condition, and participant's sex as between-participant variables were carried out for the overall free recall and recognition scores. Neither of these analyses revealed significant main effects nor interactions involving sex (all $ps > .05$). Thus, in further analyses, we did not include sex as a variable. For all multiple hypotheses testing, we used Bonferroni-adjusted alpha levels in pairwise comparisons.

Effect of gesture condition on recall performance

We first examined the effect of condition (iconic, beat, or no gesture) on recall. We converted participants' raw scores on each type of information (path or event) into percentages by dividing the number of pieces of path or event information recalled into the total number of pieces of information possible to recall.

A 2 (Age Group) × 3 (Gesture Condition) × 2 (Type of Information: path or event) mixed-design ANOVA was conducted with age group and gesture condition as between-participant factors and type of information as a within-participant factor. Results yielded significant main effects of age group and gesture condition, $F(1, 119) = 117.31$, $p < .01$, partial $\eta^2 = .51$ and $F(2, 119) = 3.92$, $p = .022$, partial $\eta^2 = .07$, respectively. Overall, adults recalled significantly more information than children (see Table 2). Moreover, post hoc analyses indicated that participants who observed iconic gestures at the encoding phase recalled more information than participants in either the beat or no gesture conditions (Bonferroni, $ps < .05$). However, there was no significant difference between the beat gesture and no gesture conditions (Bonferroni, $p > .05$) (see Table 2).

Although there was no significant main effect of type of information, $F(1, 119) = 1.19$, $p = .277$, partial $\eta^2 = .01$, a significant interaction between age group and type of information was found, $F(1, 119) = 30.59$, $p < .01$, partial $\eta^2 = .21$. In particular, the mean difference in recall between adults and children was greater for path information ($M_{\text{diff}} = 41.28$) than for event information ($M_{\text{diff}} = 20.63$). Moreover, adults recalled more path information than event information, whereas children recalled more event information than path information (see Table 2). There was no significant interaction between gesture condition and type of information or between age group and gesture condition, $F(2, 119) = 0.95$, $p = .391$, partial $\eta^2 = .02$ and $F(2, 119) = 0.39$, $p = .676$, partial $\eta^2 = .007$, respectively. Finally,

Table 2
Descriptive statistics on children's and adults' recall and recognition performances by condition.

		Children				Adults			
		M	*SD*	Min	Max	*M*	*SD*	Min	Max
Total free recall	Iconic	27.06	12.30	0	45	60.29	14.22	40	92.5
	Beat	21.63	15.38	0	52.5	45.00	22.64	0	95
	No gesture	20.34	12.82	0	45	48.44	18.84	15	72.5
	Total	23.05	13.69	0	52.5	51.30	19.66	0	95
Recall in path information	Iconic	19.13	13.62	0	50	68.53	15.98	45	100
	Beat	20.65	18.48	0	60	51.18	28.31	0	100
	No gesture	17.04	15.40	0	40	54.38	23.30	10	85
	Total	18.97	15.80	0	60	58.10	23.88	0	100
Recall in event information	Iconic	35.43	19.06	5	70	52.06	21.07	30	85
	Beat	22.60	17.70	0	55	38.82	22.81	0	90
	No gesture	23.63	13.90	0	50	45.63	20.15	0	75
	Total	27.27	17.81	0	70	45.50	21.67	0	90
Recognition task	Iconic	7.65	1.50	4	10	9.47	0.62	8	10
	Beat	7.52	1.44	4	10	8.75	1.44	6	10
	No gesture	7.05	1.68	4	10	8.94	1.24	6	10
	Total	7.41	1.54	4	10	9.06	1.16	6	10

no significant three-way interaction among age group, gesture condition, and type of information was found, $F(2, 119) = 2.40$, $p = .095$, partial $\eta^2 = .04$.

Last, a 2 (Age Group) × 3 (Gesture Condition) between-participant ANOVA was conducted to compare the scores of adults and children in the three conditions for the recognition task. There was a main effect of age, $F(1, 119) = 44.09$, $p < .01$, partial $\eta^2 = .28$, with adults performing better than children. There was no significant main effect of gesture condition or interaction between gesture condition and age, $F(2, 119) = 1.83$, $p = .165$, partial $\eta^2 = .03$ and $F(2, 119) = 0.90$, $p = .411$, partial $\eta^2 = .02$, respectively (see Table 2).

Adults' and children's spontaneous gesture frequency

We asked participants four questions (two daily activity questions and two route description questions) to measure their spontaneous gesture use. Here, 2 children did not respond to the daily activity questions, and 8 children did not respond to the route description questions. All but 6 of the remaining children produced at least one gesture while answering these questions. All adults responded to each question and produced at least one gesture for each question (see Table 3).

As participants talked more, the number of gestures produced increased. Thus, to measure gesture frequency, we calculated the number of gestures per spoken word. In the following analyses, we used this score (the number of gestures produced divided by the number of words spoken) as participants' gesture frequency. For preliminary analyses regarding age group differences in producing gestures for each task, see the online supplementary material, Analysis 1.

We investigated whether participants' spontaneous gesture frequency was related to their recall performance. We found that spontaneous gesture frequency (the total score from both questions) correlated with overall free recall score ($r = .37$, $p < .01$). Moreover, there was a significant correlation between gesture frequency in the daily activity questions and recall of event information ($r = .22$, $p < .01$). No significant correlation was found between spontaneous gesture frequency in the route description questions and recall of path information ($r = .005$, $p = .959$).

To examine the interaction between spontaneous gesture frequency and individuals' recall performance based on gesture condition, we created a categorical variable for gesture use. We defined two categories (low and high gesturers), partitioning the scores using the median for each group. A 2 (Spontaneous Gesture Production: low or high) × 2 (Age Group) × 3 (Gesture Condition) × 2 (Type of Information: path or event) mixed-design ANOVA was conducted with spontaneous gesture production, age group, and gesture condition as between-participant factors and type of information as a within-participant factor. Results yielded significant main effects of age group and gesture condition, $F(1, 114) = 108.08p < .001$, partial $\eta^2 = .50$ and $F(2, 114) = 3.56p < .05$, partial $\eta^2 = .06$, respectively. The main effects of spontaneous gesture production and type of information were not significant, $F(1, 114) = 0.007$, $p = .931$, partial $\eta^2 = .01$ and $F(1, 114) = 1.54$, $p = .217$, partial $\eta^2 = .014$, respectively. There was a significant interaction between type of information and age group, $F(1, 114) = 30.09$, $p < .01$, partial $\eta^2 = .22$.

Table 3
Descriptive statistics for children's and adults' gesture frequency during talking about daily activities, describing a route, and free recall phase of the task.

	Children				Adults			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max
Daily activity questions	.03	.05	0	.22	.17	.09	0	.38
Route description questions	.25	.21	0	.41	.23	.13	0	.45
Free recall (total)	.04	.08	0	.40	.19	.13	0	.44
Free recall (iconic)	.04	.05	0	.05	.09	.05	0	.21
Free recall (deictic)	.02	.03	0	.09	.02	.02	0	.10
Free recall (iconic–deictic)	.03	.04	0	.18	0	0	0	0
Free recall (beat)	0	0	0	0	.08	.05	0	.20
Free recall (other & emblems)	.01	.02	0	.12	.01	.01	0	.03

As reported above, adults recalled more path information than event information, whereas children recalled more event information than path information. Furthermore, an interaction between type of information and spontaneous gesture production was found, $F(1, 114) = 4.96$, $p < .05$, partial $\eta^2 = .04$. Participants with higher spontaneous gesture use recalled more path information ($M = 41.74$, $SD = 2.47$) than event information ($M = 35.29$, $SD = 2.45$). No other two-way, three-way, or four-way interactions were found (see supplementary material, Analysis 2, for details of these analyses).

Adults' and children's spontaneous gesture production during story recall

Of 71 children, 46 did not produce any gestures during their free recall of the story. Of 25 children who did produce gestures, 12 produced only one gesture. Therefore, we could not analyze the effects of producing gestures during the recall phase on children's recall performance. However, all but 6 adults produced gestures during recall (see Table 3). Three separate one-way analyses of covariance (ANCOVAs) were carried out to examine the effects of gesture conditions on adults' recall performance (total, path, or event), controlling for their gesture frequency during free recall. The results indicated that the number of gestures produced per word was not significant in any analyses, $F_{total}(1, 50) = 0.230$, $p = .634$, partial $\eta^2 = .005$, $F_{path}(1, 50) = 2.25$, $p = .139$, partial $\eta^2 = .04$, and $F_{event}(1, 50) = 1.41 p = .241$, partial $\eta^2 = .03$. We also checked whether gesture production during recall was related to participants' recall performance regardless of gesture condition. No correlations were found between adults' gesture use and recall performance, $r_{total} = .12$, $p = .387$, $r_{event} = -.12$, $p = .388$, and $r_{path} = .25$, $p = .069$.

Relation among language abilities, working memory, and children's recall of the story

One of the aims of the current study was to understand whether the effects of gestures on children's memory depend on individual differences in working memory and language abilities. We analyzed the relationship between children's recall of the story and their working memory and language abilities for each condition (for the correlations regardless of condition, see Table 4; for the correlations in each gesture condition, see Table 5 and supplementary material, Analysis 3).

With respect to working memory scores, the forward digit span scores did not correlate with children's recall performance in any of the conditions. The backward digit span scores correlated with recall performance in the iconic gesture and beat gesture conditions. These results could be misleading because the variance was very low (see Table 1). For this reason, in our final analyses, we analyzed only whether children's language abilities interacted with the effects of observing different gestures. We needed to convert the receptive and expressive language scores into categorical variables to examine the interaction between language skills and gesture condition. We defined two categories (low and high), partitioning the scores by the median of the receptive and expressive language scores. For the

Table 4
Correlations among children's scores of working memory, language abilities, spontaneous gesture frequency, and recall of information.

	1	2	3	4	5	6	7	8	9	10
1. Forward digit span score	1									
2. Backward digit span score	.243*	1								
3. Receptive language	.560**	.404**	1							
4. Expressive language	.375**	.472**	.507**	1						
5. Gesture frequency, total	.134	.012	.104	.157	1					
6. Gesture frequency, daily questions	−.047	.069	.062	.018	.534**	1				
7. Gesture frequency, route description	.155	.026	.125	.147	.817**	.152	1			
8. Recall in path information	.155	.158	.458**	.402**	.135	−.051	.095	1		
9. Recall in event information	.194	.125	.324**	.295*	.029	−.164	.174	.304*	1	
10. Total recall	.222	.164	.474**	.430**	.089	−.151	.171	.831**	.781**	1

*$p < .05$.
**$p < .01$.

Table 5
Correlations among children's scores of working memory, language abilities, and recall of information for the iconic gesture condition (A), the beat gesture condition (B), and the no gesture condition (C).

	1	2	3	4	5	6
A. Iconic gesture condition						
1. Forward digit span score	1					
2. Backward digit span score	.093	1				
3. Receptive language	.749**	.191	1			
4. Expressive language	.544**	.007	.505*	1		
5. Recall of path information	.282	−.225	.412	.314	1	
6. Recall of event information	.259	−.355	−.003	.261	.023	1
B. Beat gesture condition						
1. Forward digit span score	1					
2. Backward digit span score	.444*	1				
3. Receptive language	.667**	.528**	1			
4. Expressive language	.544**	.562**	.506*	1		
5. Recall of path information	.244	.369	.509*	.417*	1	
6. Recall of event information	.286	.515*	.542**	.350	.446*	1
C. No gesture condition						
1. Forward digit span score	1					
2. Backward digit span score	.128	1				
3. Receptive language	.269	.501*	1			
4. Expressive language	−.006	.745*	.558**	1		
5. Recall of path information	−.113	.195	.470*	.444*	1	
6. Recall of event information	.004	.300	.380	.386	.531	1

expressive language scores, 35 children were in the "low" group and 36 children were in the "high" group. For the receptive language scores, 37 children were in the "low" group and 34 children were in the "high" group.

A 2 (Expressive Language: low or high) × 3 (Gesture Condition) × 2 (Type of Information: path or event) mixed-design ANOVA was conducted with expressive language ability and gesture condition as between-participant factors and type of information as a within-participant factor. Results yielded significant main effects of participants' expressive language abilities and type of information, $F(1, 65) = 6.71$, $p < .05$, partial $\eta^2 = .10$ and $F(1, 65) = 16.80$, $p < .01$, partial $\eta^2 = .22$, respectively. Overall, children with higher language abilities recalled more information compared with children with lower language abilities. Children recalled event information more than path information (see Fig. 2). The main effect of gesture condition was not significant, $F(2, 65) = 2.31$, $p = .107$, partial $\eta^2 = .07$. However, a significant interaction was found between type of information and gesture condition, $F(2, 65) = 3.71$, $p < .05$, partial $\eta^2 = .11$. In the iconic gesture condition, children recalled more event information than path information (see Table 2). No significant interaction was found between type of information and expressive language abilities $F(1, 65) = 0.014$, $p = .906$, partial $\eta^2 = .00$. There was no significant interaction between gesture condition and expressive language ability $F(2, 65) = 0.027$, $p = .973$,

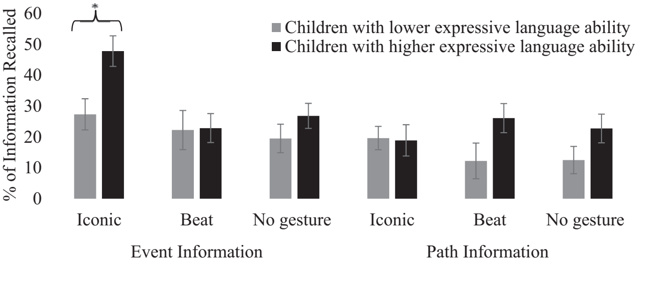

Fig. 2. The percentage of path and event information recalled during the free recall of children grouped by expressive language abilities. *$p < .05$.

partial η^2 = .001. However, a three-way interaction was found among type of information, gesture condition, and expressive language abilities $F(2, 65) = 4.94$, $p < .01$, partial η^2 = .14. Simple-effect analyses revealed that in the iconic gesture condition, children with higher expressive language abilities recalled more event information than children with lower language abilities (M_{diff} = 27.50). No other simple effects were significant (*ps* > .05).

A 2 (Receptive Language: low or high) × 3 (Gesture Condition) × 2 (Type of Information: path or event) mixed-design ANOVA was conducted with receptive language ability and gesture condition as between-participant factors and type of information as a within-participant factor. Results yielded significant main effects of participants' receptive language abilities and type of information, $F(1, 65) = 11.74$, $p < .01$, partial η^2 = .16 and $F(1, 65) = 12.59$, $p < .01$, partial η^2 = .17, respectively. Overall, similar to the pattern in expressive language scores, children with higher receptive language abilities recalled more information than children with lower receptive language abilities. Children recalled event information more than path information. The main effect of the gesture condition was not significant, $F(2, 65) = 1.91$, $p = .156$, partial η^2 = .06. However, a marginally significant interaction was found between type of information and gesture condition $F(2, 65) = 3.01$, $p = .057$, partial η^2 = .09. As reported above, children recalled more event information than path information in the iconic gesture condition. No significant interaction was found between type of information and receptive language abilities, $F(1, 65) = 0.043$, $p = .836$, partial η^2 = .001. There was no significant interaction between gesture condition and receptive language scores, $F(2, 65) = 0.108$, $p = .898$, partial η^2 = .003, nor was there a three-way interaction among type of information, gesture condition, and expressive language abilities, $F(2, 65) = 0.74$, $p = .481$, partial η^2 = .023.

Discussion

The current study examined (a) the effects of observing different types of gestures on recalling path and event information in both children and adults and (b) whether recalling information after being exposed to different gestures was related to children's working memory scores, language abilities, and gesture use. We found that regardless of gesture condition, adults performed better in recalling information than 5-year-olds. As seen in previous studies (Aussems & Kita, 2019; Macoun & Sweller, 2016; So et al., 2012), for both age groups, observing iconic gestures at the encoding phase enhanced recall of information compared with observing beat gestures or listening to the story without any gestures. We did not find any enhancing effects of beat gestures on remembering information as found in some studies (Austin & Sweller, 2014; Igualada et al., 2017; Kushch et al., 2015; Llanes-Coromina et al., 2018).

Our study provides evidence concerning the relation between producing gestures and perceiving gestures. Participants' spontaneous gesture production in answering daily activity questions and route description questions positively correlated with their overall recall performance. However, this could be due to adults' recall of more information from the story. In addition, individuals who used more gestures in answering these questions remembered more path information later in recalling the story. We did not find any relation between producing gestures during the recall phase and individuals' recall performance.

Another contribution of this study is how individual differences in the language and working memory abilities of children were related to encoding and recalling information. We showed that children's language abilities, but not working memory capacities, were related to their recall performance. Children with better language abilities (expressive and receptive) recalled more information than children with lower language abilities regardless of gesture condition. We also found a three-way interaction among gesture condition, children's language abilities, and recall of different types of information. Children who had better expressive language abilities and who observed iconic gestures during encoding recalled more event information than children in other conditions and children who had lower language abilities.

Effect of gesture condition on recall performance

We found that participants who observed iconic gestures at encoding performed better in their recall of information than participants who observed beat gestures or who were not exposed to any gestures. Previous research suggested that the addition of different modalities (verbal, visual, and motor) at encoding leads to a better memory trace for the encoded information (Cutica & Bucciarelli, 2008; Madan & Singhal, 2012; Thompson et al., 1998). In the case of gesture, two different mechanisms might be responsible for these beneficial effects on memory (Austin & Sweller, 2014; Feyereisen, 2006; Kushch et al., 2015). First, gestures complement the verbally presented information and illustrate spoken messages during story narration (Austin & Sweller, 2014; Feyereisen, 2006; So et al., 2012). Observing redundant iconic gestures facilitates preschoolers' comprehension of a narrative (Dargue & Sweller, 2018). Second, gestures might be useful as an attention-getter to highlight target information in speech (Kushch et al., 2015; So et al., 2012). The current study revealed beneficial effects only of observing iconic gestures in recalling information for both adults and children. Iconic gestures in our study did not provide additional information (i.e., these gestures only highlighted the speech content). These gestures express semantic information and complement spoken messages, and they can enhance memory by providing non-propositional spatial information. Iconic gestures also stimulate visual and motor representations of concepts. As a result, observing iconic gestures assists listeners' recall by providing richer mental representations of semantic information.

As suggested by Aussems and Kita (2019), it is also important to highlight that iconic gestures can serve two functions by providing a semantic cue and directing attention to certain parts of the story. In contrast, beat gestures only draw the attention of the listener and thereby highlight information in speech. Thus, it seems unlikely that iconic gestures benefitted memory solely by highlighting target information in the current study. Previous work regarding the role of beat gestures has been contradictory. Some have argued that the meaning of a gesture matters for the facilitative effect of observing gestures (Feyereisen, 2006; So et al., 2012), whereas others have reported that beat gestures enhanced recall of information (Austin & Sweller, 2014; Igualada et al., 2017). These studies discussed that a failure to find enhancing effects of beat gestures often depends on using beat gestures unnaturally (Igualada et al., 2017; Llanes-Coromina et al., 2018). In our study, we tried to use the beat gestures in a naturalistic way by embedding them in sentences to highlight target information. We nevertheless did not find any beneficial effects of beat gestures on participants' recall performance.

We examined whether seeing gestures influences recall of particular types of information. We found a difference between children's recall of path and event information. Children who were exposed to iconic gestures at encoding performed better in recalling event information than children who were exposed to beat gestures or no gestures. This finding is in line with the study by Aussems and Kita (2019), which showed that iconic gestures helped children to encode action events. In their study, children who saw action events accompanied by iconic gestures remembered the actions and actors better than children who saw action events accompanied by interactive gestures or no gesture at all. The facilitative role of iconic gestures in children's recall was not present for path information that represented trajectories of actions. Path descriptions represent the specific aspects of actions as walking "up" or "down," which is related to memories of route descriptions. Children in our study seemed to remember the action itself rather than focusing on specific aspects of the action.

In contrast to our results, Austin and Sweller (2014) found that children's recall of route directions, but not adults', improved due to observation of gestures during encoding. In their study, even though children benefitted from beat gestures, observing iconic gestures improved children's recall the most. They used a spatial array to represent routes, which may have provided children with a cue for recalling the routes. It is also possible that only typical iconic gestures (i.e., gestures that are produced more frequently and naturally by the speakers) could be more valuable for recalling information (Dargue & Sweller, 2018). In our study, we tried to use typical and simple iconic gestures, but there may still be important gesture differences between our study and previous studies.

Adults' and children's spontaneous gesture production and information recall

We also examined whether overall spontaneous gesture use was related to individuals' recall performance. Regardless of question type, adults gestured more than children. Moreover, in both age groups, participants produced more gestures for route descriptions than for daily activity questions. Several theories of gesture production argue that the production of gesture relies on spatial imagery (de Ruiter, 2006; Kita & Özyürek, 2003). When we speak, there is a simultaneous activation in the motor cortex and premotor cortex, and if this activation passes a threshold, we will produce gestures (Hostetter & Alibali, 2008, 2019). Studies also reported that people produce many gestures while expressing spatial information such as giving directions, describing spatial patterns, and describing motion in space (e.g., Alibali, 2005; Allen, 2000; Kita & Özyürek, 2003; Melinger & Kita, 2007). Our findings indicated that both adults and children use gestures more when they speak about space and directions. Previous results have demonstrated developmental differences in gesture production when describing a target route (Austin & Sweller, 2018; Sekine, 2009). For example, Austin and Sweller (2018) found that when describing routes, 3- and 4-year-old children produced more iconic gestures than adults. They argued that the developmental difference between adults and children might stem from children's limitations in cognitive capacity for space and language.

In our study, gesture rate in route description questions did not differ between age groups. Children produced more gestures in responding to route description questions than in responding to daily activity questions. We also examined the relation between spontaneous gesture frequency and participants' recall performance. Participants' spontaneous gesture use in answering daily activity questions and route descriptions positively correlated with their overall recall performance. This may be due to adults' superior performance in remembering information. Further analysis showed that individuals who produced more spontaneous gestures also remembered more path information than individuals who gestured less. Nevertheless, there was no interaction between people's spontaneous gesture production and gesture condition. That is, we did not find evidence for our prediction that individuals who produced more gestures would also benefit more from observing gestures (but see Wakefield et al., 2018). Further investigation is needed to understand the relation between the spontaneous gesture frequency and people's integration of gesture and speech.

Previous studies demonstrated that producing gestures during recall enhances memory (Austin & Sweller, 2014; So, Shum, & Wong, 2015; Stevanoni & Salmon, 2005). Because very few children used gestures during the recall phase, we could not analyze how gesture production during recall relates to children's memory. Austin and Sweller (2014) found that producing gestures during recall helped participants to retrieve spatial information. Other studies asked participants to use gestures during recall. For example, Stevanoni and Salmon (2005) found that children who were encouraged to produce gestures during recall performed better in retrieving the correct information than children who were allowed to engage in spontaneous gestures without any explicit instructions. We did not give any instructions about using gestures. We also did not provide cues, such as a map and a spatial array, to encourage children to produce gestures. Even among adults, we did not find a benefit of spontaneous gesture production on memory during recall, failing to support previous findings. Future studies may encourage adults and children to produce gestures during story retelling and assess the effects of different types of individual differences (overall language abilities, working memory, and gesture use) on recalling specific types of information.

Children's language abilities, working memory, and recall of the story

We investigated whether the effects of gesture on children's recall depend on individual differences in language abilities and working memory capacity. We found that children's receptive and expressive language abilities were associated with their recall performance for both types of information. Children with better language abilities recalled more information than children with lower language abilities in all conditions. When we tested the interaction among gesture conditions, children's language abilities, and the type of information they recalled, children with higher expressive language scores in the iconic gesture condition recalled more event information than children with lower expressive language scores. Children with lower language abilities might have benefitted more from the semantic cues provided by iconic gestures because they could rely on gestural information more. Our findings did not support such an effect. We also did not replicate the same result with children's receptive language abilities. Although we divided children into two groups by a median split into lower and higher receptive language ability groups, many children scored around the mean. Thus, expressive language scores may be a better measure of language abilities in our sample.

Why would children with higher expressive language scores benefit from observing iconic gestures in recalling certain information? Children can use different resources while listening to a story. Those who have better verbal skills can turn their attention to other cues in the environment. In our context, children knew that they would be asked to recall the story. Children who know many words can better integrate gestural information and remember the cues that come from gestures. The combination of speech and gesture can illustrate concepts better (Sauter et al., 2012). Gestures might also be meaningful only when a child already knows the current concept. For example, the dynamic action gesture for "jumping over a fence" might make sense to the child only when the child knows what a fence is. Then, the child could focus on gestural information. Among children with lower language abilities, gestural information—even when it is redundant—may impose extra cognitive load (Post, van Gog, Paas, & Zwaan, 2013). Although we tried to use words a 5-year-old could understand, some children could be better than others at comprehending and producing these words. In addition, we used only complementary gestures in this study. Children with better language abilities may be more vulnerable to mismatching gestures or may be better able to detect additional gestural information from a story. Future studies should examine when and how language abilities allow benefit from observing iconic gestures in a bigger sample size.

Last, working memory has been shown to predict learning math, language comprehension, and academic progress of children across different ages (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Bull & Scerif, 2001; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000). Moreover, adult studies reported that gesture frequency depends on the working memory capacity of individuals (Chu et al., 2014; Gillespie et al., 2014). However, we did not find any relation between working memory and children's recall performance.

Limitations

Our study adds to the body of literature on children's and adults' recall of information while listening to a story with different types of gestures. We tried to control the prosody in different gesture conditions. The experimenter produced beat gestures and iconic gestures at the same moment and for the same duration within the target phrases. Children may be more attentive during live presentations. However, live demonstrations of gestures can also be a limitation because there may be slight differences in prosody or gesture duration among the conditions.

We also did not provide any visual cues (e.g., a map, a spatial array) at either encoding or retrieval of the story. Our task might be too demanding for children, and perhaps they could remember only the events or actions. Another consequence of not providing a spatial array was the low number of spontaneous gestures during the recall phase. When talking about a route or event sequences, visual cues may help participants refer to the routes.

Last, for children, we had two individual differences measures: working memory and language. However, most children failed to perform the backward digit span task. For the forward digit span, the variance was low; children usually did not proceed after the third series of numbers. Therefore, our findings with respect to working memory may have been limited by the task we used.

Conclusion

The results of the current study suggest that observing iconic gestures, but not beat gestures, enhances information recall. Not surprisingly, adults performed better than children in recalling the details of our story. Adults' and children's spontaneous gesture use positively correlated with their overall recall performance. Moreover, children's language abilities, but not working memory scores, were related to their overall recall performance. Importantly, children with better expressive language abilities benefitted the most from seeing iconic gestures, recalling more event information than children with lower expressive language abilities. Together, this research extends the existing literature on the effect of observing different types of gesture on memory. Our findings also suggest a role for children's language abilities in recalling information from a story.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2019.104725.

Appendix B

The Story

Zeynep (Kaan) arkadaşı Ceren'in (Emre) evine davetliymiş. Bu yüzden uzun bir yolculuğa çıkmış.

1. Zeynep'in karşısına dağlar çıkmış bu dağların **etraflarından dolanmış**.
2. Daha sonra bir bank görmüş ve biraz dinlenmek için **üstüne oturmuş**.
3. Yola devam etmiş ve ağaçlı bir yola gelmiş. Zeynep ağaçların **arasından yürümüş**.
4. Bu sırada bir sürü güzel çiçek görmüş ve **çiçeklerden toplamış**.
5. Daha sonra karşısına bir nehir çıkmış, nehri geçmek için köprünün **üstünden geçmiş**.
6. Köprüden indiğinde **bir arkadaşına rastlamış** ve sohbet etmişler.
7. Yoluna devam eden Zeynep evin bahçesini görmüş ve **çitlerin üzerinden** bahçeye atlamış.
8. Bahçede bir sürü kedi görmüş ve onları **teker teker sevmiş**.
9. Ceren'in hazırladığı **sofranın yanından geçip** evin kapısına gitmiş ve kapıyı çalmış.
10. Sonunda bir araya gelebilmelerine çok sevinen iki arkadaş birbirlerine **sıkıca sarılmışlar**.

Zeynep (Kaan) was invited to her friend Ceren's (Emre's) house. Therefore, she went on a long journey.

1. Zeynep came across mountains, she **walked around** the mountains.
2. After a while, she saw a bank and took a **rest on the bank**.
3. She kept going and came to a path with trees. Zeynep **passed through** trees.
4. Meanwhile, she saw beautiful flowers and **picked up** some flowers.
5. Then, she came across a river, she **crossed over** a bridge to pass the river.
6. After she crossed over the bridge, she **came across** a friend and chatted for a while.
7. Zeynep moved on and saw the garden of the house and **jumped over** the fence.
8. She saw many cats in the garden, and she **petted** the cats.
9. She **passed by** the table that Ceren had prepared and went to the door, rang the bell.
10. Two friends were very happy to finally get together, and they **hugged each other**.

Appendix C

Recognition task

1. Zeynep ilk önce hangisinden geçmiş? (*Which one did Zeynep pass first?*)
   a. Ağaçlı yol (*The path with trees*)
   b. Dağlar (*The mountains*)

2. Zeynep nerede dinlenmiş? (*Where did Zeynep take a rest?*)
a. Bankın üstünde (*On the bank*)
b. Ağacın gölgesinde (*At the shade of the tree*)

3. Zeynep ağaçlı yoldan nasıl geçmiş? (*How did Zeynep pass the trees?*)
a. Ağaçların etraflarından dolanmış (*Walked around the trees*)
b. Ağaçların arasından yürümüş (*Passed the trees*)

4. Zeynep ağaçlı yolda hangisini toplamış? (*What did Zeynep pick up on her path?*)
a. Meyve (*Fruits*)
b. Çiçek (*Flowers*)

5. Zeynep nehri nasıl geçmiş? (*How did Zeynep pass the river?*)
a. Köprünün üstünden (*Crossed over the bridge*)
b. Köprünün altından (*Crossed under the bridge*)

6. Zeynep köprüden indiğinde hangisine rastlamış? (*Which one did Zeynep encounter after she crossed the bridge?*)
a. Bir arkadaşına (*A friend*)
b. Kedilere (*Cats*)

7. Zeynep bahçeye nasıl girmiş? (*How did Zeynep enter the garden?*)
a. Çitlerin yanından geçerek (*By passing near the fences*)
b. Çitlerin üzerinden atlayarak (*By jumping over the fences*)

8. Zeynep bahçede ne yapmış? (*What did Zeynep do in the garden?*)
a. Kedileri sevmiş (*She petted the cats*)
b. Çiçek toplamış (*She picked flowers*)

9. Zeynep kapıya nasıl gitmiş? (*How did Zeynep go to the door?*)
a. Sofranın önünden geçerek (*Passing in front of the table*)
b. Sofranın yanından geçerek (*Passing by the table*)

10. Zeynep ve Ceren birbirlerini görünce ne yapmışlar? (*What did Zeynep and Ceren do when they saw each other?*)
a. Sarılmışlar (*They hugged each other*)
b. Sohbet etmişler (*They chatted*)

Note. English translations are presented in italic font within parentheses.

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