warwick.ac.uk/lib-publications

Seeing Iconic Gestures while Encoding Events Facilitates Children's Memory of these Events

Suzanne Aussems & Sotaro Kita

University of Warwick

Author Note

Suzanne Aussems, Department of Psychology, University of Warwick

Sotaro Kita, Department of Psychology, University of Warwick

Correspondence concerning this article should be addressed to Suzanne Aussems,

Department of Psychology, University of Warwick, Coventry CV4 7AL, United Kingdom.

Contact: s.aussems@warwick.ac.uk

Abstract

An experiment with 72 three-year-olds investigated whether encoding events while seeing iconic gestures boosts children's memory representation of these events. The events, shown in videos of actors moving in an unusual manner, were presented with either iconic gestures depicting how the actors performed these actions, interactive gestures, or no gesture. In a recognition memory task, children in the iconic gesture condition remembered actors and actions better than children in the control conditions. Iconic gestures were categorized based on how much of the actors was represented by the hands (feet, legs, or body). Only iconic hand-as-body gestures boosted actor memory. Thus, seeing iconic gestures while encoding events facilitates children's memory of those aspects of events that are schematically highlighted by gesture.

Keywords: recognition memory, encoding action events, iconic gestures

Seeing Iconic Gestures while Encoding Events Facilitates Children's Memory of these Events

Children spend a considerable proportion of their day watching what other people do. Accurate memory of *who* did *what* is crucial for their social-cognitive development, because it lies at the core of social interactions (Vogelsang & Tomasello, 2016), cooperative activities (Milward, Kita, & Apperly, 2014), and learning how things "ought" to be done (Burdett et al., 2016; Schmidt, Rakoczy, & Tomasello, 2016). To make sense of the events they see, children must learn how to encode, process, and organize the various aspects of those events. Children can recognize people's actions in impoverished stimuli such as point-light displays at age 3 (e.g., Golinkoff et al., 2002), but rich action events with real people are much more complex to encode. This study focuses on children's memory of such events, more specifically, their memory representation of real-life actors and their actions.

The Challenge of Encoding Action Events

Action events are difficult to encode for young children (Imai, Haryu, & Okada, 2005). The challenge that they must overcome is understanding that an action event consists of both stable components such as people and objects, and transient components such as the things that people do (e.g., actions such as yawning or jumping). The transient nature of actions makes it difficult for children to remember them. In an event recognition task, children remember stable aspects of events (e.g., objects) better than actions (Imai et al., 2005). Because actions are transient and other aspects of an event are stable, it is also difficult for children to focus on an action as the sole referent of a verb. Word learning tasks in which children were taught a verb while watching an actor performing an action on an object (e.g., whipping the whisk) showed that children map a verb to the combination of an object and action, rather than to action alone

(Imai et al., 2005; 2008). Verb learning studies have repeatedly demonstrated that 3-4-year-old children focus too much on stable aspects of action events (e.g., objects, instruments, actors) rather than on actions (Behrend, 1990; Forbes & Farrar, 1993; Imai et al., 2005; 2008; Kersten & Smith, 2002). This focus on stable aspects prevents children from generalizing action labels to novel events in which the same actions are shown, but the objects, actors, or instruments have changed.

Encoding with the Help of Iconic Gestures

In the current paper, we investigate whether seeing iconic gestures helps children to encode an action event in a recognition memory task. People naturally produce iconic gestures when they speak (McNeill, 1985). Iconic gestures are referential symbols, which function via their formal and structural resemblance to events, objects, or people (McNeill, 1992). For instance, an iconic gesture can depict the things that people do (e.g., wiggling the index and middle fingers to depict a person walking).

Observing iconic gestures while encoding *verbally presented* information (e.g., words, explanations) can influence children's performance in a subsequent task, in which they use the encoded information (e.g., a recall task, a test of word meaning, problem solving). Three lines of evidence support this. First, iconic gestures facilitate memory for familiar and novel words. For instance, 4-5-year-old children recalled more familiar words (e.g., look, swim, brush) when they encoded these words while observing iconic gestures which were semantically related to those words than when encoding words alone (So, Chen-Hui, & Wei-Shan, 2012). Additionally, 5-year-old French children who encoded common English words while observing iconic gestures that depicted the meaning of those words recalled more words than children who encoded the

same words while observing pictures showing the word meanings (Tellier, 2008). Second,

children use iconic gestures to disambiguate the meanings of novel verbs. In an experiment by

Goodrich and Hudson Kam (2009), 3- and 4-year-olds were taught two novel verbs for actions

performed by a puppet on unfamiliar toys (e.g., rolling down a ramp in a tube). The experimenter

demonstrated two actions, one at a time. Subsequently, the experimenter taught the children one

verb per action, while accompanying each verb with an iconic gesture that depicted the action

(e.g., rolling down the ramp gesture; index finger tracing circles while moving downward at an

angle). When the children were subsequently asked "Which toy lets the puppet go (*novel verb*)-

ing?" (without a gesture), they picked the toy which operated in the way that corresponded to the

verb. Third, iconic gesture facilitates learning of verbally explained strategies for problem

solving. In a study by Ping and Goldin-Meadow (2008), 5-7-year-olds received verbal

instructions on how to solve Piagetian conservation problems. For instance, in the case of liquid

conservation with two differently shaped glasses that contained the same amount of water, an

experimenter explained to children that one glass was tall and skinny and the other was short and

wide. The explanation was either accompanied by iconic gestures indicating the height and width

differences between the glasses, or no gesture. For half of the children, the glasses were not

present during this instruction, and thus the gestures iconically depicted the dimensions of the

glasses. The participants were then asked whether the amount of water in the two glasses was the

same and if they could explain their answer. Children who saw iconic gestures during the

instruction solved the quantity conservation problems more often than children who did not see

gesture, even when the objects were not present during the instruction. The above studies

indicate that seeing iconic gestures influences how children encode and subsequently use

verbally presented information. However, much less is known about how seeing iconic gestures influences memory of *nonlinguistic* information, for instance, memory of events.

Seeing Iconic Gestures Influences How Children Recall Events

Previous research on the impact of seeing iconic gestures on children's event memory always presented children with iconic gestures at the recall stage, but never at the encoding stage. For instance, research on eyewitness testimony suggests that seeing iconic gestures at the recall stage can alter children's memory representation of an event long after they have witnessed this event. In a study by Broaders and Goldin-Meadow (2010), a musician visited 5-6-year-olds in their classroom and in the weeks after the visit, the children were asked questions about the appearance of the musician in scripted interviews. During the questioning, the interviewer conveyed misleading information in gesture (e.g., moving the hand towards the head as if putting on a hat), but not in speech (e.g., "What was the musician wearing?"). In their responses to the interviewer's questions, children often said that the musician wore a hat, which was false. This information corresponded to what was encoded in the interviewer's gestures, but not in their speech. When children narrated the event in a free recall task a few weeks after the scripted interviews, their stories included information gleaned from the interviewer's gestures during the scripted interviews. Children had thus incorporated misinformation from the interviewer's gestures in their memory representation of the event.

One might argue that children are prone to the influence of seeing iconic gestures at the recall stage, because they presume that the experimenter is signaling the correct answers to them. However, Kirk, Gurney, Edwards, and Dodimead (2015) showed that the influence of iconic gesture cannot solely be attributed to such a demand characteristic. In their study, 2-4-year-olds

and 7-9-year-olds watched a video clip showing a series of events (e.g., a lady and a man roller-skating) and were required to narrate the events to the experimenter afterwards. The experimenter then questioned the children about the events (e.g., "What was the lady wearing?") under one of two conditions: accurate gesture (e.g., moving the hands towards the head as if putting on a hat) or misleading gesture (e.g., moving the left hand over the right hand as if putting on a glove). The lady in the video clip was in fact wearing a hat, but no gloves. After the interview, the children narrated the events again to the experimenter. In both gesture conditions and both age groups, children's post-interview narrations included information that was absent from their pre-interview narrations, but consistent with information the experimenter had encoded in gesture during the interview. Seeing iconic gestures at the recall stage thus changed children's memory of events. Importantly, when children retold their version of the witnessed events after the interview, they added more information gleaned from accurate gestures than from misleading gestures to their stories, which rules out the possibility that gestures represent a *demand characteristic* (i.e., children concur indiscriminately with any information conveyed by the experimenter's gestures under the presumption that the experimenter is signaling the correct answers to them).

To summarize, seeing iconic gestures influences children's memory of *verbally presented* information and *nonlinguistic* information. However, research on the influence of seeing iconic gestures on children's event memory is sparse, and in such studies, iconic gesture was always manipulated at the recall stage (Broaders & Goldin-Meadow, 2010; Kirk et al., 2015), but never at the encoding stage. From these studies, we can conclude that children's memory representation of an event is prone to the influence of (misleading) nonverbal cues at the recall stage. Yet, it remains unclear how seeing iconic gestures when children encode an event may

influence their memory representation of this event. In the current study, children performed an event recognition task, in which iconic gestures were manipulated at the encoding stage. Specifically, we asked whether encoding action events with the help of iconic gestures leaves children with a stronger memory representation of these events.

Possible Mechanism

Observing iconic gestures can draw children's attention to certain aspects of an event and boost their memory of those aspects. Iconic gestures can encode information in an abstract, schematic manner (Kita, 2000; de Ruiter, 2000). For example, when depicting the hopping movement of a bunny going down a slope, an iconic gesture can capture this information simply by tracing the animal's trajectory (using the extended index finger to trace an arch for every hop, while generally going downward diagonally). Such a gesture focuses on the manner and path of the motion, stripping it from everything else (e.g., what the bunny looked like, any background objects and characteristics of the landscape).

The literature on gesture production suggests that the schematic nature of the gestural representation shapes the self-oriented function of gesture (Goldin-Meadow, 2015; Kita, Alibali, & Chu, 2017; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Novack & Goldin-Meadow, 2016). More importantly for the current study, Kita et al. (2017) claim that the schematic nature of the gestural representation impacts *how the observer processes information* about complex events. Because schematic representations highlight only a certain aspect of a complex event, they may help observers to focus on certain information in the event. This idea is supported by a study which demonstrates how iconic gestures shape children's interpretations of novel verb meanings. Mumford and Kita (2014) taught 3-year-olds novel verbs that could be

interpreted as manner verbs (e.g., "to pull") or change-of-state verbs (e.g., "to break"). In one of

the trials, children saw a video of a hand creating a cloud shape by pushing pieces of paper

together with the index finger. Children were then taught a novel verb by the experimenter; for

some children, the experimenter produced a manner gesture (e.g., representing the manual action

of pushing the pieces into place), and for others, the experimenter produced an end-state gesture

(e.g., tracing the final cloud shape these pieces formed). Children's performance on a verb

generalization task showed that they interpreted the novel verb meanings consistent with

information encoded in gesture: as manner verbs when they saw iconic manner gestures and as

change-of-state verbs when they saw iconic end-state gestures. Thus, the schematic

representation in iconic gesture directed children's attention to a particular aspect of a complex

event.

The Current Research

This study investigates whether seeing iconic gestures facilitates children's recognition

memory of action events. The events, which included videos of real-life actors moving across a

scene in an unusual manner, were presented in three gesture conditions. The first condition

showed iconic gestures depicting how the actors in the action events moved (i.e., their manner of

locomotion). The second condition showed interactive gestures (Bavelas, Chovil, Lawrie, &

Wade, 1992), which communicated excitement and surprise to the children, but were unrelated to

the action events. The third condition showed no gestures at all. After a delay, children were

asked to point out the video that they had seen before in a two-way forced choice task. Their

memory of both actions and actors was tested. For action memory, children chose between the

seen video and a video that included the same actor moving in a different manner, and for actor

memory they chose between the seen video and an unseen video that included a different actor

moving in the same manner (cf. Imai et al., 2005).

When children encode events while observing iconic gestures that represent how an actor

moves, this may leave a stronger trace in children's memory because a schematic gestural

representation focuses children's attention on the motion event itself as opposed to other

information (e.g., details of the scene). Thus, we predict that seeing iconic gestures which

highlight how an actor moves will boost children's action memory compared to seeing

interactive gestures, or no gesture. As the iconic gestures also represent, to some extent, the actor

who is carrying out the movement (e.g., both hands flicking upward to represent the actor's legs

while marching), we predict that children's actor memory will also be boosted when they see

iconic gesture, compared to seeing interactive gesture, or no gesture at all. However, since

manner of motion is omnipresent in the gestures and in most cases only part of the actor's body

is gesturally represented, we predict that action memory will be boosted more so than actor

memory.

Furthermore, we predict that the extent to which the actor is represented in gesture could

have an impact on actor memory. In our iconic gestures, the hands represent either the feet, legs,

or body of the actors to depict how they moved. While the gestures do not express any person-

specific features of the feet, legs or body (e.g., a particular actor with long legs), they should

draw children's attention to particular aspects of the actor that they depict. This idea is supported

by a previous finding that iconic gestures can make children focus on a particular aspect of a

complex event in a verb learning task (Mumford & Kita, 2014). We inferred that when children

focus on the actors' bodies, they have more opportunities to pick up person-specific information,

as compared to when they focus on their feet or legs. Thus, observing a hand-as-body gesture

should lead to better actor memory; that is, actor memory performance increases as more of the

actor is represented in gesture (e.g., hand-as-body gestures > hand-as-leg gestures > hand-as-foot

gestures). If this prediction is borne out, then this is also in line with the idea that gesture

schematizes information, which helps children to focus on particular aspects of events.

Method

Design

The experiment had a mixed 3 x 2 x 3 design with gesture type as a between-subjects

factor (iconic gesture vs. interactive gesture vs. no gesture) and memory type (action memory vs.

actor memory) and semiotic type (feet vs. legs vs. body) as within-subjects factors. The

dependent variable was children's performance in each of 12 trials of an event recognition

memory task (binary: 1=correct, 0=incorrect).

Participants

The data were collected between the 23rd of March 2016 and the 27th of September 2016.

Our sample size was determined a priori using G*Power version 3.1.9.2 (odds ratio=2.30,

α=0.05, power=0.80). We recruited 85 typically developing children from a database of families

who showed interest in participating in child research and from six public and private nurseries

in the West-Midlands and Warwickshire, England. A total of 13 children were excluded because

they were outside the age range on the day of testing (N=11), or pointed exclusively to answers

on one side of the screen in test trials (N=2). The final sample included 72 children (35 girls)

between the ages of 35–48 months old (M=41.11, SD=3.67). There were 24 children in each of

the three gesture conditions. The gender distribution of the children was the same across

conditions χ^2(2)=0.11, p=.946, as well as their age in months, F(2, 69)=0.58, p=.561. All

children were exposed to the English language at home for >75% of the time (as indicated by their caregivers). Informed parental consent was obtained for all participants. In return for their participation, nurseries received a voucher for educational goods and children who were tested in the research lab received a certificate.

Materials

A set of 48 short video clips (4-14 seconds) was taken from the GRACE video database (Aussems, Kwok, & Kita, 2017; in press). The set included videos of 24 actors (12 males, 12 females), each performing two of 24 unusual actions (see Table A1 in Appendix A). Actors always moved from the left side to the right side of a scene such that the *path* of motion was the same for each action, but the *manner* of motion differed. To create a two-way forced choice task, we organized the actions in 12 pairs of distinctive actions. Actions within each pair were depicted by *one* male actor and *one* female actor in separate videos. Trials on which we tested for children's memory of actors always showed a distractor video of an actor of the opposite gender performing the same action as the actor in the target video, because males and females have naturally distinct appearances. We chose this set-up because we did not want to make the task too difficult for the children. Each action pair was performed by different pairs of male actors and female actors, whose videos were normed for how similar the same actions by different actors were and how dissimilar the different actions by the same actor were. The videos are available from Warwick Research Archive Portal (WRAP) at http://wrap.warwick.ac.uk/78493/. Stimuli were displayed using slide presentation software Microsoft Office PowerPoint 2016 on a 14" touchscreen laptop.

Procedure

Children were tested individually in a quiet area of their nursery or in the research lab at the university. A female experimenter sat down with the children at a children's table with small chairs, always positioning herself to the child's left side. The memory task consisted of two phases: an encoding phase and a recognition phase. In the encoding phase, children were told that they were going to watch videos with the experimenter on a touch screen computer. A big button with a smiling star appeared on the screen and children were instructed to press the star with their index finger to start a video. Children were presented with 12 videos, which showed 12 unusual actions performed by different actors (six males, six females). Each video was shown twice in the following way. When the video played the first time the experimenter said: "Wow! Look at what he (or she) is doing!" and when the video played the second time the experimenter said: "Oh! Look, he (or she) is doing it again!". Depending on the condition, the experimenter produced iconic gestures, interactive gestures, or no gesture.

Figure 1 shows the three gesture conditions used in the experiment. Iconic gestures depicted the manners in which actors moved across a scene in hand shape and in motion. Interactive gestures indicated excitement and surprise, but were unrelated to the events (see Figure B1 in Appendix B for more detail). In the no gesture condition, the experimenter kept her hands in her lap while children viewed the action events.

-Insert Figure 1 about here-

Each iconic gesture matched one manner of motion. Iconic gestures were categorized into three semiotic types (see Figure 2). First, hand-as-foot gestures depicted the actors' manners of motion by representing the actors' feet with both hands (the left panel in Figure 2; the hand shape and the alternating circular hand movements resemble the actor's creeping feet

movements). Second, hand-as-leg gestures depicted the actors' manners of motion by

representing the actors' legs with both hands (the mid panel in Figure 2; the hand shape and the

alternating lifting movements resemble the actor's trotting leg movements). Third, hand-as-body

gestures depicted the actors' manners of motion by representing the body with one hand (the

right panel in Figure 2; bending the hand at the wrist resembles the actor's body bending at the

torso).

-Insert Figure 2 about here-

All gestures were performed for the entire duration of a video and the experimenter

alternated her gaze between the child and the video (and did not look at her own gestures).

Gestures were produced in the left part of the children's field of vision, in front of their left

shoulder and at eye height, so that they would not have to turn their heads to look at the gestures

while watching the videos. Note that the children were not instructed to look at the

experimenter's gestures or remember the actors or actions. Children were not told about the

upcoming test trials either.

After the encoding phase, children spent approximately five minutes decorating a

wristband with colorful stickers. The experimenter asked children to count the stickers and name

the colors during this distraction task.

The recognition phase consisted of two practice trials and 12 experimental trials. During

practice trials participants saw a picture of a cat and a dog on the left and right sides of the

screen. Children were asked to point (without touching the screen) at the cat and the dog to

familiarize them with pointing at both sides of the screen. The experimental trials each showed

two videos playing simultaneously side-by-side (see Figure 3). Half of the test trials tested action

memory and the other half actor memory. In action memory trials, six of the videos that children

had seen during the encoding phase were paired up with videos of the same actor performing a

different action. In actor memory trials, the other six videos from the encoding phase were paired

up with videos of a different actor performing the same action. In each trial, the experimenter

asked the child "Which one did you see before?". The experimenter looked at the child when

making this request and did not look at the screen. The videos played automatically on loop until

the child pointed at one of them. If the child did not respond or asked whether a video was shown

before, the question was repeated until a video was chosen. If the child pointed at both videos,

the experimenter asked the child to pick one.

-Insert Figure 3 about here-

Randomization and Counterbalancing

We created 24 versions of the experiment in which every stimulus video appeared as a

target and distractor on action memory trials and actor memory trials. We counterbalanced the

gender of the actors in the videos, the left-right position of the videos on the screen, and we

randomized the order of trials in each experiment version. Children were randomly assigned to

conditions using the nursery registers, which were either ordered alphabetically by the children's

surname or by their date of birth. One nursery did not provide a register and the experimenter

used the order in which the consent forms were received. The conditions were rotated across

participants within each testing site, and the experimenter continued the order of conditions when

a participant was tested in the research lab in between nursery visits. Participants from each

testing site were thus presented equally in each condition.

Data Analysis

Our binary dependent variable (correct vs. incorrect responses in the recognition memory task) was analyzed using mixed-effects logistic regression analyses. We used a maximal random-effects structure in all models (cf. Barr, Levy, Scheepers, & Tily, 2013), by including random slope variation, random intercept variation, and the covariance between the two, for participants and items. All analyses were carried out in the R software for statistical analyses (R Development Core Team, 2011) with the *lme4* package (Bates, Mächeler, Bolker, & Walker, 2015). Using likelihood ratio tests (χ^2), we compared each model with updated versions of the model that systematically excluded the main effect and interaction terms of interest. Both marginal and conditional R^2 values were calculated using the *piecewiseSEM* package (Nakagawa & Schielzeth, 2013). Marginal R^2 reflects variance explained by fixed factors and conditional R^2 reflects variance explained by both fixed and random factors. The raw data file and the R Markdown file with the analyses and plot code are available from the Open Science Framework at https://osf.io/tqk34/.

Results and Discussion

General Findings

Figure 4 shows children's recognition memory performance organized by gesture type and memory type. Children's recognition memory performance (correct vs. incorrect) was entered into a mixed-effects logistic regression analysis with gesture type as between-subjects factor and memory type as within-subjects factor. The main effect of gesture type was significant, $\chi^2(2)=13.18$, $p=.001$, but not the main effect of memory type, $\chi^2(1)=0.25$, $p=.617$, or the interaction, $\chi^2(2)=2.89$, $p=.236$. The model explained approximately 10% of the variance in children's recognition memory performance (marginal $R^2=.03$, conditional $R^2=.10$).

-Insert Figure 4 about here-

To further explore the nature of the main effect of gesture type, we examined the beta estimates in a comparison of the three gesture conditions. Children's recognition memory performance was significantly better in the iconic gesture condition than in the interactive gesture condition (β=-0.99, *SE*=0.27, *p*<.001) and the no gesture condition (β=-0.79, *SE*=0.27, *p*=.003). Then, we compared recognition memory performance between the two control conditions by releveling gesture type with the interactive condition as the reference point. The performance did not differ significantly between the interactive gesture condition and the no gesture condition (β=0.20, *SE*=0.25, *p*=.426).

To investigate whether children showed a better recognition memory performance than chance for each of these gesture types, we compared the proportion of correct trials in each condition against a test value of 0.5 (chance level of 50%). The proportion of correct trials was analyzed with one-sample t-tests in which equal variance was assumed. In the iconic gesture condition, children's memory performance was significantly above chance (*M*=0.70, *SD*=0.21, *t*(23)=5.71, *p*<.001, 95% CI [0.63, 0.77]), as well as in the no gesture condition (*M*=0.58, *SD*=0.16, *t*(23)=3.05, *p*=.006, 95% CI [0.52, 0.63]), but not in the interactive gesture condition (*M*=0.55, *SD*=0.22, *t*(23)=1.26, *p*=.220, 95% CI [0.47, 0.62]).

Thus far, our findings demonstrate that children who saw action events accompanied by iconic gestures related to these events, recognized these events more often than children who saw them accompanied by interactive gestures which were semantically unrelated to the events, and children who saw no gesture at all. Our prediction that action memory would be boosted more strongly than actor memory was not borne out statistically. Instead, a main effect of gesture type

showed that iconic gestures boosted both action memory and actor memory, but descriptively they boosted actor memory less than action memory.

Gesture Type, Memory Type, and Semiotic Type

We conducted a more in-depth analysis of the effect of seeing different semiotic types of iconic gestures on children's actor recognition memory. We categorized our iconic gestures as representing the feet, legs, or body of the actors (see Figure 2 and Table A1 in Appendix A). We reasoned that gestures which represent actors differently may influence children's memory for actors differently. In our analysis, we compared the iconic gesture condition with the no gesture condition, because the experimenter's hands in the no gesture condition certainly did not represent aspects of the events (the analyses show the same results when the iconic gesture condition is compared with the interactive gesture condition).

Figure 5 shows children's recognition memory performance organized by gesture type, memory type, and semiotic type. Children's recognition memory performance was entered in a mixed effects logistic regression analysis with gesture type as a between-subjects factor and memory type and semiotic type as within-subject factors. Our analysis revealed a significant interaction effect between gesture type, memory type, and semiotic type on children's recognition memory performance, $\chi^2(2)=6.51$, $p=.039$. The model explained approximately 23% of the variance in recognition memory performance (marginal $R^2=.08$, conditional $R^2=.23$).

-Insert Figure 5 about here-

To further investigate the three-way interaction, we split our data based on memory type (see panels of Figure 5). When action memory performance was entered into the analysis (left panel) with gesture type and semiotic type as predictors, the main effect of gesture type was

significant, $\chi^2(3)=10.40$, $p=.015$, but not the main effect of semiotic type, $\chi^2(4)=1.42$, $p=.842$, or the interaction, $\chi^2(2)=0.50$, $p=.777$. We predicted that actor memory would increase when more of the actor is represented in gesture (e.g., hand-as-body gestures > hand-as-leg gestures > hand-as-foot gestures). The right panel of Figure 5 shows that descriptively, the benefit of iconic gestures (compared to no gesture) on actor memory increases as more of the actor is depicted in gesture. When actor memory performance was entered into the analysis, we found a significant interaction effect between gesture type and semiotic type on actor memory performance, $\chi^2(2)=6.81$, $p=.032$. The three-way interaction is thus driven by the interaction effect on actor memory. We compared the size of the iconic gesture vs. no gesture benefit by examining the beta estimates for the interaction effect of each semiotic type (with iconic gesture as a reference point for gesture type and hand-as-body gestures as a reference point for semiotic type, followed by hand-as-leg gestures). Hand-as-body gestures boosted actor memory in comparison to the no gesture condition more strongly than hand-as-leg gestures ($\beta=1.88$, $SE=0.92$, $p=.040$) and hand-as-foot gestures ($\beta=2.15$, $SE=1.03$, $p=.038$), which themselves did not differ ($\beta=0.26$, $SE=0.79$, $p=.739$). Though there was no statistically significant difference between hand-as-foot and hand-as-leg gestures, the overall descriptive trend was as predicted and the two conditions that were predicted to be most different from each other were significantly different from each other. This model explained approximately 27% of the variance in actor memory performance (marginal $R^2=.11$, conditional $R^2=.27$). We split the data based on semiotic type to test whether children performed better in the iconic gesture condition than in the no gesture condition. The iconic gesture benefit was significant when the experimenter's hands represented the body of the actors ($\beta=1.76$, $SE=0.65$, $p=.006$), but not their feet ($\beta=-0.17$, $SE=0.68$, $p=.803$), or legs ($\beta=0.07$, $SE=0.36$, $p=.857$) (see the right panel of Figure 5).

General Discussion

To examine whether seeing iconic gestures can help children to encode *nonlinguistic* information, we conducted an experiment in which we tested children's recognition memory of action events. This study has two key findings. First, 3-year-old children who saw action events (videos of actors moving in an unusual manner) accompanied by iconic gestures depicting those events, remembered actions (manners) *and* actors better than children who saw the same events accompanied by interactive gestures unrelated to the events, or no gesture at all. Thus, seeing iconic gestures while encoding events facilitates children's memory of these events. Second, the benefit of iconic gesture on actor recognition memory increases as more of the actor is represented in gesture. Thus, iconic gestures boost event memory by schematically highlighting particular aspects of events. More specifically, we argue that iconic gestures facilitate action memory because they encode distinctive features of actions in a schematic manner, thereby drawing children's attention to the actions in a complex event. Iconic hand-as-body gestures facilitated actor memory because they guide children's attention to the actors' whole body, which created more opportunities to pick up person-specific information about the actors.

Our findings go beyond the previous demonstration of the effect of seeing iconic gestures on cognitive processes in the following way. Previous research has shown that observing gesture while encoding *verbally presented* information (e.g., words and explanations) influences how children remember and subsequently use this information (e.g., Booth et al., 2008; Goodrich, Hudson-Kam, 2009; Mumford & Kita, 2014; So et al., 2012). Fewer studies have investigated the impact of seeing iconic gestures on children's memory of *nonlinguistic* information, such as event memory. Some of the existing studies have shown that seeing iconic gestures at the recall stage influences children's memory of past events (e.g., Broaders & Goldin-Meadow, 2010; Kirk

et al., 2015). However, our study is the first to show that seeing iconic gestures when *encoding* events influences children's memory of these events.

The finding that seeing iconic gestures facilitates action event memory is in line with studies showing that producing iconic gestures facilitates action event memory (Cook, Yip, & Goldin-Meadow, 2010). In their study, Cook et al. (2010) instructed participants to gesture or not to gesture while encoding events shown in short video clips (e.g., a man spinning a bucket). It was found that when participants produced gestures that encoded aspects of the events (e.g., a circular movement with the hand shaped as a fist as if holding a bucket), they mentioned more aspects of the events in a free recall task than participants who were instructed not to gesture. Producing gestures thus facilitates a stronger memory representation of witnessed events than not producing gesture.

Children's event memory performance in the no gesture condition is consistent with Imai et al.'s (2005) experiment on recognition memory for action events, in which the authors also found that 3-year-old children recognize action events above chance level. However, in our no gesture condition, and neither of the gesture conditions, did children reach the 84.5% memory accuracy of children in Imai et al.'s study and this discrepancy needs further explanation. There are three possible reasons for the worse performance of children in the current study. First, children in our study had to encode twice as many events as in Imai et al.'s study. Second, remembering an action and the actor who performs the action (the current study) may be more difficult than remembering an action and the object acted upon (Imai et al.'s study). Encoding an actor (e.g., a person), based on appearance, is more complex than encoding an object, which could be based simply on its shape. Furthermore, the actor cannot be physically separated from the action, whereas the object acted upon can. Third, it is possible that children in the gesture

conditions of the current study divided their attention between the gestures and the stimulus videos, which were both in children's field of vision. However, this cannot be the sole reason for the discrepancies with Imai et al.'s results, because the children in the no gesture condition, who had no reason to divide their attention, also performed worse than children in Imai et al.'s study.

Can gestures that do not carry meaning relevant to the task boost event memory in children? We argue that interactive gestures in our study did not improve memory performance because they do not encode any information useful for the task. Consistent with this interpretation, Goodrich and Hudson-Kam (2009) found that interactive gestures did not help 2-, 3-, and 4-year-old children in a verb learning task. Similarly, So et al. (2012) showed that beat gestures did not help 4-5-year-old children to recall a list of words. However, Lüke and Ritterfeld (2014) showed that children remembered novel character names better when they encoded these names while seeing iconic gestures and "arbitrary gestures" than without gesture. In their study, 3-5-year-olds were introduced to cartoon characters that had distinctive visual features (e.g., a large nose). While the children heard the novel names of the characters, the experimenter produced iconic gestures that encoded the characters' distinctive visual features (e.g., extending the nose with the hand), arbitrary gestures that did not depict such features (e.g., producing a circular motion with an open palm facing inward in front of the face), and no gesture. Children then performed a picture selection task, in which they were presented with pictures of the characters, and required to point at the character that one of the novel names referred to. Children selected more characters correctly when they had seen iconic and arbitrary gestures than when they had seen no gesture. Their result on iconic gestures is compatible with the current finding; the iconic gestures helped children to zero-in on the distinctive features of the cartoon characters. What about their result on arbitrary gestures? We argue that the arbitrary

gestures benefited the children because they also helped children focus on the information

relevant to the task. The arbitrary gestures were hand movements produced around the face and

neck areas, and the characters could be distinguished from each other by features visible in those

areas (e.g., a large nose or a long beard). Thus, the arbitrary gestures may have focused

children's attention on the (body) parts of the characters where the distinctive features could be

seen, and this helped children to map different novel names to the characters. This explanation is

similar to our explanation as to why the hand-as-body gestures, which did not encode any actor-

specific information, improved actor memory in the current study. Gestures that do not iconically

encode the specific relevant information for a task can still improve task performance if they

guide children's attention to the part of the event where the useful information can be seen. The

arbitrary gestures in the study by Lüke and Ritterfeld (2014) did so via *deixis* (spatio-temporal

contiguity) and the hand-as-body gestures in the current study did so via *iconicity* (similarity).

Thus, the current study suggests that iconic gestures can boost memory in two different

ways. Iconic gestures helped children focus on key parts of action events, namely the action and

some parts of the actor's body, and this focusing had two consequences. For action memory,

gestures directly encoded task-relevant information, namely, distinctive features of actions,

which left children with a stronger memory trace. This led to better action recognition memory.

For actor memory, gestures did not directly encode task-relevant information, but highlighted

particular parts of the event (e.g., the actor's body) that may include task-relevant information,

and guided children's attention to these parts. This, in turn, helped children find and encode

actor-specific features, which led to better actor recognition memory. It is well-documented that

pointing gestures (e.g., Langton, O'Malley, & Bruce, 1996) and the deictic component of iconic

gestures (i.e., location in gesture space, at which iconic gestures are produced) (Sekine & Kita,

2015), can direct the recipient's attention to particular areas of the interactional space. The current study demonstrates for the first time that iconicity in iconic gestures can also direct the recipient's attention to a particular part of an event that includes the referent of the gestures.

The two mechanisms proposed above are based on the fact that iconic gestures convey semantic information (Broaders & Goldin-Meadow, 2010; Goldin-Meadow, 2003; Goldin-Meadow et al., 1993; Hostetter, 2011; Kirk et al., 2015; Mumford & Kita, 2014) by depicting a referent in a schematic manner (Chu & Kita, 2008; de Ruiter, 2000; Goldin-Meadow, 2015; Kita et al., 2017; Novack et al., 2014; Novack & Goldin-Meadow, 2016). Specifically, such schematic representations are efficient in that they help children to focus on a subset of the information useful for the task at hand, which is crucial to how observing gestures promotes cognitive processing (Kita et al., 2017). In the current study, the iconic gestures schematically highlighted the relevant parts of the events, which helped children focus on the information relevant for the actor and action memory trials. This is in line with Mumford and Kita's (2014) word learning study, which showed that schematization of events by iconic gesture influences children's interpretation of novel verb meanings. Children interpreted novel verbs as manner verbs when manner was highlighted in iconic gesture, but as change-of-state verbs when end-state was highlighted in iconic gesture. Thus, observing iconic gestures can boost children's event memory and word learning by schematically highlighting the relevant component of complex events. That is, schematization helps children to focus on the key information.

The current result may also provide an alternative explanation for the putative finding that gesture *production* influences solving math problems via schematization (Novack et al., 2014). In the study by Novack et al. (2014), children learned how to solve mathematical-equivalence problems on a white board (e.g., $6 + 3 + 8 = \ldots + 8$). During the training phase,

children produced a pre-trained equalizer strategy in speech (e.g., "I want to make this side equal

to the other side. Six plus three plus eight is seventeen, …") with one of three pre-trained hand

movements: actions (e.g., moving magnetic numbers to the other side of the equal sign), concrete

gestures (e.g., mimicking the movements of the practical actions), or abstract gestures (e.g.,

grouping the magnetic numbers important for solving the equations). Children in the gesture

conditions solved more problems in the paper-and-pencil posttest with new, similar equations

than children in the action condition. The authors concluded that gesture production, which is

based on schematic representations, leads to deeper and more flexible understanding of

mathematical-equivalence problems than actions. However, the gesture production manipulation

was confounded with what children *observed* in the pre-instruction phase. In this phase, the

experimenter produced the hand movements three times to show children how to move their

hands, which children repeated in the subsequent training phase. Thus, it is not clear whether

observing or producing gestures influenced the children's post-test performance. Given the result

of the current study, the most parsimonious explanation may be to attribute this effect to *seeing*

gestures. However, there are two caveats. First, in Novack et al.'s study, children saw hand

movements only three times during pre-instruction, but produced hand movements 15 times

(three times during pre-instruction and 12 times during subsequent training). Thus, it is difficult

to distinguish between a potential effect of gesture observation and gesture production in this

study. But, an important note here is that gesture observation alone can indeed benefit children's

understanding of mathematical equivalence (Cook, Duffy, & Fenn, 2013). Second, the current

study is about recognition memory, but Novack et al.'s study is about learning how to solve

problems, thus the mechanisms involved may differ. More research is needed to investigate the

beneficial effects of gesture observation and gesture production on children's memory and learning.

For future research, it may also be interesting to investigate whether iconic gestures can help adults to teach children about fundamental movement skills such as stability (e.g., balancing, twisting), physical fitness (e.g., stretching, bending), locomotor skills (e.g., running, jumping), object manipulation and control (e.g., throwing, catching), and the way the human limbs work. If confirmed, iconic gestures would become an even more useful tool for teaching as the mastery of fundamental movement skills is widely believed to facilitate children's physical, cognitive, and social development and provides the foundation for an active, healthy lifestyle (Lubans, Morgan, Cliff, Barnett, & Okely, 2010).

To conclude, our study demonstrates that iconic gestures at the stage of encoding are meaningful social cues, which can facilitate action event memory in 3-year-old children. The mechanisms that underlie this effect are based on the information that gesture conveys. Iconic gestures schematize particular aspects of complex events, and boost the recognition memory of information that they selectively highlight. This is important as action event memory helps children to construct knowledge of *who* does *what*, which is a key aspect of early social-cognitive development (Burdett et al., 2016; Milward et al., 2014; Schmidt et al., 2016; Vogelsang & Tomasello, 2016).

References

Aussems, S., Kwok, N., & Kita, S. (2017). *Digital resource to support: GestuRe and ACtion Exemplar (GRACE) video database [online]. University of Warwick, Department of Psychology.* Available at: http://wrap.warwick.ac.uk/78493/

Aussems, S., Kwok, N., & Kita, S. (in press). GestuRe and ACtion Exemplar (GRACE) video database: Stimuli for research on manners of human locomotion and iconic gestures. *Behavior Research Methods*. DOI: 10.3758/s13428-017-0942-2

Barr, D., Levy, R., Scheepers, C., & Tily, H. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68,* 255–278. DOI: 10.1016/j.jml.2012.11.001

Bates, D., Mächeler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*, 1–48. DOI: 10.18637/jss.v067.i01

Bavelas, J., Chovil., N., Lawrie, D., & Wade, A. (1992). Interactive gestures. *Discourse Processes, 15*, 469–489.

Booth, A., McGregor, K., & Rohlfing, K. (2008). Socio-pragmatics and attention: Contributions to gesturally guided word learning in toddlers. *Language Learning and Development, 4,* 179–202. DOI: 10.1080/15475440802143091

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

Burdett, E., Lucas, A., Buchsbaum, D., McGuigan, N., Wood, L., & Whiten, A. (2016). Do children copy an expert or a majority? Examining selective learning in instrumental and normative contexts. *PLoS ONE, 11,* e0164698. DOI: 10.1371/journal.pone.0164698

Chu, M., & Kita, S. (2008). Spontaneous gestures during mental rotation tasks: Insights into the microdevelopment of the motor strategy. *Journal of Experimental Psychology: General, 137,* 706–723. DOI: 10.1037/a0013157

Cook, S., Duffy, R., & Fenn, K. (2013). Consolidation and transfer of learning after observing hand gesture. *Child Development, 84*, 1863–1871. DOI: 10.1111/cdev.12097

Cook, S., Yip, T., & Goldin-Meadow, S. (2010). Gesturing makes memories that last. *Journal of Memory and Language, 63,* 465–475. DOI: 10.1016/j.jml.2010.07.002

de Ruiter, J. P. (2000). The production of gesture and speech. In D. McNeill (Ed.), *Language and Gesture* (pp. 284–311). Cambridge, UK: Cambridge University Press.

Forbes, J., & Farrar, M. (1993). Children's initial assumptions about the meaning of novel motion verbs: Biased and conservative? *Cognitive Development, 8,* 273–290.

Goldin-Meadow, S. (2003). *Hearing gesture.* Cambridge, MA: Harvard University Press.

Goldin-Meadow, S. (2015). From action to abstraction: Gesture as a mechanism of change. *Developmental Review, 38,* 167–184. DOI: 10.1016/j.dr.2015.07.007

Goldin-Meadow, S., Alibali, M., & Church, R. (1993). Transitions in concept acquisition: Using

the hand to read the mind. *Psychological Review, 100,* 279–297.

Golinkoff, R., Chung, H., Hirsh-Pasek, K., Liu, J., Bertenthal, B., Brand, R., Maguire, M., &

Hennon, E. (2002). Young children can extend motion verbs to point-light displays.

Developmental Psychology, 38, 604–614. DOI: 10.1037//0012-1649.38.4.604

Goodrich, W., & Hudson Kam, C. (2009). Co-speech gesture as input in novel verb learning.

Developmental Science, 12, 81–87. DOI: 10.1111/j.1467-7687.2008.00735.x

Hostetter, A. (2011). When do gestures communicate? A meta-analysis. *Psychological Bulletin, 137,*

297–315. DOI: 10.1037/a0022128

Imai, M., Haryu, E., & Okada, H. (2005). Mapping novel nouns and verbs onto dynamic action

events: Are verb meanings easier to learn than noun meanings for Japanese children?

Child Development, 76, 340–355. DOI: 10.1111/j.1467-8624.2005.00849_a.x

Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R., Shigematsu, J. (2008).

Novel noun and verb learning in Chinese-, English-, and Japanese-speaking children.

Child Development, 79, 979–1000. DOI: 10.1111/j.1467-8624.2008.01171.x

Kirk, E., Gurney, D., Edwards, R., & Dodimead, C. (2015). Handmade memories: The

robustness of the gestural misinformation effect in children's eyewitness interviews.

Journal of Nonverbal Behavior, 39, 259–273. DOI: 10.1007/s10919-015-0210-z

Kita, S., Alibali, M., & Chu, M. (2017). How do gestures influence thinking and speaking? The gesture-for-conceptualization hypothesis. *Psychological Review, 124*, 245–266. DOI: 10.1037/rev0000059

Langton, S., O'Malley, C., & Bruce, V. (1996). Actions speak no louder than words: Symmetrical cross-modal interference effects in the processing of verbal and gestural information. *Journal of Experimental Psychology-Human Perception and Performance, 22,* 1357–1375. DOI: 10.1037/0096-1523.22.6.1357

Lubans, D., Morgan, P., Cliff, D., Barnett, L., & Okely, A. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Medicine, 40,* 1019–1035. DOI: 10.2165/11536850-000000000-00000

Lüke, C., & Ritterfeld, U. (2014). The influence of iconic and arbitrary gestures on novel word learning in children with and without SLI. *Gesture, 14,* 204–225. DOI: 10.1075/gest.14.2.04luk

McNeill, D. (1985). So you think gestures are nonverbal? *Psychological Review, 92,* 350–371.

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

Milward, S., Kita, S., & Apperly, I. (2014). The development of co-representation effects in a joint task: Do children represent a co-author? *Cognition, 132,* 269–279. DOI: 10/1016/j.cognition.2014.04.008

Mumford, K., & Kita, S. (2014). Children use gesture to interpret novel verb meanings. *Child Development, 85,* 1181–1189. DOI: 10.1111/cdev.12188

Nakagawa, S., & H., Schielzeth (2013). A general and simple method for obtaining R^2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution, 4,* 133–142. DOI: 10.1111/j.2041-210x.2012.00261.x

Novack, M., & Goldin-Meadow, S. (2016). Gesture as representational action: A paper about function. *Psychonomic Bulletin Review, 24,* 652–665. DOI: 10.3758/s13423-016-1145-z

Novack, M., Congdon, E., Hemani-Lopez, N., & Goldin-Meadow, S. (2014). From action to abstraction: Using the hands to learn math. *Psychological Science, 25,* 903–910. DOI: 10.1177/0956797613518351

Ping, R., & Goldin-Meadow, S. (2008). Hands in the air: Using ungrounded iconic gestures to teach children about conservation of quantity. *Developmental Psychology, 44,* 1277–1287. DOI: 10.1037/0012-1649.44.5.1277

R Development Core Team. (2011). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, Retrieved from: http://www.R-project.org/.

Schmidt, M., Rakoczy, H., & Tomasello, M. (2016). Young children force social norms selectively depending on the violator's group affiliation. *Cognition, 123,* 325–333. DOI: 10.1016/j.cognition.2012.06.004

Sekine, K., & Kita, S. (2015). Development of multimodal discourse comprehension: cohesive

      use of space by gestures. *Language, Cognition and Neuroscience, 30,* 12451258. DOI:

      10.1080/23273798.2015.1053814

Tellier, M. (2008). The effect of gestures on second language memorisation by young children.

      Gesture, 8, 219–235. DOI: 10.1075/gest.8.2.06tel

Vogelsang, M., & Tomasello, M. (2016). Giving is nicer than taking: Preschoolers reciprocate

      based on the social intentions of the distributor. *PLoS ONE, 11,* e0147539. DOI:

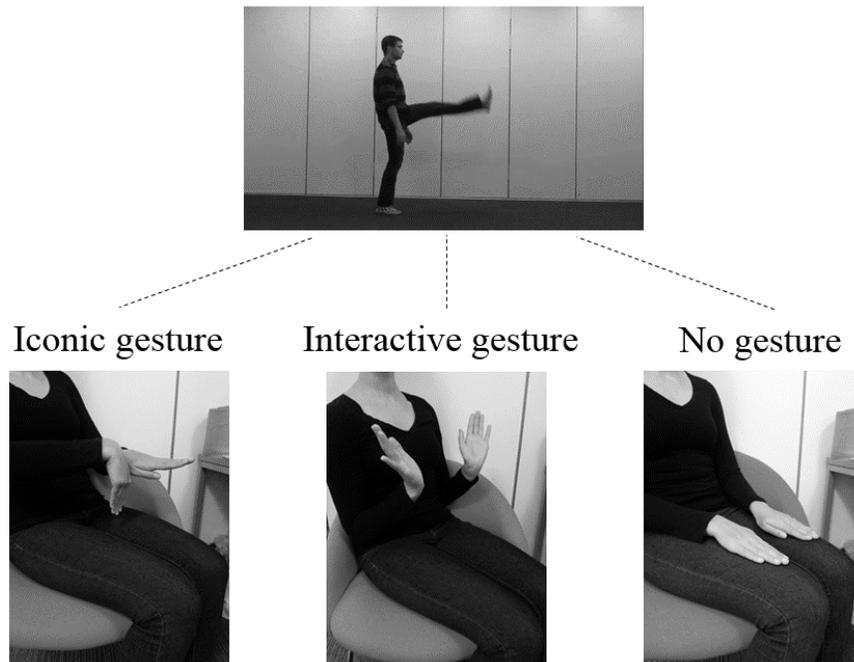   10.1371/journal.pone.0147539

Figure 1. Three gesture conditions used in the experiment. Top panel shows an action event in which an actor performs a marching movement with stretched legs. From left to right the bottom panels show an iconic gesture depicting the actor's manner of motion, an interactive gesture unrelated to the event, and no gesture.
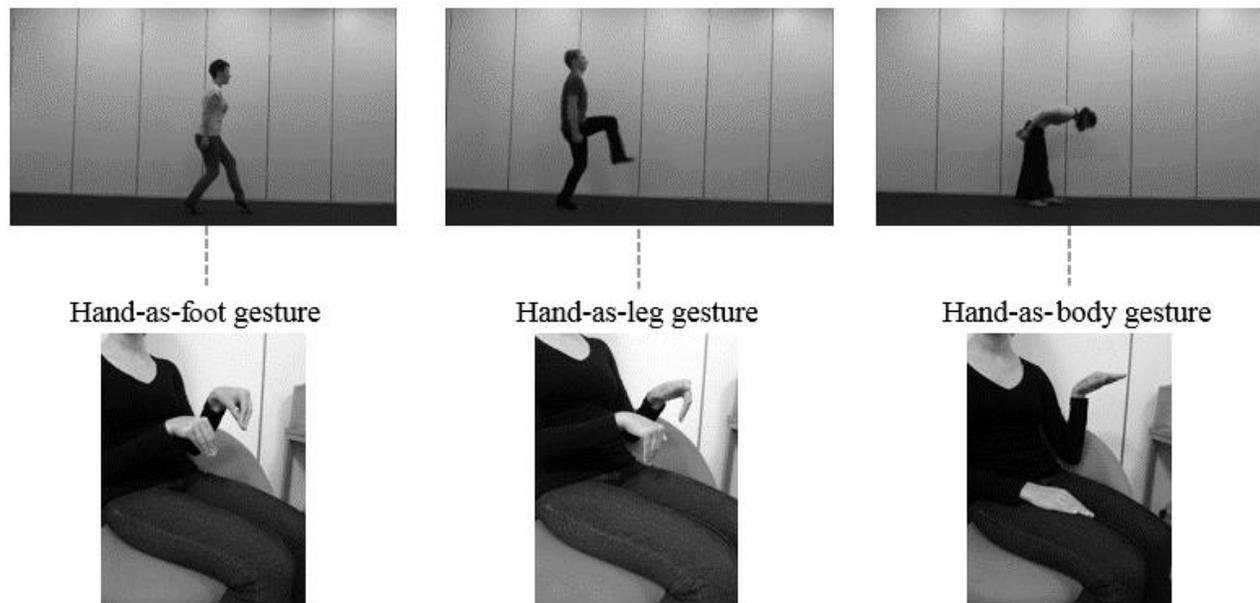
Figure 2. The semiotic types of iconic gestures used in the experiment. From left to right the bottom panels show the experimenter's hands depicting the manners in which the actors in the top panels move by representing their feet (hand-as-foot gesture), legs (hand-as-leg gesture), or body (hand-as-body gesture).
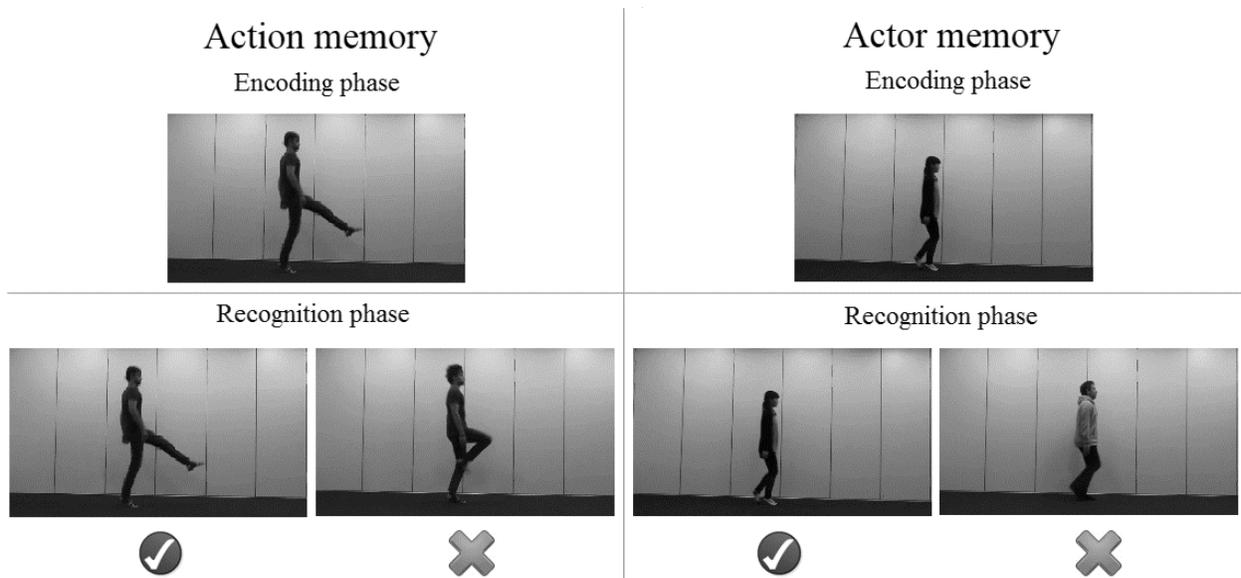
Figure 3. Still frames of videos shown in the encoding phase and recognition phase of the memory task, which show examples of action memory trials (left panels) and actor memory trials (right panels). Check marks indicate correct answers and crosses indicate incorrect answers.

Figure 4. Children's recognition memory performance (*y*-axis shows proportion of correct

responses) for actions (dark grey) and actors (light grey), organized by gesture type (*x*-axis).

Error bars represent 95% confidence intervals of the means. Dotted line represents chance level.

Figure 5. Children's recognition memory performance (*y*-axis shows proportion of correct responses) in the iconic gesture condition (dark grey) and no gesture condition (light grey), organized by memory type (panels) and semiotic type (*x*-axis). Error bars represent 95% confidence intervals of the means. Dotted line represents chance level.

Appendix A

Table A1.

List of Video Files Taken from the GRACE Video Database for the Memory Task. Column 1

Describes the Action Labels Used for Reference to Video Files in the Database. Columns 2 and 3

List the ID Numbers of the Female Actors and Male Actors in the Database (Numbers 01-13 in

the Video File Names). Column 4 (Semiotic Type) Indicates Whether the Experimenter's Hands

Were Representing the Feet, Legs, or Body of the Actors while Depicting How the Actors Moved.

The GRACE Video Database is Openly Accessible at http://wrap.warwick.ac.uk/78493/.

Actions	Female Actor	Male Actor	Semiotic Type
Bowing	12	06	Body
Skating	12	06	Feet
Wobbling	06	09	Body
Marching	06	09	Legs
Mermaiding	09	03	Legs
Overstepping	09	03	Legs
Creeping	03	07	Feet
Crisscrossing	03	07	Feet
Turning	01	11	Body
Hopscotching	01	11	Legs
Swinging	13	05	Legs
Skipping	13	05	Legs
Dropping	08	02	Body

Folding	08	02	Legs
Twisting	04	01	Body
Stomping	04	01	Feet
Trotting	05	08	Legs
Hopping	05	08	Body
Flicking	11	10	Legs
Dragging	11	10	Feet
Grapevining	07	12	Legs
Shuffling	07	12	Feet
Groining	10	04	Legs
Scurrying	10	04	Feet

Appendix B

We presented children in the interactive gesture condition with three interactive gestures (see Figure B1). A first interactive gesture involved the experimenter moving both hands up to shoulder height with the palms facing forward to indicate surprise (Panel A). A second interactive gesture involved moving both hands up and folding them together at chin height (Panel B). A third interactive gesture also indicate excitement by moving two hands up to chin height in a reversed triangle shape (Panel C). The experimenter rotated these interactive gestures across trials for each child in the interactive gesture condition.
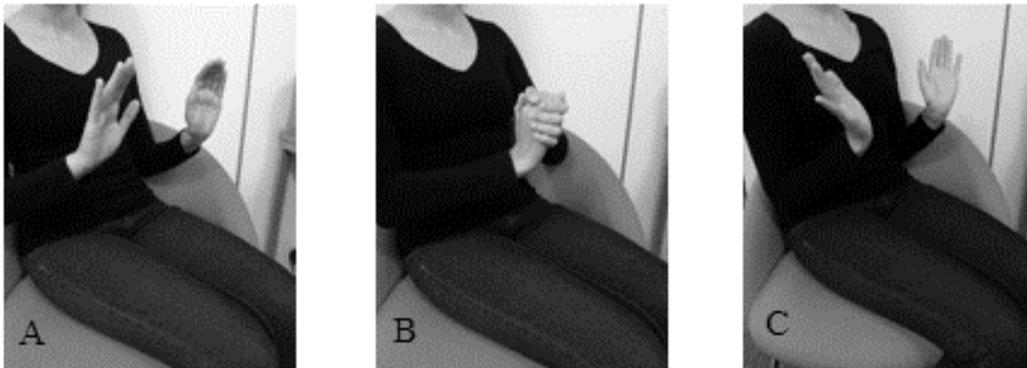

Figure B1. Three interactive gestures (Bavelas et al., 1992) used in the experiment. The gestures indicate surprise (Panel A) and excitement (Panel B & C).