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Gesture and Memory: Investigating the Effect of Gesture on Children's Spatial and Event Memory

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STATEMENT OF AUTHORSHIP

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ABSTRACT

This study asked (1) the effects of observing different types of gestures at encoding on recall of information (event and path) in both 5-year-old children and adults and (2) whether the effects of types of gestures on children's recall of information depend on any individual differences such as children's working memory capacities, language abilities, their own overall spontaneous gesture frequency, and gesture production during the recall task. First, participants were asked 4 questions (2 daily activity and 2 route description) to measure their spontaneous gesture frequency. Then, all participants listened a story that included different path and event information. Depending on the assigned condition, participants listened the story with accompanying iconic gestures, beat gestures or no gesture. After the encoding, we immediately asked them to tell what happened in the story and then participants were provided a recognition task about the story. Finally, children were given standardized tests to assess individual differences in language and working memory skills.

Our results showed that observing iconic gestures at the encoding phase enhanced the recall performance of both adults and children compared to observing beat gestures or no gesture. We could not find any enhancing effects of beat gestures in recalling any type of information. Children who were exposed to iconic gestures at encoding performed better in recalling event information compared to children in either beat or no gesture conditions. However, there was no significant difference among conditions for children's recall of path information. Moreover, children's language abilities, but not working memory capacity, predicted their recall performance. The gesture frequency of children while describing routes predicted their performance in recall of path information. Also, adults who were engaged in gesture production during the recall phase performed better in recollecting information. Our results suggest that relying on semantic content, observing iconic gestures at encoding information facilitates recall for both adults and children.

Keywords: gesture, encoding, event memory, spatial memory

ÖZET

Bu çalışmada bilgi kodlaması sırasında farklı türlerde jest gözlemlemenin yetişkin ve çocukların (5 yaş) olay ve mekansal bilgiyi hatırlamasındaki etkileri araştırılmaktadır. Bununla beraber, çocukların bu bilgileri hatırlamalarında onların dil becerileri, işler bellek kapasiteleri, spontane jest kullanımları ve hatırlama sırasındaki jest kullanımlarının etkileri incelenmiştir. Deney sırasında, spontane jest kullanımını ölçmek için katılımcılara 4 soru (2 günlük aktivite ve 2 yol tarifi) soruldu. Daha sonra, tüm katılımcılar 3 farklı gruptan birine atanarak, olay ve yol bilgisi içeren bir hikaye dinledi. Bir grup hikayeyi ikonik jest eşliğinde, diğer bir grup ritmik jest eşliğinde ve son grup hiç jest olmadan dinledi. Daha sonra, katılımcılardan hikayede ne olduğunu anlatmaları istendi ve tanıma testi (recognition test) yapıldı. Son olarak, çocukların dil ve işler bellek becerileri ölçüldü.

Sonuçlar, kodlama sırasında ikonik jest gözlemleyen yetişkin ve çocukların, ritmik jest gözlemleyen ve jest gözlemlemeyenlere göre, hikayeyi daha iyi hatırladıklarını gösterdi. Ritmik jest gözlemlemenin hatırlama üzerinde herhangi bir geliştirici etkisi bulunamadı. İkonik jest gözlemleyen çocuklar, ritmik jest gözlemleyen ve jest gözlemlemeyen çocuklara göre, hikayedeki olay bilgilerini daha çok hatırladı. Fakat, mekansal bilgiyi hatırlamada 3 gruptaki çocuklar arasında fark bulunamadı. Ayrıca, çocukların dil becerileri ile hatırlama performansları arasında pozitif bir ilişki bulundu. Çocukların işler bellek kapasitesi ve hatırlama performansları arasında bir ilişki bulunamadı. Çocukların yol tarif ederken yaptıkların spontane jest sayısı ile mekansal bilgiyi hatırlamaları arasında pozitif bir ilişki bulundu. Bu bulgulara dayanarak yetişkin ve çocuklarda bilgi kodlama sırasında ikonik jest gözlemlemenin hatırlama üzerindeki olumlu etkileri tartışılmıştır.

Anahtar kelimeler: jest, kodlama, olaysal bellek, mekansal bellek

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INTRODUCTION

Speakers in all languages gesture when they speak (Goldin-Meadow & Alibali, 2013). Research on gestures has extensively reported that 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). Gesture and speech can carry different information, in which speech represents highly structured and symbolic information and gesture displays visual and motor information (McNeill, 1992). When speech is accompanied by a gesture, it provides additional information to the listener and makes an illustration of the spoken message (Sauter et al., 2012). Indeed, gestures can enhance comprehension of the spoken message in both adults and children (Goldin-Meadow & Alibali, 2013; Krauss et al, 1995; Macoun & Sweller, 2016). Observing gestures not only enhances comprehension, but also improves the recall of the target information in both adults and children (Austin & Sweller, 2014; Church, Gaber & Rogalski, 2007; Woodall & Folger, 1985; Thompson, Driscoll & Markson, 1998; So, Chen-Hui &Wei-Shan, 2012). These studies agreed that observing gestures are related to different cognitive processes of the listeners such as comprehension, memory and learning; however, they conflicted on the effects of different types of gestures on these cognitive processes of listeners.

Types of gestures:

McNeill (1992) reported that there are four different forms of gestures: deictic, beat, iconic, and metaphoric gestures. In deictic gestures, speakers point to an object or a location in the environment, whereas beat gestures are the rhythmic movements without any semantic content (Hostetter, 2011). Iconic gestures illustrate the aspects of actions or visuospatial features of an action or an object. Metaphorical gestures are similar to iconic gestures in their form, presenting abstract ideas rather than concrete objects or actions (McNeill, 1992). There are contradictory findings on how seeing different types of gestures are related to memory processes, particularly recalling a previously presented information (e.g., Austin & Sweller, 2014; Feyereisen, 2006; Igualada, Esteve-Gibert & Prieto, 2016; So, Chen-Hui &Wei-Shan, 2012). For instance, some suggested that iconic gestures but not beat gestures aid children's memory (Aussems & Kita, 2017; So et al., 2012) Others found that children also benefited from beat gestures (Austin & Sweller, 2014). Iconic gestures encode information in a different modality (Paivio, 1986), whereas beat gestures emphasize information (Feyereisen, 2006). As these gestures differ in content, they might use different mechanisms in encoding information, such that iconic gestures aid encoding by providing a semantic cue whereas beat gestures might be useful by drawing attention to the target information (Feyereisen, 2006; Kushch, Igualada & Prieto, 2015). The current study aims to examine three questions: (1) Does observing gestures at encoding affect children's recall of specific type of information (i.e., spatial and event information in a narrative)? (2) Does the type of gesture (iconic vs. beat) matter for children's recall of information? and (3) Are there individual differences in terms of who benefit most from observing gestures during encoding?

Memory and Multimodal Encoding

Several researchers have focused on understanding how exposure to different modalities (i.e. verbal, visual, or motor) affect 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 non-symbolic (imageable) representations. Thus, individuals' memory traces of information are enriched when the information is encoded in both verbal and nonverbal modalities (Clark & Paivio, 1991). Paivio (1986) argued that non-symbolic representations might provide two benefits. First, images create an additional cue for a given information, which make them easier to retrieve, because the target information can be recalled either by recalling the label or by remembering the images. Second, an image can be used as a tool that integrates separate concepts into one entity. Accordingly, Moreno and Mayer (2002) investigated how addition of visual information to the verbal material affect learning a scientific explanation. College students learned better when they were provided verbal explanations with pictures rather than providing verbal only explanation or pictures alone. This finding is consistent with the Dual Coding Theory, which suggests that images can be useful as additional cues to integrate information.

In addition to imagery, the motor component of a message is also beneficial especially for memory of action sentences (Cohen, 1989). Participants who performed actions of phrases recalled more phrases later compared to the participants who did not perform the actions (Cohen & Otterbein, 1992; Engelkamp & Cohen, 1991). This *enactment effect* leads to better memory, because it adds a third representation to visual and verbal modalities and make the trace for the action phrases richer or more distinctive (Engelkamp & Zimmer, 1985). Interestingly, Mohr, Engelkamp, and Zimmer (1989) revealed that the facilitating effect of enactment does not require the real objects. Instead, a pantomime, as a form of gesture without speech, is sufficient for the enactment effect.

Although some studies reported an advantage of producing the action rather than observing it (e.g., Hornstein & Mulligan, 2004), many others revealed the enhancing effects of enactment occur when participants merely observe the gestures of the speaker (Bucciarelli, 2007, Cutica & Bucciarelli, 2008; Madan & Singhal, 2012). For instance, Cohen (1989) found that free recall of action phrases was enhanced when the participants performed the action with gesture or when they observed the experimenter enacting the action compared to the condition in which participants only heard the phrases. Another study investigated the differences in adults' and 9- to 10-year-old children's memory for sentences accompanied by gestures compared to sentences without any gestures (Thompson, Driscoll, & Markson, 1998). They found that even though adults were better at retrieving sentences, both children and adults had better memory for sentences accompanied by gestures. Children were better at recruiting information from speech when it was accompanied by gestures compared to speech without any gestures. Furthermore, in a study by Feyereisen (2009), younger (*Mage*= 24 years) and older adults (*Mage*= 68 years) were given action phrases in three conditions: purely verbal tasks, subject-performed tasks, and experimenter-performed tasks. Results revealed that observing the actions have the similar facilitative effect of producing the actions on memory of action phrases in both age groups.

Similar to the enactment effect, the Mental Model Theory (Johnson-Laird, 1983, 2006) proposed that a strong comprehension and memory for a discourse could be reached by the construction of an iconic, non-discrete mental representation. Cutica and Bucciarelli (2008) examined whether co-speech gesture use of the speaker affect listener's learning from discourse. Participants listened the discourses either from a speaker who produced gestures or who did not produce any gestures. They found that participants who observed gestures performed better in retention of information. They also reported that observing gestures helped the listeners in making correct inferences about the discourse. They argued that deep learning should facilitate the ability to manipulate the information and the listener should draw correct inferences. Recollection of the information and drawing correct inferences can be achieved through enriched mental models (Bucciarelli, 2007). Observing gestures constructs a richer mental model of the discourse; therefore, the listeners who observed gestures performed better in both recall of the information and drawing inferences from them (Cutica & Bucciarelli, 2008).

Iani and Bucciarelli (2017) argued that a mental model includes both declarative (knowing what) and procedural (knowing how) knowledge. The information given by co-speech gestures is also iconic and non-discrete; therefore, the message can easily be involved in the construction of mental models. In other words, because gestures activate motoric information, they add procedural knowledge to declarative knowledge of linguistic information. In a series of experiments, they tested whether gestures improved memory by using listeners' motor systems. First, they replicated the enhancing effects of observing gestures in recall of actions. Second, they asked what would happen if the motor system of the listener is engaged in another task. If observing gesture enhances memory through occupying motor systems of the listener, then the effects of observing gesture should disappear when the listener's motor system is engaged in another task. Consistent with this hypothesis, they found that when the listeners performed a motor task with their hands and arms, the improving effect of observing gestures disappeared. Interestingly, if the listeners had performed a motor task with their legs instead of arms, the enactment effect would have remained. Therefore, they concluded that gesture improves memory by using the listener's motor system, specified for hand movements. These findings were also consistent with those by Ping et al. (2014), who investigated the effects of performing a motor task while observing gestures on comprehension of these gestures. They also found that understanding gestures involved motor simulation and when the listener was engaged in another motor task that included arms, the listener slowed down in responding to the gesture comprehension task (Ping, Goldin-Meadow & Beilock, 2014).

Do all types of gestures aid the listener's recall of information? Is the enactment effect valid only for meaningful gestures? There are contradictory findings on how different types of gestures influence the recall of information. Woodall and Folger (1985) investigated whether gestures could play a contextual role for verbal information that would lead to a better memory trace for the information. They found that the speech phrases accompanied by representational gestures (i.e., iconic and deictic gestures) were more likely to be recalled compared to the speech phrases accompanied by emphasizing gestures (i.e., beat gestures). They argued that because of their semantic content, representational cues provide more information than other gesture types and are more closely related to the target information. On the other hand, Cohen and Otterbein (1992) demonstrated that adults recalled more sentences when they observed gestures (regardless of the type of gesture) than when they did not see any gestures. Yet, the meaningful gestures provided stronger memory trace for the sentences than the meaningless gestures. While meaningful gestures provide richer information compared to the only verbal coding, non-meaningful gestures might attract the attention of the listener.

Parallel to the study by Cohen and Otterbein (1992), Feyereisen (1998) investigated whether the beneficial effects of gestures on memory stem from the *distinctive effect* of observing gestures or from the additional meaning in visual modality as the Dual Coding Theory introduced. Feyereisen (1998) provided the participants with sentences in three conditions: no gesture, iconic gestures that matched the meaning of the content, or iconic gestures that did not match the meaning of the content. The results of the recall task revealed that only iconic gestures that matched the content enhanced the subsequent performance. In another study, Feyereisen (2006) conducted a series of experiments to explore whether the meaning of gestures influenced the memory for sentences in adults. In a within-subject design, adult participants were presented with a series of sentences. Half of the sentences were presented with gestures and the other half were presented without any gestures. There were two types of gestures: representational and non-representational gestures (beat). Results showed that sentences with representational gestures were recalled more compared to sentences with non-representational gestures or sentences without any gestures. Based on the results of these two studies, Feyereisen (1998, 2006) provided support for the Dual Coding Theory and discussed that the enhancing effects of gestures depend on the meaning and the activation of visual modality rather than just increasing attention to the content.

Even though, many findings on gestures demonstrated the beneficial effects of representational gesture in encoding processes, several recent studies have also reported mnemonic effects of beat gestures on information encoding (Igualada, Esteve-Gibert, Prieto, 2017; Kushch, Igualada & Prieto, 2015; Kushch & Prieto, 2016). These studies criticized previous research because of the unnatural use of beat gestures. For instance, Kushch and Prieto (2016) found that observing beat gestures enhanced the recollection of the target words when beat gestures produced together with the prosodic prominence compared to the prominence in speech alone. They discussed that beat gestures can also improve memory because they function as focus-markers and highlight the target information (Kushch & Prieto, 2016).

Overall, these studies highlighted the beneficial effects of the multimodal encoding of information on later recall of target information. However, there seems to be a disagreement on how different types of gestures influence adults' memory. Another important question that needs to be addressed is that whether similar mechanisms are observed in children's encoding and comprehension of information.

The Effects of Gestures on Children's Comprehension and Memory

Studies demonstrated that observing gestures enhances children's comprehension and learning (Macoun & Sweller, 2016; McNeil, Alibali & Evans, 2000; Valenzeno, Alibali & Klatzky, 2003). For instance, preschool children learned more in a lesson about symmetry when the instructions included gestures (Valenzeno, Alibali & Klatzky, 2003). Similarly, 6- to 7- year-old children learned the Piagetian conservation task better when the instructor used gestures than showing the task without gestures, even when the related object was not present in front of the children (Ping & Goldin-Meadow, 2008). Children at different ages also benefited from the teachers' gestures in understanding mathematical concepts and problem-solving tasks (Cook et al., 2013; Singer and Goldin-Meadow, 2005). Tellier (2008) demonstrated that the beneficial effects of observing gestures in children go beyond learning in children's first language. Children who observed gestures in a word learning task showed better memory for the second language compared to children who observed pictures of the words.

Parallel to the findings with adults, there are contradictory findings on how seeing different gesture types affect children's recall of information. For instance, Macoun and Sweller (2016) found that observing iconic and deictic gestures enhances narrative comprehension of children more than observing beat gestures or listening the story without gestures. Furthermore, So, Chen-Hui, and Wei-Shan (2012) investigated whether meaning of gestures matters in recollection of verbs in both adults and children. They expected that adults would benefit from both beat and iconic gestures whereas children would need meaningful gestures for a stronger memory trace. They found that both adults and children had a better memory for a list of verbs when words accompanied by iconic gestures. The facilitative role of gestures was preserved for the adults when words accompanied by beat gestures. However, such enhancing effect of beat gestures was not found for children.

Only a few studies investigated the effects of gestures on nonlinguistic information, such as memory of events (Aussems & Kita, 2017). Aussems and Kita (2017) investigated whether seeing iconic gestures helps children to encode an action event in a recognition memory task. Three-year-old children sat down with an experimenter and watched action videos, in which actors were moving in unusual manners. Children watched videos twice. There were three conditions: iconic gesture, interactive gesture (drawing children's attention to the action, but irrelevant to the action itself) or no gesture. When the video played second time, depending on the assigned condition, the experimenter produced either iconic gestures, interactive gestures or no gesture. At the end, children were given a recognition task that measured memory for both actions and actors. Children who saw action events accompanied by iconic gestures remembered the actions and actors better than children who were in the other two conditions. There was no difference between children in interactive and no gesture conditions. They suggested that iconic gestures encode “distinctive features of actions in a schematic manner” (p. 10). In other words, iconic gestures have the function of encoding the distinctive features of the actions and help children encode specific information; thereby improving their retrieval of the related information.

Both So et al. (2012) and Aussems and Kita (2017) revealed that iconic gestures but not meaningless gestures enhance children’s recall of verbs, actions, and actors. On the other hand, beat gestures have been shown to function as focus-markers in adults (Jannedy & Mendoza-Denton, 2005; Loehr, 2012). Recently, similar findings were reported on effects of beat gestures on children’s comprehension and memory (Igualada, Esteve-Gibert & Prieto, 2017; Llanes-Coromina et al.; 2018). Igualada et al. (2017) argued that the reason for the negative result of So et al.’s study is methodological. So et al. (2012) used a beat gesture for every word in a list, whereas in natural speech we use beat gesture to highlight particular information. Therefore, Igualada et al. (2017) tested the effects of beat gesture on a word recall test in a different paradigm. Three- to 5-year-old children were provided with a list of nouns. The experimenter either produced beat gestures for the target nouns or did not use any gestures. They found that preschoolers’ recall performance improved by observing beat gestures when the beat gestures highlighted a word to demonstrate that word is the target. Additionally, they also investigated whether the facilitating effects of beat gestures on recall were only valid for the word that accompanied by a beat gesture (a local effect) or whether the effect spread to adjacent words (a global effect). They reported that beat gestures did not cause an overall improvement in recall of an adjacent word; rather a local effect on highlighted word was detected.

Furthermore, Llanes-Coromina and colleagues (2018) also revealed that beat gestures help children’s comprehension and recall of the narratives. They conducted two experiments to explore whether beat gestures combined with the prosodic saliency enhanced children’s comprehension and recall of a narrative. In these experiments, all participants were exposed to three different narrative contexts. In a counterbalanced order, children were exposed to the discourses with beat gestures and prosodic saliency (i.e., changing the voice to make children attend to the target information), the discourses that are prominent in speech without any gesture, and the discourses without any saliency in speech and without any gesture. They found that children remembered more information when the messages were presented with prominence in both speech and gesture compared to the other two conditions. As opposed to the findings of So et al, they concluded that beat gestures can help children in comprehending and recalling messages. Thus, beat gestures can function as highlighters in sentences and can be useful for children for encoding information, if they are produced in natural and pragmatically relevant ways.

Do children encode different types of information similarly with and without gestures? Another research line on the effects of gestures in children focuses on recalling route descriptions (Austin & Sweller, 2014, 2017). Memory for route descriptions is unique because it requires the listener to mentally visualize a space, which was not experienced before. Moreover, the listener needs to remember and follow the specific steps to reach the target location (Allen, 2000). Therefore, recalling route descriptions is a demanding process for both adults and children. Austin and Sweller (2014, 2017) conducted a series of experiments to investigate the effects of gestures on spatial communication about recalling of route descriptions. In the first study (Austin & Sweller, 2014), adults and 3- and 4-year-old children were provided with the verbal descriptions of a target path on a small-scale spatial array. Participants encoded the route descriptions in one of the three conditions: combined gesture (verbal descriptions accompanied by deictic, iconic, beat and metaphoric gestures), beat gesture, and no gesture. Children, but not adults, benefited from observing gestures in recalling the route directions. Children in combined gesture group recalled more information compared to the other groups; yet, children in beat gesture condition performed better than children in the no gesture condition. In a follow-up study (Austin & Sweller, 2017), they investigated the effects of observing different types of gestures at the encoding on recall of the route directions in a larger scale spatial array. Larger scales require more cognitive demands compared to the small-scale arrays and they wanted to see whether the effects of observing gestures would apply to the larger environments. There were again three conditions: combination of iconic and deictic gestures, beat gestures, and no gesture. Three- to 5-year-old children listened the route descriptions in one of these conditions, then they were asked to recall the route directions. After that, they were asked to walk in the spatial array and navigate the path that was described earlier. Children in the iconic/deictic condition recalled more information compared to the children 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 the route directions with iconic/deictic or beat gestures navigated more accurately compared to the children in no gesture condition (Austin & Sweller, 2017). These findings suggest that observing gestures enhances children's memory for the route descriptions. Even though children benefit from beat gestures, representational gestures improve children's recall most.

Why would observing gestures be helpful for children's encoding of specific information? Different gesture theories agreed that gestures are communicatively intended; therefore, they can affect the listeners' cognitive processes (de Ruiter, 2000; Goldin-Meadow & Alibali 2013; Kita & Özyürek, 2003; McNeill, 1992). According to the gesture as simulated action (GSA) framework, when we speak, there is a simultaneous activation in motor and premotor cortex and if this activation passes a threshold, we would produce gestures (Hostetter & Alibali, 2008). For instance, when speakers talk about an action, this stimulates mental representations of that action, exceeds the threshold, and then the speaker will produce gestures that imitate the action. This framework also proposed that both speech and gesture activate perceptual and motor systems of the listeners. As discussed in Austin and Sweller (2014), the GSA framework directed us to two possible mechanisms to understand why gesture might aid the listener. Observing gestures may activate cognitive processes by providing mental representations of the semantic information (Hostetter & Skirving, 2011); or by eliciting overt mimicry (Hostetter & Alibali, 2010; Morsella & Krauss, 2004). Both mechanisms are in line with the effects of multimodality on memory which were discussed above.

In addition to the benefits of elaborated encoding with multiple modalities, children may benefit from gestures for different reasons (Austin & Sweller, 2017; McNeil, Alibali & Evans, 2000). Because children are in the process of language development, comprehending a spoken message might be more demanding (McNeil, Alibali & Evans, 2000). Gesture is a form of external support and can serve as a “scaffold” for comprehending messages (McNeil, Alibali & Evans, 2000). Children may understand the overall message by understanding either the spoken message or the related gesture. The combination of speech and gesture aids children by providing additional cues and information, and illustrating particular concepts (Sauter, Uttal, Alman, Goldin-Meadow, & Levine, 2012). Therefore, it becomes easier for children 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 or communication of spatial information (Cook, Duffy & Fenn, 2013; Austin& Sweller, 2014; 2017).

Although the above discussed arguments may enlighten us to understand why representational gestures lead to a stronger memory trace, it does not elaborate on why beat gestures might be useful for the memory. As supported by different findings, beat gestures can aid the memory by emphasizing specific information and functioning as focus-markers in a narrative both in adults and children (Austin & Sweller, 2014; Llanes-Coromina et al., 2018).

Recently, a few studies have addressed the question of whether the effects of gesture on memory depend on any individual difference (e.g., Chu, Meyer, Foulkes & Kita, 2014; Marstaller & Burianova, 2013; Wagner, Nusbaum & Goldin- Meadow, 2004). These studies mostly focused on gesture production and suggested that 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 spatial abilities of the learner. Gesture production aided the memory for the route for individuals with lower spatial abilities (Galati, Weisberg, Newcombe & Avraamides, 2015, 2018). Working memory capacity has also found to be related with gesture production. Some studies reported that adults with low verbal working memory capacity produce more gestures (Gillespie, James, Federmeir & Watson, 2014), or high frequency of producing representational gestures is related to poor performance in visual and spatial working memory (Chu, Meyer, Foulkes & Kita, 2014). All reported studies focused on individual differences among adults. To our knowledge, there is no research investigating whether the effects of gesture observation on memory depends on individual differences in children. With this study, we also aimed to examine children's individual differences in benefiting from gestures for recalling information.

The Present Study

The present study aimed at investigating the effects of observing gestures on children's later recall of information. Specifically, we examined the role of observing different types of gestures (iconic vs. beat) in children's recall and recognition of path information and event sequences. Previous studies indicated that observing gestures help children's comprehension and memory in different tasks (e.g., Broaders et al., 2007; Church, Garber, & Rogalski, 2007; Austin & Sweller, 2014). However, there are contradictory findings on how gesture type might be related the memory processes (e.g., Llanes-Coromina, 2018; So, Sim Chen-Hui & Low Wei-Shan, 2012). The main goal of the present study was to understand how observing different types of gestures could influence children's recall of path information and event information. We predicted that children who observed gestures at encoding would recall both path and event information more compared to the children who were not exposed to any gestures. Moreover, as discussed in So et al. (2012), since children might need meaningful gestures for a stronger memory, the presence of iconic gestures at the encoding phase would lead a better memory compared to the presence of beat gestures. Yet, considering the findings on beneficial effects of beat gestures (Austin & Sweller, 2014; Llanes-Coromina et al., 2018), we expected that observing beat gestures at the encoding would lead a better recall performance compared to encoding without seeing any gestures.

Second, another purpose of this study was to understand whether the effects of gestures on children's memory depend on any individual differences. We examined whether individual differences in children's working memory capacities and language abilities were related to children's performance. We expected that children with higher language abilities would recall more information. Moreover, it was also expected that children with high working memory capacity would perform better in recall of information regardless of how they listen the story.

Third, gesture frequency varies across individuals (Galati, Weisberg, Newcombe, Avraamides, 2018; Suppes, Tzeng & Galguera, 2015). This variation may generate differences in how individuals are affected by being exposed to gestures. Therefore, we explored whether the differences in children's gesture frequency was related to their performance in remembering a story. Do children who produce more gestures in a spontaneous conversation comprehend a given message in speech better and therefore show better recall when they observe gestures? Or because those children depend more on the manual modality, can using gestures frequently cause poor performance in memory when the information is conveyed only with speech?

Another individual difference could be related to how children will recall any information. One study by Stevanoni and Salmon (2005) found that children who were instructed to use gestures verbally reported more correct information than did children who were able to engage in spontaneous gestures and children who were prevented from gesturing. Moreover, So et al. (2015) found that when participants rehearsed the target path with gestures, they recalled the path information more than participants who drew or mentally simulated the path. Based on these findings, children who produced gestures at the recall phase were expected to perform better in retrieving the information.

Last, the current study was also designed to compare adults and children in the effects of observing gestures on recall. Regarding developmental differences, adults were expected to recall more information (both in path and event information) compared to children. Moreover, it was expected that adults would produce more gestures both in initial questions and free recall. We also expected that the effects of types of gestures would be similar to children, such that participants who observed iconic gestures would recall more information compared to participants in beat and no gesture conditions. Similarly, participants in the beat gesture group would perform better than participants in the no gesture condition. Furthermore, for adults, it was also expected that producing gestures at the recall would enhance performance in retrieving the information.

METHOD

Participants

The final sample included 71 children (36 females) between the ages of 54 and 73 months old (M = 64, SD = 4.97). The gender distribution of the children was the same across three conditions, χ^2 (2) = .43, p = .80, as well as their age in months, F(2,68) = .29, p = .75. This age group was chosen for the present study based on the following reasons. First, at this age, children can understand and express causal relations significantly better than younger children (Göksun, Hirsh-Pasek, & Golinkoff, 2010). The level of causal understanding was important because our narrative consisted of causal sentences and children should have been able to comprehend causal events in the narrative. Second, children at this age differ in their ability to comprehend speech alone compared to comprehend it with gestures (Macoun & Sweller, 2016; McNeil, Alibali & Evans, 2000). Additional data from 7 children were excluded either because there were recording problems in the sessions (n = 4) or children did not meet the criteria for the experiment (e.g., non-native speaker, atypical development). The children were native speakers of Turkish and were recruited from various childcare centers and kindergartens in Istanbul, Turkey. Approvals were obtained from the parents and the principals of the centers. As a control group, we collected data from 50 native Turkish-speaking adults (41 females, M =21.5, SD = 1.95). One of the adult participants was not a native speaker of Turkish, therefore the data was excluded from the final sample. Our adult participants were undergraduate students from Koç University and they received course credit for their participation.

Tasks

Spontaneous gesture production of children

One of the aims of this research was to examine whether individual differences in frequency of children's gestures was related to their comprehension and recall information. To test children's gesture production frequency, we asked 4 questions. Two of them were related to children's daily activities: "What do you do on weekends?" and "Can you explain how to play your favorite game?" Then, we asked 2 questions to observe children's gesture production while talking about space (route descriptions). To measure this, we asked the following questions: "Can you describe how you would go from the kitchen to the bathroom in your home?" and "How you would go from the door to your bedroom?"

Encoding events and spatial information

Participants listened a story that included both event sequences and path descriptions. The story was about a journey of a character who followed a path to find her friend's house (see Appendix A for the story). This journey involved 5 different path information: "walked around the mountains," "passed through trees," "crossed over the bridge," "jumped over the fence to the garden," and "passed by the table." Each path information was followed by an event sentence (a total of 5): "took a rest on a bank," "picked up flowers," "came across with a friend on the road," "petted the cats in her friend's garden," "hugged with the friend who invited her." These event sentences did not include any spatial content. We piloted 8 children to ensure that the story and the instructions were appropriate for preschoolers.

All children listened the same narration and the sex of the character was same with the participant's sex. However, we manipulated the gestures produced during the narration. There were three conditions. In one condition, children listened the narrative with accompanying iconic gestures. For example, while saying "walked around the mountain," the experimenter drew a circular shape by moving her fingers to show the "walking" action. For the "crossed over the bridge" and "jumped over the fence," the experimenter slightly moved her hand up and down to demonstrate "jump over" or "crossover." For the "passed through trees," she moved her two hands forward in a parallel manner to describe a road between trees and the action. For the "passed by the table," she slightly moved her right hand to the left as there was a table in space and the gesture was referring the action. Thus, 5 different gestures accompanied each path information. For the events, the number of gestures was same. For example, while saying, “took a rest on a bank,” the experimenter represented the “the bank” by using her two hands. For “picked up flowers,” she moved her hand as picking something and taking that up. For the “came across with a friend on the road,” the experimenter moved her two hands towards each other to represent “come across.” For the “petted the cats in her friend’s garden,” she moved her hands as there is a “cat” in her hands. Last, when she said, “hug with the friend who invited her” she performed a “hug” by using her two arms (see Appendix B for the details).

In the second group, the story was narrated with beat gestures. In this condition, a random movement of the hand appeared with the path information and event sentences above. The number of gestures was equal for both iconic and beat gesture conditions and the gestures performed for the same parts of the sentences with the same hand (see Appendix B for the details). In the third condition, children heard the narration without any gestures. These three conditions were to investigate whether the presence of gesture or the type of gesture would influence the recollection of information.

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

Testing the individual differences

Participants were given several standardized tests to assess individual differences in children’s language and working memory skills. We used Turkish Early Language Development Inventory (TEDIL) to measure children’s language abilities. This test assesses both receptive and expressive language development in children aged 2-7 years. In this test, there is a record form for the experimenter and a picture book for children. The test includes two sub-tests: Receptive and expressive. The receptive language sub-test includes 37 items, 24 of them assesses the semantics and 13 items measures grammar. For example, in 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 stand next to the chair”). The maximum score was 37 for the receptive language test. There were 39 items for the expressive language sub-test. In this test, for example, the experimenter pointed to the picture of a woman who goes shopping and asked the child to tell what is happening in the picture. The child got a point if the child mentioned the woman and the event. The maximum score was 39 for the expressive language test. The test would have ended if the child had 3 errors consecutively.

For the working memory abilities, we used the Forward and Backward Digit Span Tasks. In the Forward Digit Recall, 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 Recall, children were asked to repeat sequences in the reverse order. In this test, children were given digit series from two to six and the maximum score was 10. If the child did not recall the correct order in both trials, the test would be finished.

Procedure

Children were tested individually in a quiet room of their kindergarten. A female experimenter and the participant sat face to face during the sessions. The order of tasks was the same for all participants. First, the experimenter asked daily activity questions and route descriptions that measured individuals’ spontaneous gesture production. Because we were interested in participants’ spontaneous gesture production, no instruction was given about gesturing. Next, the experimenter told, “I am going to tell you a story, please listen carefully because I am going to ask you questions about it.” Then, participants listened the story based on their assigned condition. Participants were randomly assigned to one of the three conditions: iconic gesture, beat gesture or no gesture. As it was described above in the iconic gesture conditions, the experimenter performed an iconic gesture that depicted the referred 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, children only heard the narration without any gesture. When a participant seemed to be distracted during the encoding, the experimenter asked, “Are you listening?” After the encoding, participants were asked, “Can you tell me everything you remember from the story?” If the participants had failed to respond, they would have been encouraged to tell anything that they remembered from the story. After the participant stopped responding, they were once again asked, “Do you remember anything else?” There was no restriction on the recalling time. Following free recall, children were asked 10 multiple choice questions about the story. Each question had two choices. In the next step, children were given the Forward and Backward Digit Span Tasks. There were practice trials for both forward and backward digit span and when the participant failed to recall the correct order two times consecutively the task was terminated. Finally, TEDIL receptive and expressive tasks were administered.

No feedback was provided about participants’ accuracy in any task. Each session was videotaped for later transcription and coding. All participants completed the tasks in one session and the entire procedure took 20-30 min per participant, depending on the length of participant’s response.

The adult participants were tested individually in a quiet room in the research laboratory at the university. Adult participants were asked same four questions to measure their spontaneous gesture production, then listened the same story based on their assigned condition. After the encoding, participants were asked to recall what happened in the story. Finally, they were asked 10 multiple choice questions. The sessions took 10-15 min per participant.

Coding

Scoring for speech. For the path information of the story, participants were expected to recall 5 locations (mountain, a path with trees, bridge, fence/garden, table) and 5 directions (walking around mountains, passing through trees, crossing over the bridge, jumping over the fence, passing by the table). For the event sequences of the story, participants were expected to recall 5 objects/subjects (a bank, flowers, a friend, cats, the two friends) and 5 events/actions (taking a rest on a bank, picking up flowers, coming across with a friend, petting cats, hugging with the friend who invited her). Each information (i.e., locations and directions, objects/subjects, and events) was scored out of 2 points. The maximum score possible was 40. If the participant had correctly recalled the target information, a score of 2 would have given. However, for partially recalling the target information, we gave a score of 1. For example, if the participant said, “walked on the mountains,” we gave a score of 2 for the location but a score of 1 for the direction, because the correct answer should be “walked around the mountains.” A non-response or incorrect response scored as 0 (see Table 1 for the target information). For the multiple-choice questions, each correct answer was counted as 1 point. The maximum score possible was 10.

Gesture. We used ELAN software (Lausberg & Sloetjes, 2009) to transcribe and code participants’ speech and gestures during the daily and route description questions and for gestures during free recall phase. The gestures of children were categorized as iconic, deictic, iconic-deictic, and others (emblems and beat). Iconic gestures included hand movements depicting an object or action. Deictic gestures referred to hand or index finger pointing to an object or location. If the participants simultaneously convey both an object or action *and* a direction or location in a gesture, we counted it as an iconic-deictic gesture (Suppes, Tzeng & Galguera, 2015). We categorized all other formless, quick hand movements of children as “beat”.

Furthermore, we analyzed gestures for the spatial information in more detail. We categorized all spatial gestures based on the spatial information: “location” and “direction.” For example, when participants explained the route from the kitchen to the bathroom, if their gesture had depicted a location in the house such as “pointing at their right” to show the right side of the room, we would have counted the gesture as location. If the gesture had depicted information about the path from the kitchen to the next location such as “making a curve” to show the dynamic act of turning, we would have counted that gesture as direction.

Reliability

To establish reliability in gesture coding a second person independently coded 20% of the participants’ gestures. Reliability was assessed by obtaining single-rater intraclass correlation (ICC) through a consistency model. Intraclass correlations were highly significant for gesture production (ICC= .986, $p< .01$). We also obtained intraclass correlation for gesture type (ICC= .75, $p< .01$).

For the reliability of free recall scores, 20% of the participants’ free recall scores was coded by a second person. Intraclass correlation was highly significant for the free recall scores (ICC= .996, $p< .01$).

RESULTS

Preliminary analyses

We first checked whether there were differences in age, working memory scores, language abilities, and spontaneous gesture frequency of children among three conditions (iconic, beat, no gesture). Results indicated no significant differences among three conditions in children’s ages, language abilities, working memory scores and the number of gestures that they had produced ($ps>.05$) (see Table 2 for descriptive statistics).

A preliminary analysis was also conducted to explore sex of the participant had an effect on recall performance of the story. Three-way analyses of variance (ANOVAs) with age group (adults vs. children), gesture condition, and participant sex were carried out for the overall free recall and recognition scores. None of the analyses revealed significant main effects or interactions involving sex (all *p*s> .05). Thus, sex was not considered as a variable in further analyses.

In further analyses, for multiple hypotheses testing, we used Bonferroni adjusted alpha levels in pairwise comparisons.

Main analyses

The effects of gesture type on children's recall

The present study aimed to examine the effects of observing gestures on two types of information: event and path information. We converted participants' raw scores into percentages. All analyses below were calculated by using percentages.

We first conducted a one-way ANOVA to examine the effects of types of gestures on recall in children. Results revealed no significant difference among conditions in children's overall recall performance, $F(2,68) = 1.57$, $p = .21$ (*M*iconic= 27.07, *M*beat= 21.63, and *M*nogesture= 20.34) (see Table 3 for descriptive statistics). For children's recall of event vs. path information, we ran a 3 (Gesture Condition) x 2 (Type of Information: event and path information) mixed ANOVA with gesture condition as the between-subject factor and type of information as the within subject factor. There was a main effect of type of information, $F(1,68) = 12.60$, $p = .01$, $\eta^2 = .16$. As indicated above, children recalled more event information (M=27.23) compared to path information (M=18.94). Results yielded no significant main effect of gesture condition, $F(2,68) = 1.71$, $p = .18$. However, there was a significant interaction between the type of information and gesture condition $F(2,68) = 3.33$, $p = .04$, $\eta^2 = .10$. Pairwise comparisons revealed that children who observed iconic gestures (M=35.43) at encoding recalled more event information compared to children in beat (M=22.60) and no gesture conditions (M=23.63), $F(2,68) = 3.99$, $p = .02$, $\eta^2 = .11$. However, no significant difference was found among conditions for path information $F(2,68)= .288$, $p= .75$ (see Figure 1).

To compare two age groups and examine developmental changes on overall recall of information based on the gesture condition, a 2 (Age Group) x 3 (Gesture Condition) between-subject design ANOVA was conducted. Results yielded significant main effects of age group and gesture condition, $F(1,114)= 101.04$, $p= .00$, $\eta^2= .48$ and $F(2,114)= 4.46$, $p= .01$, $\eta^2= .07$, respectively. Adults ($M= 52.18$) recalled significantly more information than children ($M= 23.01$). Moreover, post-hoc analyses indicated that regardless of age, participants who observed iconic gestures ($M= 43.68$) at encoding recalled more information compared to participants in both beat ($M=34.72$) and no gesture conditions ($M=34.39$), $p= .01$ (see Figure 1). There was no significant difference between beat and no gesture conditions, $F(2,114)= 4.46$, $p= 1.00$. There was no significant interaction between age and gesture condition, $F(2,114)= .462$, $p= .61$ (see Figure 2).

We then analyzed the effects of types of gesture on two types of information. A 2 (Age Group) x 3 (Gesture Condition) x 2 (Type of Information: event and path information) mixed design ANOVA was conducted, with age group and gesture condition as the between-subject factors and type of information as the within-subject factor. Results yielded significant main effects of age group and gesture condition, $F(1,114)= 103.04$, $p= .00$, $\eta^2= .49$ and $F(2,114)= 4.15$, $p= .02$, $\eta^2=.07$, respectively. As reported for the overall information, adults ($M= 52.70$) recalled significantly more information than children ($M= 23.09$), $F(1,114)= 103.04$, $p= .00$, $\eta^2= .49$. Moreover, post-hoc analyses indicated that participants who observed iconic gestures ($M= 43.68$) at encoding recalled more information compared to participants in both beat ($M= 34.72$) and no gesture conditions ($M= 34.39$), $F(2,114)= 4.15$, $p= .02$, $\eta^2=.07$. There was no significant difference among beat gesture and no gesture conditions, $F(2,114)= 4.46$, $p= 1.00$.

Additionally, there was no significant main effect of type of information, $F(1,114)= 1.34$, $p= .25$. However, there was a significant interaction between age group and type of information $F(1,114)= 29.28$, $p= .00$, $\eta^2= .21$, such that the mean difference in recall between adults and children was greater for the path information (M_{adult} - $M_{children}$= 40.15) than for the event information (M_{adult} - $M_{children}$= 19.09). Further pair-sampled *t* tests indicated that adults recalled more path information (*M*= 59.09) compared to event information (*M*= 46.31), $t(48)= -4.00$, $p= .00$, whereas children recalled more event information (*M*= 27.22) compared to path information (*M*= 18.94), $t(70)= 3.44$, $p= .00$. The analysis revealed no significant three-way interaction among age group, gesture condition, and the type of information, $F(2,114)= 2.30$, $p= .11$ (see Figure 3).

A 2 (Age Group) x 3 (Gesture Condition) between-subject ANOVA was conducted to compare scores of adults and children in three conditions for the recognition task. There was a main effect of age, $F(1,114)= 39.99$, $p=.01$, $\eta^2=.27$, with adults (*M*= 9.05) performing better than children (*M*= 7.41) in the recognition task. There was no significant main effect of gesture condition or no interaction between gesture condition and age, $F(2,114)= 1.75$, $p= .18$ and $F(2,114)= .65$, $p= .53$, respectively (see Tables 3 and 4).

Adults' and children's spontaneous gesture production

We asked participants four questions (two daily activity questions and two route description questions) to measure their spontaneous gesture frequency. Two children did not answer the daily activity questions, whereas eight children did not respond to the route description questions. All but 6 remaining children produced at least one gesture while answering these questions (see Table 5). All adults answered each question and produced at least one gesture for each question (see Table 6). A 2 (Age Group) x 2 (Type of Question: daily activities or route description) mixed ANOVA was conducted to examine the effects of age and the type of question in spontaneous gesture production. Results yielded a main effect of age, $F(1,118)= 63.57$, $p= .01$, $\eta^2=.36$. Adults ($M=11.86$) produced significantly more gestures than children ($M=3.52$). Moreover, there was also a main effect of the type of questions, $F(1,118)=5.07$, $p= .02$, $\eta^2=.05$, such that participants produced more gestures in daily activity questions ($M= 7.30$) than route description questions ($M= 6.74$) (see Figure 4). Yet, this effect might have been resulted from the excessive numbers of gestures that adults produced while answering daily questions. We also found an Age Group x Type of Question interaction, $F(1,118)=74.48$, $p= .01$, $\eta^2=.40$. Post-hoc analyses revealed that children produced significantly more gestures in the route description questions ($M= 6.33$) than in the daily activity questions ($M= 1.52$), $t(62)= -7.04$, $p= .01$ (see Table 5). In contrast, adults produced significantly more gestures in daily questions ($M= 15.47$) compared to the route description questions $M= 8.24$, $SD= 5.99$), $t(48)= -5.65$, $p= .01$.

We then investigated whether children's spontaneous gesture production was related to their recall performance. There was no correlation between spontaneous gesture frequency (total score from both questions) and children's overall recall performance ($r=.20$, $p= .11$). No significant correlation was found between producing gestures in daily questions and event free recall scores ($r= .13$, $p= .74$). However, children's gesture frequency in the route description questions was related with their performance in their recall of path information ($r= .34$, $p= .01$). There was no such relationship between spontaneous gesture frequency in these questions and adults' recall performance ($ps> .05$).

How is gesture production during recall related adults' and children's performance?

Forty-six children out of 68 did not produce any gestures during their free recall of the story. Twelve children out of 22 who produced gestures had only one gesture. Therefore, we could not analyze the effects of producing gestures during the recall phase on children's performance. However, all but 5 adults produced gestures during the recall (see Table 6). Adults' gesture production at the recall phase correlated with their overall recall performance (*r*= .33, *p*= .02). Moreover, there was also correlation between gesture production at the recall and adults' performance in recall of path information (*r*= .36, *p*= .01). No correlation was found between gesture production at the recall and memory for event information *(r*= .13, *p*=.38). Additionally, a linear regression was carried out to predict adults' recall performance based on their gesture production during the free recall. We ran three linear regressions for each dependent variable: total free recall, recall of event information, recall of path information. Because there were three conditions, we defined two dummy variables to conduct a linear regression. The no gesture condition was chosen as reference group and coded as 0, whereas iconic and beat gesture conditions were coded as 1. The two gesture condition variables and the number of gestures produced at recall entered the model as predictors. The results of the regression indicated that the number of gestures produced during the recall explained 12% of the variance in overall recall performance, $F(3,45)= 3.12$, $p= .03$. The number of gestures produced during the recall (β=.54, $t(45)= 1.97$, p=.05) was a significant predictor of adults' overall recall. The variables for gesture conditions were not significant predictors, *p*s> .05. For the recall of event information, the model was not significant, $F(3,45)= .83$, $p= .48$. However, for the recall of path information the model was significant in explaining 13% of variance, $F(3,45)= 3.36$, $p= .03$. The number of gestures produced at the recall (β=.31, $t(45)= 2.25$, $p= .03$) was a significant predictor of adults' recall of path information.

The effects of language abilities, working memory, and gesture production in children's recall

Children's overall recall performance was related to their receptive and expressive language abilities (*r*= .47, *p*=.00 and *r*= .43, *p*=.00, respectively). The correlation between children's overall recall performance and forward digit span scores was not significant (*r*=.23, *p*=.06). No significant correlation was found between children's scores in the backward digit span task and overall recall (*r*=.16, *p*=.18). Furthermore, a positive correlation was found between children's receptive language scores and their recall performance in event sequences (r= .32, p= .01). Similarly, children's expressive language abilities were related to their recall of event information (r= .30, p= .02). No significant correlation was found between event recall and working memory scores ($r_{forward}$=.19, p= .11 and $r_{backward}$=.12, p= .31). Finally, children's receptive and expressive language abilities were related to their recollection of path information (r=.46, p= .00 and r=.40, p= .00, respectively). No significant correlation was found between recalling the path information and working memory scores ($r_{forward}$=.15, p= .21 and $r_{backward}$=.16, p= .21) (see Table 7).

One of the purposes of the current study was to understand whether individual differences among children were related to their recall performance. After running simple correlations, a multiple linear regression was carried out to predict three dependent variables (total free recall, the recall of event information, the recall of path information) with the following predictors: children's expressive language scores, forward digit span scores, spontaneous gesture frequency, and their age in months. There was a high correlation between receptive and expressive language scores (r=.52, p= .01), so we entered only expressive language scores to the model. We also only used children's forward digit span task as working memory scores, because 47 children had the score of 0 in the backward digit span task. We entered spontaneous gesture production to the analyses to see whether gesture frequency contributed to children's recall performance. To control age, we also included it to the model. Because there were three conditions, we defined two dummy variables to enter the model. The no gesture condition was chosen as reference group and coded as 0, whereas iconic and beat gesture conditions were coded as 1. We then entered the two dummy variables to each analysis.

For the overall free recall, a significant regression equation was found that explains 20% of the variance in recall performance, $F(6,62)$= 3.59, p= .01. The two gesture condition variables were not significant predictors (*p*s>.05), while expressive language abilities significantly contributed to the model (*β*=.44, *t*(62)=3.57, *p*= .01). The working memory score (*β*=.08, *t*(62)=.70, *p*=.49) and spontaneous gesture production (*β*=.06, *t*(62)=.52, *p*=.60) did not predict the overall recall. The contribution of age was marginally significant (β =-.22, *p*=.06) (see Table 8).

For the recall of event information, 16% of the variance was explained by the model, *F*(6,62)= 2.99, *p*< .05. While expressive language abilities significantly contributed to the model (*β*=.31, *t*(62)=2.49, *p*= .02), working memory (*β*=.11, *t*(62)=.93, *p*=.35), spontaneous gesture production in daily activity questions (*β*=.06, *t*(62)=.52, *p*=.60) and age did not (*β*=-.20, *t*(62)=-1.71, *p*=.09). Moreover, the iconic gesture condition was significantly different than the reference condition (no gesture) after controlling other predictors, *β*=.32, *t*(62)=2.35, *p*= .02. The variable for beat gesture condition was not a significant predictor, *β*=-.05, *t*(62)=-.40, *p*= .69 (see Table 9).

For the recall of path information, a significant regression equation was found, which explained 16% of the variance in recall performance, *F*(6,62)= 2.98, *p*= .01). The two gesture condition variables did not significantly contribute to the model (*p*s>.05). The expressive language abilities (*β*=.37, *t*(62)=2.90, *p*= .01) and spontaneous gesture production in the route description question (*β*=.25, *t*(62)=2.04, *p*= .05) significantly contributed to the model. However, working memory (*β*=.-.03, *t*(62)=-2.04, *p*=.84) and age (*β*= -.16, *t*(62)=-1.36, *p*=.18) did not (see Table 10).

DISCUSSION

The present study examined (1) the effects of observing gesture at encoding on recall of information (event and path) in both children and adults and (2) whether the effects of types of gestures on children's recall of information are related to any individual differences. Based on the previous findings (e.g., Austin & Sweller, 2014; So, Chen-Hui &Wei-Shan,

2012), we predicted that children who observed iconic gestures at encoding would recall both path and event information more than children who were in the beat gesture condition and no gesture condition. Yet, children who observed beat gestures at the encoding would perform better in recalling information compared to children who did not observe any gestures. We then examined whether individual differences in children's working memory capacities and language abilities were related to their performance. We hypothesized that children with higher language abilities would recall more information than children with lower language abilities. It was also expected that children with high working memory capacity would perform better in recall of information than children with lower working memory capacity. We also examined whether spontaneous gesture frequency of children correlated with their performance in recalling information and whether gesture production during the recall task was related to participants' performance in recalling information.

We found that regardless of condition adults performed better in recalling both types of information. Regardless of age, observing iconic gestures at the encoding phase enhanced the recall of information compared to observing beat gestures or no gesture. We could not find any enhancing effect of beat gestures in recalling information. Moreover, adults recalled more path information compared to event information. However, children recalled more event information compared to path information. Even though we could not find a three-way interaction among age group, gesture condition, and type of information, when we analyzed only children, results yielded that children who were exposed to iconic gestures at encoding performed better in recalling event information compared to children in both beat and no gesture conditions. However, there was no significant difference among conditions for children's recall of path information. Moreover, children's language abilities, but not working memory capacity, predicted their recall performance. We also found that children's spontaneous gesture frequency in route description question was related with their performance in recall of path information. Finally, we found that adults who engaged in gesture production during the recall phase performed better in recollecting information.

Our study revealed that children who were exposed to iconic gestures at encoding performed better in recall of event information than children who were exposed to beat gestures or who were not exposed to any gestures. Observing beat gestures did not have an additional benefit on recalling compared to only verbal encoding of event information. This finding is in line with the study by Aussems and Kita (2017), which showed that iconic gestures helped children encode action events. In their study, they found that children who saw action events accompanied by iconic gestures remembered the actions and actors better than children who saw the action events accompanied by interactive gestures or no gesture at all (Aussems & Kita, 2017). The facilitative effects of iconic gestures on children were not present for recalling path information. There was no significant difference between children in three conditions. That is, we could not support the previous findings on benefits of observing gesture on children's memory for route descriptions (Austin & Sweller, 2014, 2017). Austin and Sweller (2014) found that children's, but not adults', recall of route directions improved by observing gestures during encoding. In their study, even though children benefited from beat gestures, observing iconic gestures improved children's recall most. The difference could be due to the task differences. Austin and Sweller (2014) used a spatial array, which represented the space that the route takes place in. This might provide children a cue for recalling the routes. However, we did not provide any visual cues other than gestures. Therefore, our task might become too demanding for children. Indeed, we found that the difference between adults and children was greater for recalling path information than recalling event information.

Previous findings argued that the addition of different modalities (verbal, visual, motor) at encoding leads better memory trace for the encoded information (Cutica &

Bucciarelli, 2008; Madan & Singhal, 2012; Thompson, Driscoll, & Markson, 1998). In the case of gesture, two different mechanisms might be responsible for these beneficial effects on memory (Austin & Sweller, 2014; Feyereisen, 2006; Kushch, Igualada & Prieto, 2015). First, gestures might encode additional cues and information to the verbally given information (Austin & Sweller, 2014; Feyereisen, 2006; So et al., 2012). Second, gestures might be useful as an attention-getter to highlight the target information in speech (Kushch, Igualada & Prieto, 2015; So et al, 2012). The present study revealed beneficial effect of observing iconic gestures in recall of information for both adults and children. According to the GSA framework iconic gestures stimulate visual and motor representations of concepts. Therefore, observing iconic gestures benefit listeners, providing richer mental representations of semantic information (Hostetter & Alibali, 2010; Hostetter & Skirving, 2011). Yet, we failed to find any beneficial effects of beat gestures later recalling information. Previous work also had contradictory findings regarding the role of beat gestures. Some argued that the meaning of a gesture matters for the facilitative effect of observing gestures (So et al, 2012; Feyereisen, 2006), whereas others reported that beat gestures also enhance the recall (Austin & Sweller, 2014; Igualada, Esteve-Gibert, Prieto; 2017). These studies discussed that the failure in finding enhancing effects of beat gestures depends on using beat gestures unnaturally (Llanes-Coromina et al., 2018; Igualada, Esteve-Gibert, Prieto; 2017). In our study, we also tried to use the beat gestures in a naturalistic way, such that we embedded them through sentences by highlighting target information. Yet, unlike the earlier studies that demonstrated facilitative effects of beat gestures on recall, we did not manipulate the prosody of speech. This might be the reason for the discrepancy between these findings and our results.

We also examined whether overall spontaneous gesture frequency was related with the individuals' recall performance. We asked four questions (two daily activities and two route descriptions) to measure participants' spontaneous gesture production. Adults produced significantly more gestures than children for both types of questions. However, children produced significantly more gestures in route description questions than in daily activity questions. In contrast, adults gestured more in daily questions than in route description questions. Different theories of gesture production argued that producing gestures relies on spatial imagery (de Ruiter, 2000; Kita & Özyürek, 2003). Moreover, when we speak, there is a simultaneous activation in motor and premotor cortex and if this activation passes a threshold, we will produce gestures (Hostetter & Alibali, 2008, 2010). For instance, when speakers talk about an action, this stimulates mental representations of that action and if this stimulation exceeds the threshold speaker will perform gestures, which imitates that action (Hostetter & Alibali, 2008). Communicating about space might also stimulate motor cortex easily. Indeed, different studies reported that people produce many gestures while expressing spatial information such as direction giving, describing spatial patterns and motion in space (Alibali, 2005; Allen, 2003; Melinger & Kita, 2007; Kita & Özyürek, 2003). In our study, adults' greater production of gestures in daily activity questions might come from the content of what they explain in 'Can you explain how to play your favorite game?" question. Moreover, because they were asked to describe a route in their home, it might be too easy for them to verbalize the visuospatial information without using gestures. The frequency of gesture production usually increases as a function of task difficulty (Suppes, Tzeng & Galguera, 2015). This finding is also in line with the previous findings that demonstrated developmental differences in gesture production when describing a target route (Austin & Sweller, 2018; Sekine, 2009). Austin and Sweller (2018) found that when describing route directions, children aged 3-4 years 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 about space and language. Moreover, Sekine (2009) found that 4-year-old children produced more gestures than 6-year-olds. Producing gestures might aid children to communicate on concepts that they are not yet able to express verbally (Austin & Sweller, 2018). In line with this, in our study, children produced more gestures in route description questions than daily questions. Moreover, in many instances, while adults described the “turn right” description verbally, children usually used a gesture only expression rather than a verbal description. This also demonstrate that children’s gesture production reveals their knowledge about space even when they have difficulty expressing it verbally. This brings us to another finding of our study that children’s spontaneous gesture frequency in route description question was related with their performance in recall of path information. Further analyses revealed that spontaneous gesture frequency of children predicted recall of path information controlling for condition effects, language abilities, working memory, and age. By producing gestures, children get the opportunity to practice concepts that exceed their verbal capacity (Goldin-Meadow & Alibali, 2013; Hostetter & Alibali, 2007). Children who produced gestures during the route description question might be better in conceptualizing space, which in turn result in a better recall of path information.

We also investigated whether the effects of gestures on children’s recall depend on any individual differences in language abilities and working memory capacity. We found that both children’s receptive and expressive language abilities were associated with their recall performance for both types of information. Children with higher language abilities recalled more information than children with lower language abilities. Moreover, children’s language abilities significantly predicted their recall performance for both types of information when we controlled for their gesture condition, working memory capacity, spontaneous gesture frequency, and age. However, our working memory tasks did not serve well to our aim in measuring individual differences across children. Most children failed to perform the backward digit span task. For the forward digit span, the variance was low; children usually could not proceed after the third series of numbers. Therefore, we failed to demonstrate individual variance across children for working memory capacity.

Studies revealed that producing gestures during the recall phase enhances the memory (So, Shum & Wong, 2015; Stevanoni and Salmon, 2005). Due to the limited number of children who produced gestures during the recall phase, we could not analyze how gesture production during recall may be related to children's memory. Stevanoni and Salmon (2005) found that children who produced gestures during recall performed better in retrieving the correct information. However, in their study children were instructed to gesture during the recall task. Indeed, they reported that children who were instructed to use gestures recalled more correct information than children who could engage in spontaneous gestures without any explicit instructions. We did not give any instructions about gesture production. However, we found that adults who engaged in gesture production during the recall phase performed better in recollecting information. Furthermore, regardless of the condition, the number of gestures produced predicted the recall of path information in adults. Previous research has also noted that adults and children produce gestures when recalling spatial information (Allen, 2003; Austin & Sweller, 2018). So, Shum, and Wong (2015) argued that gestures might be more effective than spatial language in encoding spatial information. They reported that adults who were encouraged to gesture during rehearsal recalled more than adult who were not encouraged to gesture. Similarly, Austin and Sweller (2014) found that producing gestures during recall helped participants retrieve spatial information. Our results support these previous findings on the benefits of gesture production on memory during the recall for adults.

Overall, the results of the current study suggest that observing iconic gestures, but not beat gestures, enhance recalling information from a narrative. Adults performed better than children in recalling all types of information. Children benefited from iconic gestures for the event information, but not for the path information. Moreover, children who produced more spontaneous gestures to answer route description questions also recalled more path information. Regardless of condition, children with higher language abilities recalled more information from a narrative that involved different paths and events. Finally, we also found that gesture production during the recall benefit adults in recall of information.

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TABLES

Table 1. Target information for path description and event information

Path Descriptions		Event Sequences	
Location	Direction	Object/Subject	Event
Dağlar/ The mountains	Etrafından dolanmak/ Walking around	Bank/Bank	Üstüne oturmak
Ağaçlı yol/ Path with trees	Arasından yürümek/ Passing through	Çiçek/ Flowers	Toplamak/ Picking up
Köprü/ Bridge	Üstünden geçmek/ Crossing over	Bir arkadaş/ A friend	Rastlamak/ Coming across with
Çit/ Fence	Üstünden atlamak/ Jumping over	Kediler/ The cats	Sevmek/ Petting
Sofra/ Table	Yanından geçmek/ Passing by	İki arkadaş/Two friends	Sarılmak//Hugging

Table 2. Descriptive statistics for three conditions

		N	Mean	SD	Min	Max
Age	Iconic	24	64.43	5.089	56	72
	Beat	23	63.45	5.289	54	73
	No gesture	23	64.14	4.814	55	72
	Total	70	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	.57	.945	0	3
	Beat	24	.70	1.063	0	3
	No gesture	23	.50	.913	0	3
	Total	71	.59	.966	0	3
TEDIL_receptive	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
TEDIL_expressive	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
Gesture production	Iconic	24	9.65	8.370	0	33
	Beat	24	7.30	7.801	0	28
	No gesture	23	5.82	4.797	0	17
	Total	71	7.62	7.261	0	33

Table 3. Descriptive statistics for effects of conditions on children's recall performances

		N	Mean	SD	Min	Max
Total Free Recall	Iconic	24	27.06	12.30	0	45
	Beat	24	21.63	15.38	0	52.5
	No gesture	23	20.34	12.82	0	45
	Total	71	23.05	13.69	0	52.5
Event Free Recall	Iconic	24	35.43	19.06	5	70
	Beat	24	22.60	17.70	0	55
	No gesture	23	23.63	13.90	0	50
	Total	71	27.27	17.81	0	70
Spatial Free Recall	Iconic	24	19.13	13.62	0	50
	Beat	24	20.65	18.48	0	60
	No gesture	23	17.04	15.40	0	40
	Total	71	18.97	15.80	0	60
Recognition Task	Iconic	24	7.65	1.50	4	10
	Beat	24	7.52	1.44	4	10
	No gesture	23	7.05	1.68	4	10
	Total	71	7.41	1.54	4	10

Table 4. Descriptive statistics for effects of conditions on adults' recall performances

		N	Mean	SD	Min	Max
Total Free Recall	Iconic	17	60.29	14.22	40	92.5
	Beat	16	45.00	22.64	0	95
	No gesture	16	48.44	18.84	15	72.5
	Total	49	51.30	19.66	0	95
Event Free Recall	Iconic	17	52.06	21.07	30	85
	Beat	16	38.82	22.81	0	90
	No gesture	16	45.63	20.15	0	75
	Total	49	45.50	21.67	0	90
Spatial Free Recall	Iconic	17	68.53	15.98	45	100
	Beat	16	51.18	28.31	0	100
	No gesture	16	54.38	23.30	10	85
	Total	49	58.10	23.88	0	100
Recognition Task	Iconic	17	9.47	.62	8	10
	Beat	16	8.75	1.44	6	10
	No gesture	16	8.94	1.24	6	10
	Total	49	9.06	1.16	6	10

Table 5. Descriptive statistics for children's gesture production

	Mean	SD	Min	Max
Total	8.51	7.07	0	33
Daily Questions	1.52	3.35	0	22
Route Direction Questions	6.33	5.05	0	28
Free Recall	.65	1.34	0	9
Iconic	3.89	4.47	0	22
Deictic	1.84	2.28	0	10
Iconic-deictic	2.16	2.59	0	10
Others (beat & emblems)	.76	1.29	0	7
Location	1.90	2.27	0	9
Direction	3.81	3.50	0	20

Table 6. Descriptive statistics for adults' gesture production

	Mean	SD	Min	Max
Total	36	20.59	2	91
Daily Questions	15.47	10.96	0	53
Route Direction Questions	8.24	5.99	0	25
Free Recall	12.29	9.43	0	33
Iconic	17.43	11.33	0	53
Deictic	2.71	2.98	0	12
Iconic- deictic	0	0	0	0
Beat	14.76	10.16	0	46
Others (emblems)	.78	1.51	0	9
Location	1.84	2.68	0	12
Direction	4.90	4.50	0	25

Table 7. Correlations among children's individual differences in working memory, language abilities, spontaneous gesture frequency and recall scores, *p < .05, **p < .01.

	1	2	3	4	5	6	7	8	9	10
1. Forward digit span score	1									
2. Backward digit span score	.243*	1								
3. TEDIL_receptive score	.560**	.404**	1							
4. TEDIL_expressive score	.375**	.472**	.507**	1						
5. Gesture frequency_total	.179	.271*	.219	.172	1					
6. Gesture frequency_daily questions	-.014	.183	-.069	-.034	.687**	1				
7. Gesture frequency_route description	.245*	.247*	.330**	.254*	.860**	.258*	1			
8. Recall in event information	.194	.125	.324**	.295*	.132	.040	.117	1		
9. Recall in path information	.155	.158	.458**	.402**	.206	-.070	.329**	.304*	1	
10. Total recall	.222	.164	.474**	.430**	.197	-.022	.260*	.831**	.781**	1

Table 8. Multiple regression analyses for total free recall in children, *p < .05, **p < .01.

	Adjusted R Square	R Square Change	F Change	B	SE	β
Variables						
	.193	.268	3.59			
Iconic condition				6.27	3.80	.218
Beat condition				.376	3.73	.013
Age (in months)				-.607	.314	-.224
Forward digit span score				.873	1.25	.084
TEDIL_expressive score				1.96	.548	.438**
Spontaneous gesture frequency				.114	.217	.061

Table 9. Multiple regression analyses for recalling event information in children, *p < .05, **p < .01.

	Adjusted R Square	R Square Change	F Change	B	SE	β
Variables						
	.155	.233	2.99			
Iconic condition				11.9	5.023	.318*
Beat condition				-2.04	4.990	-.054
Age (in months)				-.722	.423	-.203
Forward digit span score				1.55	1.661	.113
TEDIL_expressive score				1.82	.731	.311*
Spontaneous gesture frequency (daily activity questions)				-.059	.632	-.011

Table 10. Multiple regression analyses for recalling path information in children, *p < .05, **p < .01.

	Adjusted R Square	R Square Change	F Change	B	SE	β
Variables						
	.155	.233	2.99			
Iconic condition				.132	4.48	.004
Beat condition				2.81	4.41	.084
Age (in months)				-.506	.372	-.161
Forward digit span score				-.302	1.48	-.025
TEDIL_expressive score				1.899	.656	.367**
Spontaneous gesture frequency (route description questions)				.753	.369	.249*

FIGURES

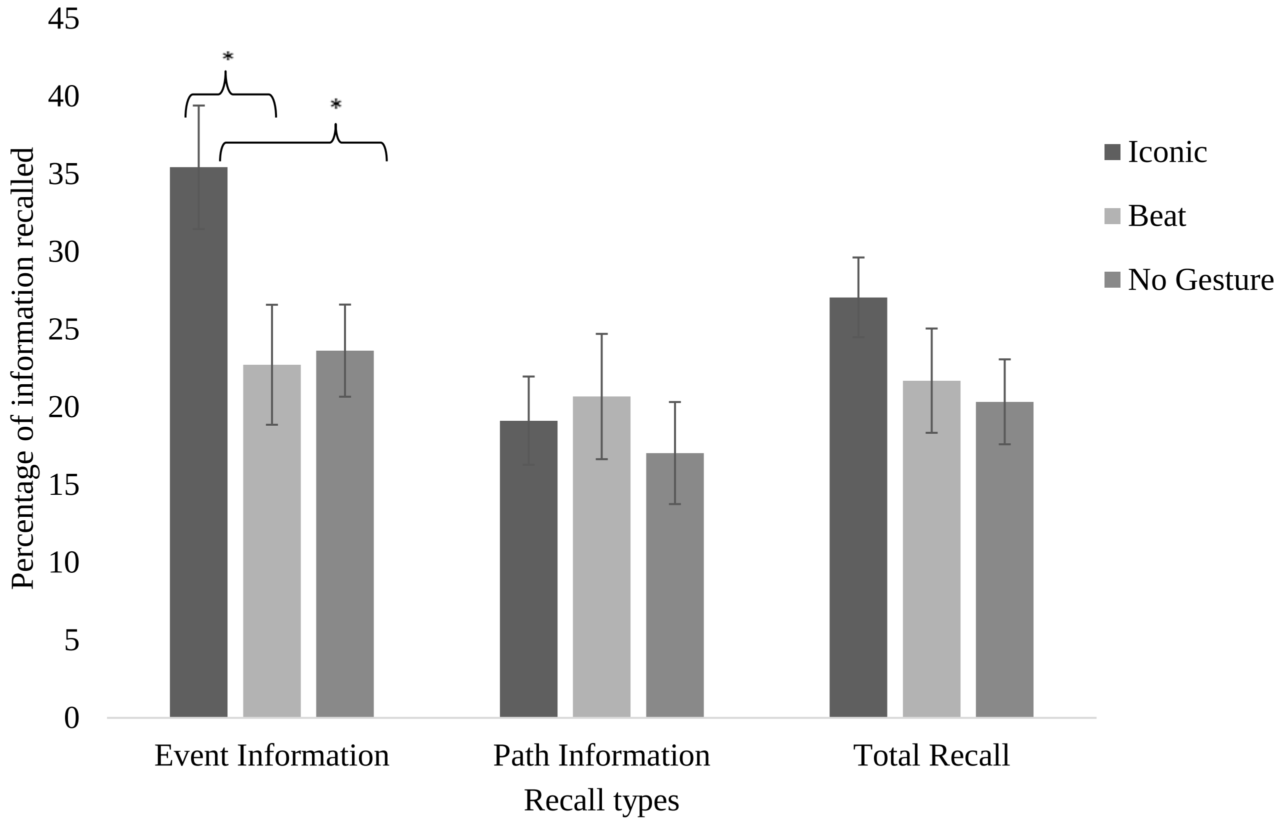


Figure 1. The mean percentages of event and path information recalled during free recall of children for each condition. Error bars represent standard errors, *$p < .05$.

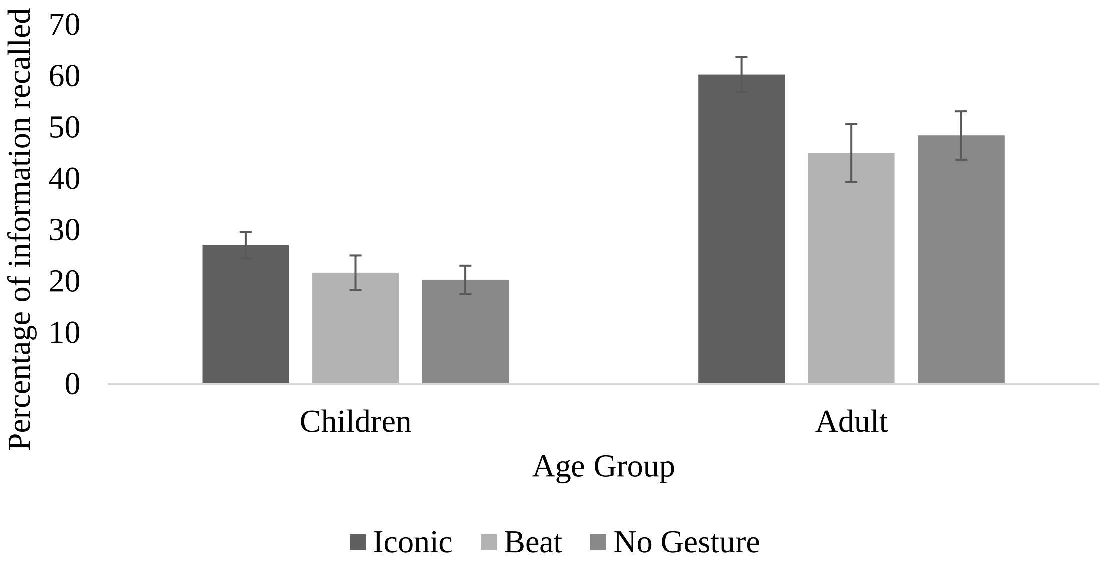


Figure 2. Percentages for the total free recall of children and adults for each condition. Error bars represent standard errors.

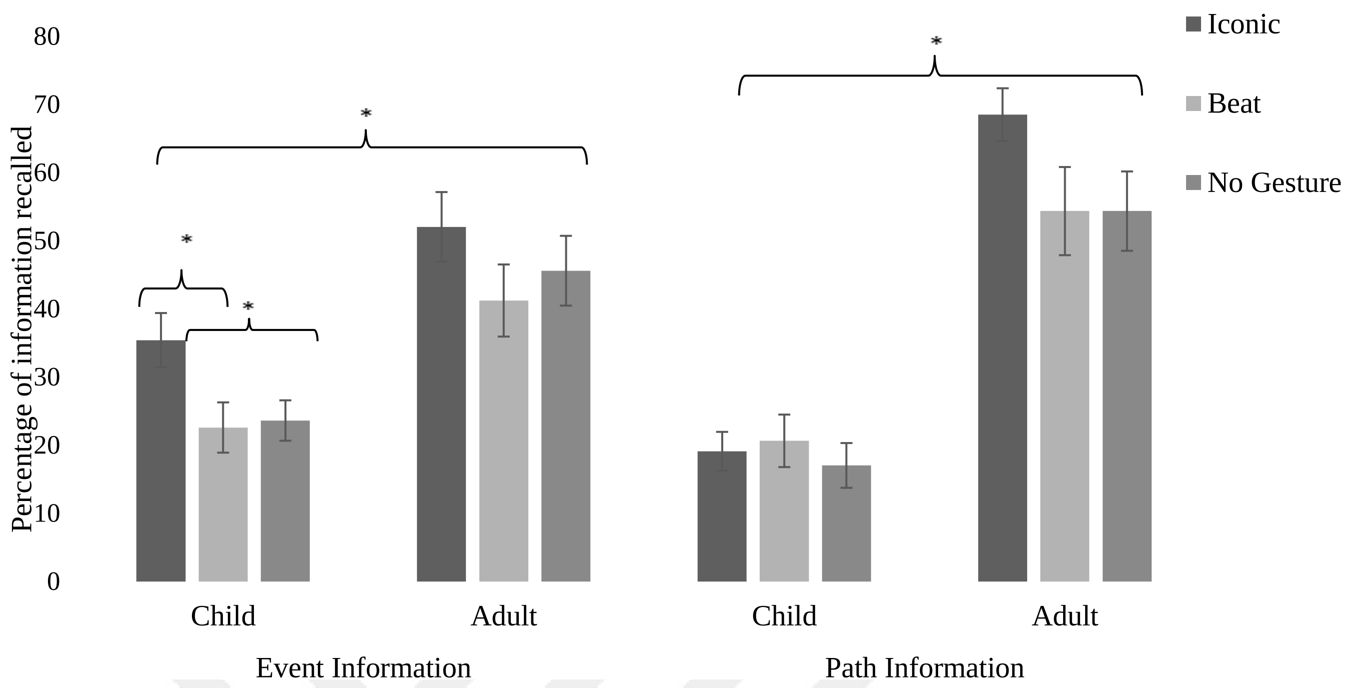


Figure 3. The mean percentages of event and path information recalled during free recall of children and adults for each condition. Error bars represent standard errors, *$p < .05$.

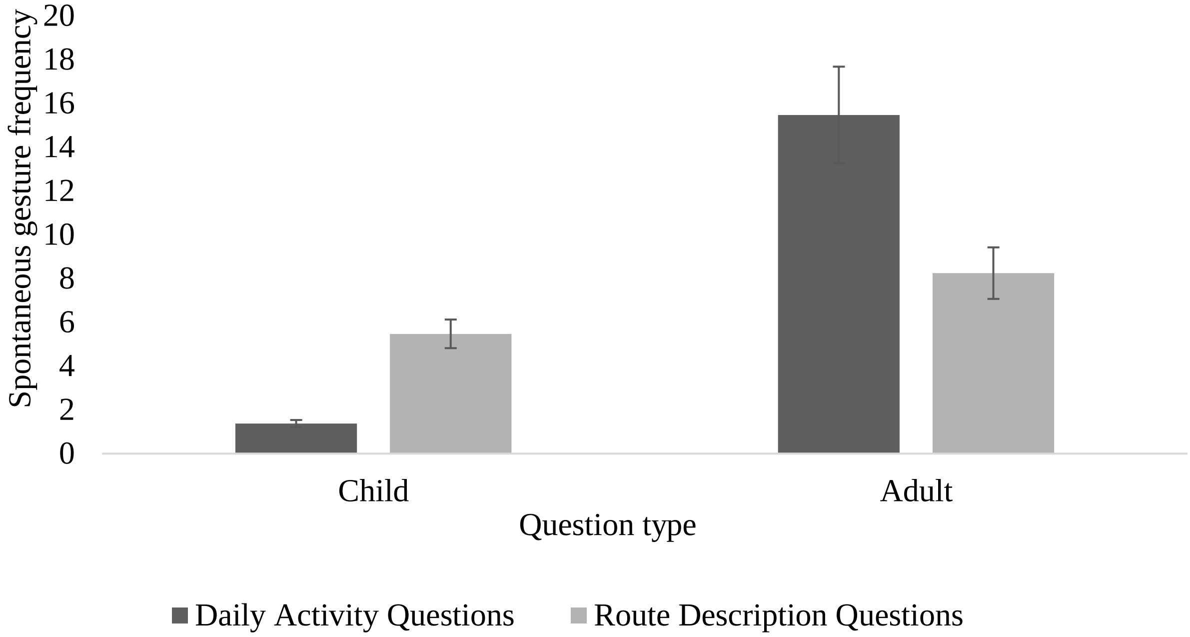


Figure 4. Number of gestures produced spontaneously during the initial questions (2 daily activity and 2 route description questions). Error bars represent standard errors**.**

APPENDICES

Appendix A

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 with 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 flowers.
5) Then, she came across with a river, she crossed over a bridge to pass the river.

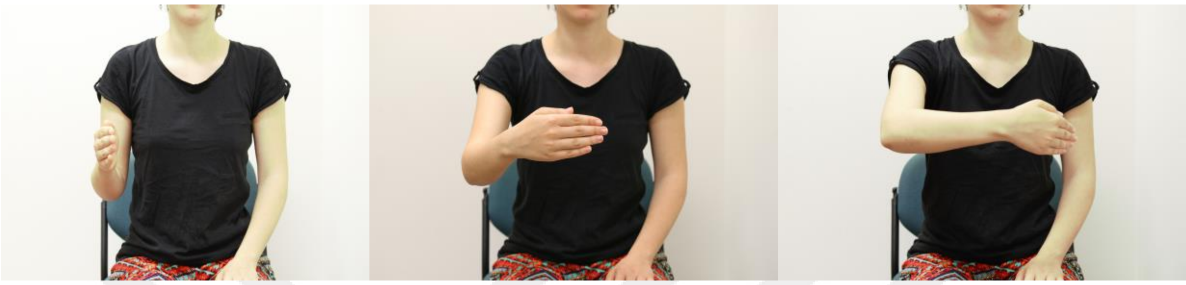
6) After she crossed over the bridge, she came across with a friend and chatted for a while.
7) Zeynep moved on and saw the garden of the house and jumped over the fence.
8) She saw cats in the garden and she petted the cats.
9) She passed by the table that Ceren had prepared and went to the door and ringed the bell.
10) Two friends who got very happy to finally get together hugged each other.

Appendix B

The Gestures at the Encoding

Iconic gestures for path descriptions

1) Dağların etrafından dolanmak/Walking around the mountains

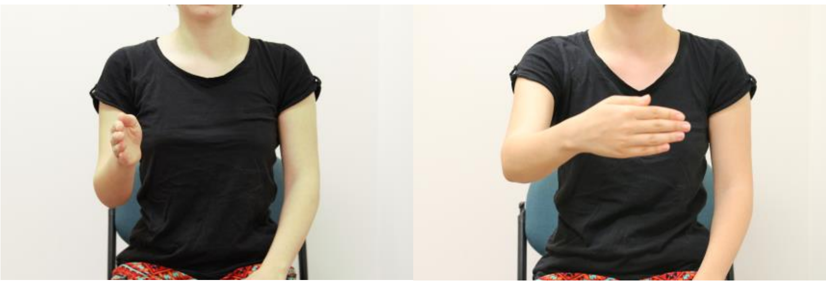


2) Ağaçların arasından yürümek/Passing through trees

3) Köprünün üstünden geçmek/Crossing over the bridge

4) Çitlerin üzerinden atlamak/Jumping over the fence

5) Sofranın yanından geçmek/Passing by the table

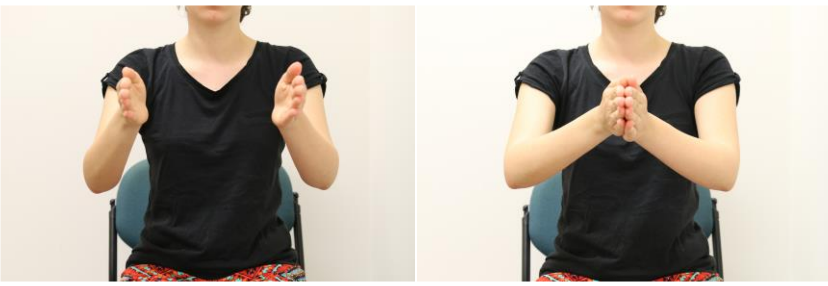


Iconic gestures for event information

1) Bankın üstüne oturmak/ Sitting on a bank

2) Çiçek toplamak/Picking up flowers

3) Arkadaşla karşılaşmak/Coming across with a friend



4) Kedileri sevmek/Petting the cats

5) Sarılmak/Hugging

Beat Gestures

1) One-hand beat gesture

2) Two-hands beat gesture

Appendix C

Recognition Task

1) Zeynep ilk önce hangisinden geçmiş?

    a) Ağaçlı yol

    b) Dağlar

2) Zeynep nerede dinlenmiş?

    a) Bankın üstünde

    b) Ağacın gölgesinde

3) Zeynep ağaçlı yoldan nasıl geçmiş?

    a) Ağaçların etraflarından dolanmış

    b) Ağaçların arasından yürümüş

4) Zeynep ağaçlı yolda hangisini toplamış?

    a) Meyve

    b) Çiçek

5) Zeynep nehri nasıl geçmiş?

    a) Köprünün üstünden

    b) Köprünün altından

6) Zeynep köprüden indiğinde hangisine rastlamış?

    a) Bir arkadaşına

    b) Kedilere

7) Zeynep bahçeye nasıl girmiş?

    a) Çitlerin yanından geçerek

    b) Çitlerin üzerinden atlayarak

8) Zeynep bahçede ne yapmış?

    a) Kedileri sevmiş.

b) Çiçek toplamış.

9) Zeynep kapıya nasıl gitmiş?

a) Sofranın önünden geçerek

b) Sofranın yanından geçerek

10) Zeynep ve Ceren birbirlerini görünce ne yapmışlar?

a) Sarılmışlar.

b) Sohbet etmişler.

1) Which one did Zeynep pass first?

a) The path with trees

b) The mountains

2) Where did Zeynep take rest?

a) On the bank

b) Under the tree

3) How did Zeynep pass the trees?

a) Walked around the trees

b) Passed through trees

4) What did Zeynep pick up?

a) Fruit

b) Flower

5) How did Zeynep pass the river?

a) Crossed over the bridge

b) Crossed under the bridge

6) Which one did Zeynep encounter after she crossed the bridge?

a) A friend

b) The cats

7) How did Zeynep enter the garden?

a) Passing by the fence

b) Jumping over the fence

8) What did Zeynep do in the garden?

a) Petted the cats

b) Picked up flowers

9) How did Zeynep go to the door?

a) Passing in front of the table

b) Passing by the table

10) What did two friends do when they see each other?

a) Hugged each other

b) Chatted