Seeing Iconic Gesture Promotes First- and Second-Order Verb Generalization in Preschoolers

Suzanne Aussems and Sotaro Kita
University of Warwick

This study investigated whether seeing iconic gestures depicting verb referents promotes two types of generalization. We taught 3- to 4-year-olds novel locomotion verbs. Children who saw iconic manner gestures during training generalized more verbs to novel events (*first-order generalization*) than children who saw interactive gestures (Experiment 1, *N* = 48; Experiment 2, *N* = 48) and path-tracing gestures (Experiment 3, *N* = 48). Furthermore, immediately (Experiments 1 and 3) and after 1 week (Experiment 2), the iconic manner gesture group outperformed the control groups in subsequent generalization trials with different novel verbs (*second-order generalization*), although all groups saw interactive gestures. Thus, seeing iconic gestures that depict verb referents helps children (a) generalize individual verb meanings to novel events and (b) learn more verbs from the same subcategory.

Verbs are an important part of speech. Recognizing a verb is often a key step in understanding the meaning of a sentence. As such, verbs play a vital role in children's acquisition of vocabulary and grammar. Children's early vocabulary skills and vocabulary size are major predictors of later school success (Anderson & Freebody, 1979; Morgan, Farkas, Hillemeier, & Scheffner Hammer, 2015; Rowe, Raudenbush, & Goldin-Meadow, 2012). It is therefore crucial to investigate how children learn verbs and this study focuses on how gesture influences this process in preschool-aged children.

Verb Learning is a Challenging Task

Associating verbs with the actions they refer to is challenging for young children, because verbs typically describe events that present a rich array of information (e.g., "the man is *running* toward the finish line"). It is difficult for children to individuate the meaning of a verb (e.g., *running*) in such a complex event (Gentner, 1978, 1981, 1982; Gentner & Boroditsky, 2001). This is partly because children focus on more salient components of the event, such as the person who is performing the action (e.g., the man), instead of the action itself (e.g., running; Aussems & Kita, 2017; Forbes & Farrar, 1995; Imai, Haryu, & Okada, 2005; Imai, Kita, Nagumo, & Okada, 2008; Kersten & Smith, 2002). For example, Imai et al. (2008) presented 3-year-old children

with videos of human actors moving across the length of a scene in unusual manners (e.g., walking with slow heavy steps). An experimenter labeled these training events with novel verbs. Children were then required to extend each novel verb to one of two videos on a split screen in a two-alternative forced-choice test. One video showed a novel actor performing the target movement (same-action event) and the other video showed the actor from the training event performing a novel movement (same-actor event). Children could not reliably pick out the same-action events in this generalization task, suggesting that, to them, a verb is not a label for action itself and both the action and actor are equally important for verb meaning. Thus, 3-year-old children find it difficult to separate an action from the actor who performs this action and to focus on an action as the sole referent of a verb. This prevented children from generalizing the newly learned verbs to novel events that showed the referent actions performed by novel actors.

Iconic Gestures Facilitate Verb Learning and Generalization

Children show reliable iconic gesture comprehension by age 3 (Hodges, Özçalışkan, & Williamson,

Correspondence concerning this article should be addressed to Suzanne Aussems, Department of Psychology, University of Warwick, CV4 7AL Coventry, United Kingdom. Electronic mail may be sent to s.aussems.1@warwick.ac.uk.

2018; Stanfield, Williamson, & Özçalışkan, 2014), and this is particularly evident for iconic gestures depicting actions (e.g., Hodges et al., 2018; Marentette & Nicoladis, 2011; Tolar, Lederberg, Gokhale, & Tomasello, 2008). Iconic gestures (McNeill, 1985, 1992) that depict actions in motion and in shape may help children to focus on actions in a rich array of event information (Goodrich & Hudson Kam, 2009; Mumford & Kita, 2014; Wakefield, Hall, James, & Goldin-Meadow, 2018). They can do so by highlighting the components of an event relevant to verb meaning (e.g., actions), while stripping away components irrelevant to verb meaning (e.g., actors). This makes iconic gesture an excellent tool for *first-order generalization*—that is, for extending knowledge about individual word meanings to novel events (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002).

Two studies have unequivocally shown a beneficial effect of seeing iconic gesture on first-order verb generalization in preschool-aged children (see Mumford & Kita, 2014 for a critical review of similar other studies). First, Mumford and Kita (2014) tested whether seeing iconic gestures compared to seeing no gestures guided children's first-order generalization of novel verb meanings. They showed 3-year-old children short video clips of an actress performing manual actions on novel objects, whereas an experimenter labeled these stimulus events with novel verbs. The experimenter produced either iconic gestures that matched the manner of object manipulation in the stimulus events (e.g., "to push objects in a particular manner"), iconic gestures that matched the end-state of the manipulated objects (e.g., "to cause objects to move into a particular shape"), or no gesture at all. Children were then required to generalize the newly learned verbs to one of two videos in an alternative-forced-choice task: one video showed the same manner of object manipulation as in the training that resulted in a different end-state (manner-same event) and the other video showed a different manner of object manipulation from the training that resulted in the same end state as in the training (end-state-same event). Children who saw iconic manner gestures generalized the verbs to manner-same events significantly more often than children who saw iconic end-state gestures or no gestures. Thus, seeing iconic gestures guided children's verb learning and generalization by highlighting the components of an event relevant to verb meaning (i.e., manners in which the objects were manipulated).

Second, Wakefield et al. (2018) showed that iconic gestures promote children's first-order verb generalization more so than acting on objects. They taught 4- and 5-year-old children four novel verbs for novel actions performed on objects and compared the effect of gesturing with that of acting on those objects. Children were required to generalize the newly learned verbs to one of two videos in an alternative-forced-choice task: the target video showed a novel action performed on the object they were trained on (object-same event) and the distractor video showed the target action performed on a novel object (action-same event). Introducing children to this distractor event allowed the researchers to test whether children understand that verb meaning includes only action, but not other salient components of an event, such as the object on which the action is performed. Children who were taught verbs with iconic gestures extended the novel verbs significantly more often to action-same events than children who learned the verbs through action, in an immediate and delayed generalization task. Thus, children who had learned verbs through iconic gesture were not distracted by the object-same events. They interpreted the verbs to refer to actions that can be applied to novel objects and this ability to generalize verbs persisted after a 24-hr-delay.

Limitations of Previous Research

Previous research is limited because it only shows that seeing iconic gestures promotes *first-order generalization* of individual verb meanings. That is, children learn that a verb refers to the referent depicted in iconic gesture and they can extend this individual verb meaning to novel events that show the verb referent (Smith et al., 2002). However, it remains unclear whether seeing iconic gestures also promotes *second-order generalization* of a subcategory of verbs (Smith et al., 2002). That is, the question is whether, when children learn a set of novel verbs with iconic gestures, this experience improves their performance in subsequent learning of other novel verbs from the same subcategory, even if they no longer see iconic gestures. If so, then this would indicate that learning verbs with iconic gesture equips children with general knowledge about semantic properties of a subcategory of verbs, which they can use when they subsequently learn more verbs from the subcategory.

It is important to investigate gesture's role in second-order generalization, because any theory of word learning must address not only how children acquire individual word meanings, but also more general categorical knowledge about words. Many studies on vocabulary development have focused

on the acquisition of individual words (e.g., Behrend, 1990; Forbes & Farrar, 1993; Goodrich & Hudson Kam, 2009; Imai et al., 2005, 2008; Kersten & Smith, 2002; McGregor, Rohlfing, Bean, & Marschner, 2009; Mumford & Kita, 2014; Wakefield et al., 2018). However, the vocabulary is more than a list of words. Each word belongs to a category of similar words, which has specific properties (e.g., verbs that describe manners of locomotion, verbs that describe manipulating objects, etc.). As such, word learning is not just learning about individual word meanings, but it also allows children to take advantage of common properties among words that belong to the same (sub)category.

Multiple Exemplars Facilitate First- and Second-Order Generalization of Novel Nouns

Second-order generalization has been investigated in the context of nouns but not verbs. For example, Smith et al. (2002) trained children to attend to shape in the context of novel object labels and this helped children to learn novel object names more rapidly. In the first part of their study, 17-month-old children were taught four novel object labels over the course of 7 weeks during once-a-week play sessions. Each label was given to two distinct objects with the same shape. A control group received no such training. In the Week 8, all children took part in a first-order generalization task for the meaning of the nouns they had learned. In each test trial, the experimenter showed children one of the training objects, labeled it (e.g., "This is a *zup*"), and asked children to get another object by the same name (e.g., "Where's the *zup*? Get the *zup*."). There were three novel choice objects that each matched the labeled object in shape only, color only, or texture only. Children who had received training selected objects with the same shape significantly more often than children in the control group, who selected objects at chance. Thus, the training facilitated first-order generalization based on shape. In Week 9, the same groups of children took part in a second-order generalization task that tested their understanding of novel object labels, which none of the children had received training for. Again, children who had received training in the first part of the study selected objects with the same shape significantly more often than children who had not received training and chance. Thus, children in the training condition deduced the abstract knowledge (i.e., second-order generalization) that novel object labels can be extended base on shape similarity at least for the type of objects used in the study.

Iconic Gestures Could Promote Abstract Linguistic Knowledge

This study investigates a novel method to promote second-order generalization for a subcategory of verbs in preschool-aged children. Specifically, we ask whether seeing iconic gestures while learning novel locomotion verbs allows children to acquire not just knowledge about individual verb meanings, but also the general knowledge that the verbs in our study refer to manners of locomotion. In this study, we will teach children locomotion verbs, while children see an event in which a person moves from one location to another in a particular manner. To successfully generalize the novel verb to novel events, children need to be able to focus on this manner of locomotion as the sole referent of the verb.

As reviewed earlier, seeing iconic gestures in this type of verb learning task should help children to focus on individual verb meanings (Mumford & Kita, 2014; Wakefield et al., 2018). This would enable children to generalize the verb to a new event in which the same action is performed by a different actor (i.e., first-order generalization). Children could also deduce the general knowledge that the verbs in our study refer to manners of locomotion. Even when they encounter a novel verb that belongs to this subcategory for the first time in the second block of our verb learning task (without seeing any iconic gesture), such abstract *linguistic* knowledge would enable children to generalize this verb to a novel event based on singling out the manner of locomotion (i.e., second-order generalization). The question we aim to answer in this study is whether seeing iconic gestures promotes such abstract linguistic knowledge.

Iconic Gestures Promote Abstract Nonlinguistic Knowledge

Seeing iconic gestures promotes *nonlinguistic* abstract knowledge in children. In a study by Cook, Duffy, and Fenn (2013), second-, third-, and fourth-grade children were instructed in mathematical equivalence (e.g., $8 + 6 = . . . + 2$) with either speech and gesture or speech alone. In both conditions, the instructor verbalized an equalizer strategy, stating the two sides of the equation must be equal. Only in the speech and gesture condition, the instructor swept her left hand back and forth under the numbers to the left of the equal sign while saying "one side," and the right hand under the numbers to the right of the equal sign while

saying "the other side," expressing equivalence of the two sides. Children in the speech and gesture condition solved more similar mathematical equations than children in the speech alone condition in an immediate and delayed posttest, but also in a delayed transfer test of novel equations with multiplication. Thus, gestures which conveyed abstract knowledge about equations (i.e., the two sides of the equation must be equal) promoted *nonlinguistic* abstract knowledge that children can use later. However, it remains unclear whether seeing iconic gestures can promote *linguistic* abstract knowledge (i.e., second-order generalization) that children can use later, and whether this is possible even when iconic gestures (and speech) do not explicitly convey abstract knowledge but only individual verb meanings.

Possible Mechanism

Iconic gesture may facilitate first- and second-order generalization through schematization of complex scenes. Gestures can schematize information by highlighting a subset of information in a rich scene (Kita, Alibali, & Chu, 2017). More specifically, in our experimental paradigm, seeing an iconic gesture depicting how an actor moves while learning a novel verb for the actor's manner of locomotion directs children's attention to manners of locomotion in rich arrays of event information. This helps children to focus on manner of locomotion as the referent of the verb and allows them to generalize this verb to a novel event that shows the same manner (i.e., first-order generalization, as also shown in Mumford & Kita, 2014; Wakefield et al., 2018). When children repeatedly schematize similar events guided by iconic gestures, children may also pick up the general knowledge that manners of locomotion are important for verbs that belong to the same subcategory, just as children in the study by Smith et al. (2002) picked up the general knowledge that shape is important for nouns that describe solid objects after repeated shape-bias training.

The Present Study

This study investigates if seeing iconic gesture promotes first- and second-order generalization of locomotion verbs in preschool-aged children. We taught 3- to 4-year-old children twelve novel locomotion verbs describing short video clips of actors moving in unusual manners shown on a computer screen. We then tested their ability to generalize

these verbs to novel events that included the verb referents across two blocks of six trials. In Block 1, the iconic manner gesture group saw iconic gestures depicting the verb referents (i.e., manners of locomotion) in the stimulus events and the control group saw interactive gestures (Bavelas, Chovil, Lawrie, & Wade, 1992), which did not depict any aspect of the stimulus events. In Block 2, children in both groups saw interactive gestures, while learning a new set of six novel verbs. Crucially, in Block 2, the actors and actions shown in the stimulus events and the novel verbs used to label these events were different from Block 1. Block 2 was administered either immediately after Block 1 (Experiment 1), or 1 week later (Experiment 2). We tested the effect of gesture after 1 week to assess whether the general knowledge about the locomotion verbs, necessary for second-order generalization, persists long term. This is plausible as seeing gesture led to increased performance on novel equations after a delay in the mathematical domain (e.g., Cook et al., 2013). Finally, we tested whether it was crucial that iconic gestures depicted the verb referents (i.e., manners of locomotion). To this end, in Experiment 3, we compared iconic gestures depicting the verb referents (i.e., manners of locomotion as in Experiments 1 and 2) and path-tracing gestures that encoded the actors' lateral path (produced near the computer screen but without touching it). These path-tracing gestures drew children's attention to the stimulus events and iconically depicted the actors' lateral path from left to right, but they did not encode any information about the verb referents (i.e., manners of locomotion). We compared two groups of children: in Block 1, the iconic manner gesture group learned verbs with iconic gestures that depicted the actors' manners of locomotion and the path-tracing gesture group with gestures that traced the actors' path. In Block 2, both groups learned verbs with interactive gestures. As the actors in all stimulus events always moved along the same path (i.e., from left to right), the path-tracing gestures that iconically encoded this path information were not useful for picking out the correct answer in the generalization task. If iconic gestures that encode the actors' *manner* are more beneficial for first- and second-order verb generalization than path-tracing gestures that encode the actors' *path*, then this shows that: (a) it is crucial that iconic gestures depict the verb referent, and (b) it is not sufficient for gesture to draw children's attention to the stimulus event.

Each trial consisted of a training and test phase. During the training phase, a stimulus event in

which an actor moved across the length of a scene in an unusual manner was labeled with a novel verb by an experimenter. Children's understanding of the novel verb's meaning was tested immediately after each training phase in a two-alternative forced-choice task. One video showed a novel actor performing the target action from the training phase (same-action event) and the other video showed the actor from the training phase performing a novel action (same-actor event). If children understand that the novel verb refers to the manner of locomotion, they should pick the same-action event over the same-actor event in the test phase.

Across the three experiments, we predicted a main effect of group where the iconic manner gesture group would outperform the control groups in Block 1 (i.e., iconic gesture promotes *first-order generalization*) and crucially, in Block 2 (i.e., iconic gesture promotes *second-order generalization*), immediately (Experiments 1 and 3) and 1 week later (Experiment 2).

Experiment 1

Methods and Materials

Design

The experiment had a 2 × 2 mixed design. Trials were grouped into a within-participant variable block, where Block 1 corresponded to Trial 1–6 and Block 2 to Trial 7–12 of the verb learning task. The between-participant variable was the gesture type presented in Block 1: iconic manner gesture versus interactive gesture. In Block 2, children in both groups were presented with interactive gestures. Our binary-dependent variable was children's verb generalization performance in each of the 12 trials of the alternative-forced-choice test (0 = incorrect, same-actor event, 1 = correct, same-action event).

Participants

The data were collected between January 25 and March 3, 2017. Our sample size was determined a priori using GPower version 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) based on pilot data that showed a medium-sized effect (odds ratio = 2.30, α = .05, power = 0.80). Participants were recruited via two public nurseries in the West-Midlands (United Kingdom), and via a database of families who expressed interest taking part in language development research. The sample included 48 typically developing children (24 girls, 24 boys) between 35 and 48 months old ($M = 41.26$, $SD = 4.01$). One additional child was tested but excluded from the analysis because she pointed exclusively to answers on one side of the screen in test trials. There were 12 boys and 12 girls in each group. Children's age in months did not differ between the two groups, F (1, 46) = 0.19, $p = .666$. Twenty-five percent of the children had a racial background other than White (i.e., 8% Asian and 17% Black). Informed written parental consent was obtained for all participants. All children were exposed to the English language for at least 75% of the time and English was the primary language spoken at home (as indicated by their caregivers). Participating nurseries received a book voucher and children who were tested in the research lab received a certificate and a toy. All studies reported in this article received ethical approval from the Humanities and Social Sciences Ethics Committee at the University of Warwick.

Materials

A set of 36 video clips (4–15 s) depicting 24 unusual manners of human locomotion was taken from the GestuRe and ACtion Exemplar database (Aussems, Kwok, & Kita, 2017a, 2017b). Stimulus videos showed 24 actors (12 males, 12 females) moving across the length of a scene using their feet, legs, and body. Their arms and hands were always kept to the side of their bodies, fingers pointing down, parallel to their torsos.

The 24 unusual actions were organized in distinctive pairs to create 12 target and distractor combinations. A matching iconic gesture was designed for each unusual action, which, at the same time, mismatched the other action in each pair. Example videos of iconic gestures are available from http://wrap.warwick.ac.uk/78493 and the file names can be found in Appendix. The matches and mismatches between iconic gestures and actions were normed for each male actor and female actor in a rating study, which is reported elsewhere (Aussems et al., 2017a, 2017b). Furthermore, the similarity between male actors and female actors performing the same matching and mismatching actions was normed, as well as the (dis)similarity between all actions in the stimulus set, and the novelty of the actions to English native speakers (see Aussems et al., 2017a, 2017b, for more detail). For each action, we picked the female actor whose rendition of the action was rated to be the best match to the corresponding iconic gesture (best among all female actors) and we did the same for male actors. For each action pair, the actor with the best match and mismatch ratings between actions

and iconic gestures performed both the target action and the distractor action (24 video clips), and the other actor performed only the target action (12 video clips). There were as many female actors as male actors performing the target and distractor actions. In the test phase, the correct choice in the two-alternative forced-choice trials was a video of a novel actor (of the opposite sex) performing the same action as seen in the training phase. We introduced an actor of the opposite sex to make it clear to the children that the actors changed.

The experimenter produced three different interactive gestures (Bavelas et al., 1992) during the experiment task, which were meant to engage the children in the interaction and generally expressed excitement and surprise. An example of an interactive gesture can be seen in Figure 1, but we have also made video recordings of the interactive gestures available via the Open Science Framework (osf.io/3jx4b). Importantly, none of the interactive gestures depicted any aspect of the verb referents. The experimenter rotated the three interactive gestures across trials in the training phase and did so in the same way for children in Block 2 for the experimental group and the control group.

The following novel verbs were used to label the unusual actions: *daxing*, *blicking*, *larping*, *stumming*, *pilking*, *krading*, *poffing*, *wepping*, *howning*, *mipping*, *glabbing*, and *yoofing*. These words are widely used in word learning studies with English-speaking children (e.g., Mumford & Kita, 2014; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009).

Video clips of action events were shown using slide presentation software Microsoft Office

Group	Training phase (block 1)	Test phase (block 1)	Training phase (block 2)	Test phase (block 2)
Iconic manner gesture (Exp. 1-3)				
Interactive gesture (Exp. 1-2)				
Path-tracing gesture (Exp. 3)				

Figure 1. Procedure of Experiments 1–3. In the training phase of Block 1 (Column 1), stimulus events were labeled with novel verbs accompanied by either iconic gestures depicting the verb referents (i.e., manners of locomotion; Row 1), interactive gestures (Row 2) or path-tracing gestures (Row 3). In the test phase of Block 1, children were asked to generalize each verb to one of two videos (Column 2). The correct generalization (i.e., same-action event) is shown on the right. In the training phase of Block 2, children in all groups were shown action events accompanied by interactive gestures (Column 3) and the actors and actions in those events were novel compared to Block 1. The test phase of Block 2 followed the same procedure as in Block 1 (Column 4). The correct generalization (i.e., same-action event) is shown on the left.

PowerPoint 2016 on a 14 in. touch screen laptop. Using on-screen buttons, programmed by Visual Basic for Applications, the children's responses were automatically recorded.

Randomization and Counterbalancing

We created 12 counterbalancing versions of the experiment in which we rotated the order of the 12 training exemplars, so that each manner of locomotion would appear an equal number of times in each trial position. Target exemplars appeared equally often on the left and right sides of the screen in the test phase. We counterbalanced the gender of the actors across the training phase and test phase. If the actor in the training exemplar was a female actor than this actor also appeared in the distractor exemplar (same-actor event) and a male actor appeared in the target exemplar (same-action event), and vice versa. An Excel spreadsheet that contains the fully counterbalanced design is available via the Open Science Framework (osf.io/3jx4b).

Participants were pseudorandomly assigned to a group, before the experimenter met them, based on their gender and age in months, so that the two groups would be comparable in terms of gender and age. We administered each counterbalancing version to one child in each group before moving on to the next version. Participants tested at different nurseries and in the research lab are therefore equally represented across the two groups. Once all 12 counterbalancing versions had been administered, we repeated this process, such that each counterbalancing version was administered to two children in each group.

Procedure

Children were tested individually in a quiet area of their nursery or preschool or in the research laboratory. The experimenter and child participant sat next to each other at a low children's table on small chairs, and the experimenter placed the laptop in front of the child. The touch screen and the experimenter's gestures were within arm's reach of the child; thus, the child could easily see both the experimenter's hands and the laptop screen at the same time. Children completed two warm-up trials followed by two blocks of six verb learning trials. The warm-up trials familiarized children with selecting answers on each side of the screen by pointing at the relevant picture, in the following way. Children were shown pictures of a cat and a dog on each side of the screen and asked to show the experimenter each animal (e.g., "Where is the dog?" and "Where is the cat?").

Verb learning trials followed immediately and included a training phase and test phase (see Figure 1). During the training phase, children watched a video of an actor who moved across the length of a scene in an unusual manner. When the video played at the first time, the experimenter said "Look! He (or she) is *daxing*!", and when the video played at the second time, the experimenter said "Wow! He (or she) is *daxing* again!". Depending on the condition, the experimenter accompanied these utterances with either an iconic gesture depicting the way the actor in the video moved or an interactive gesture that was not related to the actor's movement in any way. In the immediate test phase that followed, the experimenter asked the children to generalize the newly learned verb to one of the two videos that played simultaneously on the left and right sides of the screen ("Which one is *daxing*?"). The experimenter looked at the child and away from the screen when making this request. One video showed a novel actor performing the target movement that was labeled with a verb in the training phase (same-action event) and the other video showed the same actor as in the training phase performing a novel action (same-actor event). The two videos played continuously on loop until the child picked one. If the child did not respond to the experimenter's request or asked the experimenter whether one of the videos showed *daxing*, the question was repeated until one video was chosen. If the child pointed at both videos, the experimenter asked the child to pick one. Children received positive feedback in each trial (e.g., "Well done," "Good job") to keep them motivated to finish the task. This procedure was repeated for six verbs in Block 1, followed immediately by six verbs in Block 2. Note that all children were taught novel verbs while seeing interactive gestures in Block 2 and that the actors and actions shown in the stimulus events and the novel verbs used to label these events were different from those in Block 1.

Data Analysis

Verb generalization performance in each trial (binary: 1 = correct, same-action event, 0 = incorrect, same-actor event) was analyzed with a mixed-effects logistic regression analysis using the *lme4* package (Bates, Mächeler, Bolker, & Walker, 2015) in the R Studio software for statistical analyses (R Development Core Team, 2011). Fixed factors

included group (iconic gesture vs. interactive gesture) and block (1 = Trial 1–6 vs. 2 = Trial 7–12). All the models reported in this article included a maximal random effects structure (cf. Barr, Levy, Scheepers, & Tily, 2013), that is, random slope and intercept variation and the co-variance between the two, for participants and training exemplars (i.e., the 12 stimulus videos that were labeled with a novel verb). Likelihood ratio tests (χ^2) were used to compare the full model with updated versions of the model that systematically excluded the main effect and interaction terms of interest. Planned comparisons were carried out by running our analysis separately with children's performances in Block 1 and Block 2 as the dependent variables. The *confint()* function was used to compute 95% confidence intervals around the beta estimates of each effect. The *wilcox.test()* function was used to calculate one-sample Wilcoxon Signed Rank tests for comparisons with chance level and effect size r was calculated using Rosenthal's formula (Rosenthal, 1994). The raw data and R Markdown files for all graphs and analyses reported in this article are available via the Open Science Framework (osf.io/3jx4b).

Results

The left panel in Figure 2 shows children's performance in verb generalization trials (in proportion) of Experiment 1 organized by group and block. Children's verb generalization performance for each trial (binary: 1 = correct, same-action event, 0 = incorrect, same-actor event) was entered into a mixed-effect logistic regression analysis with group and block as fixed effects and participants and training exemplars as random effects. The main effect of group on verb generalization performance was significant, $\chi^2(2) = 14.83$, $p < .001$, but not the main effect of block, $\chi^2(2) = 2.13$, $p = .344$, or the interaction, $\chi^2(1) = 0.01$, $p = .922$. Overall, children who saw iconic gestures in Block 1 and interactive gestures in Block 2 generalized more verbs to novel same-action events than children who saw interactive gestures in both blocks ($\beta = -.91$, $p < .001$, 95% CI [-1.37, $-.47$]).

To further investigate our predictions, we compared performances between the two groups in Blocks 1 and 2. Subsets of the data that included either the children's performances in Block 1 or their performances in Block 2 were entered
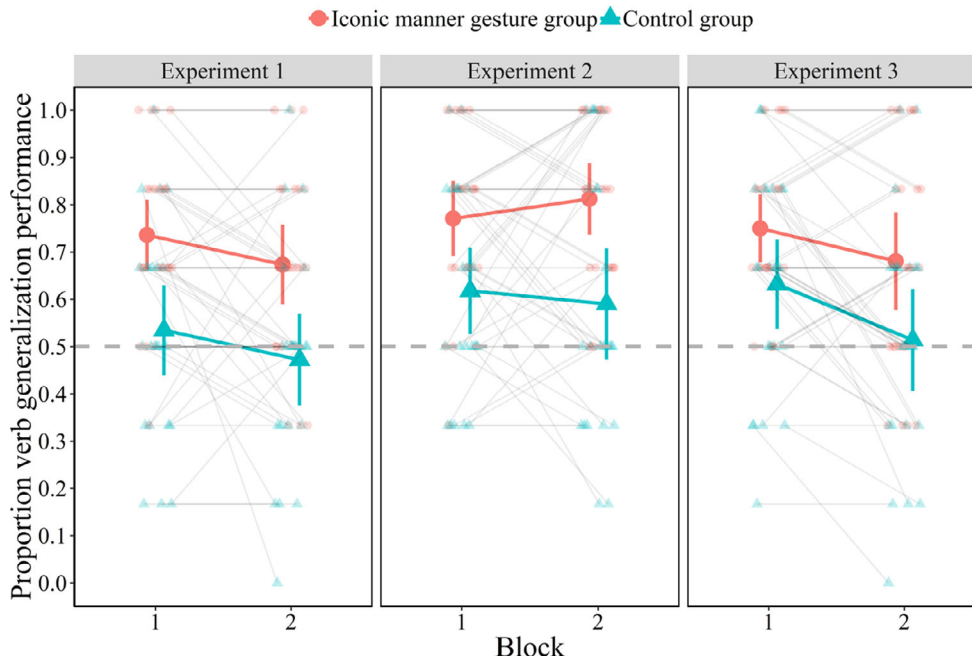
Figure 2. Verb generalization performance in Experiments 1–3 (average proportion of correct responses on the *y*-axis) organized by experiment (panels), gesture group (shapes and colors), and block (*x*-axis). In Block 1 of Experiments 1 and 2, iconic manner gestures were compared with interactive gestures. In Block 1 of Experiment 3, iconic manner gestures were compared with path-tracing gestures. In Block 2 of Experiments 1–3, all groups of children saw interactive gestures. Block 1 was followed by Block 2 immediately (in Experiments 1 and 3) or after 1 week (in Experiment 2). Jittered shapes represent individual performances in each block, with light gray lines connecting the two performances. Error bars represent 95% confidence intervals of the means. Dotted gray horizontal line represents chance level.

separately in our mixed-effect logistic regression analysis. First, children in the iconic manner gesture group (M_{prop} = 0.74, SD = 0.44) generalized significantly more novel verbs to same-action events in Block 1 than children in the interactive gesture group (M_{prop} = 0.53, SD = 0.50), β = −.90, p < .001, 95% CI [−1.46, −.39]. Second, children in the iconic manner gesture group (M_{prop} = 0.67, SD = 0.47) also generalized significantly more verbs to same-action events in Block 2 than children in the interactive gesture group (M_{prop} = 0.47, SD = 0.50), β = −.87, p = .001, 95% CI [−1.42, −.35]).

We carried out two additional analyses to investigate an alternative explanation of our findings that children in the iconic manner gesture group saw a more varying set of gestures than children in the interactive gesture group. Children in the interactive gesture group saw each of the three interactive gestures four times, over the two blocks. In contrast, children in the iconic manner gesture group saw six distinct iconic gestures in Block 1, and they saw each of the three interactive gestures twice in Block 2. Therefore, there was less repetition in the iconic manner gesture group than in the interactive gesture group, which could have led to worse performance in the interactive gesture group. Two pieces of evidence go against this alternative explanation. First, we compared the performances of the two groups in the first three trials of the task, where no gesture was repeated in either of the groups. The data from the first three trials were entered into our mixed-effect logistic regression analysis. Children in the iconic manner gesture group significantly outperformed children in the interactive gesture group in the first three trials of the experiment, (β = −1.03, p = .004, 95% CI [−1.74, −.34]). Second, we compared the performances of the two groups across four blocks of three trials. If gesture repetition affected the performance of children in the interactive gesture group compared to the unique gestures in the iconic manner gesture group, their performance should decrease with every block of three trials in which they see the same three interactive gestures repeated, compared to the iconic manner gesture group. We ran our mixed-effects logistic regression analysis over the full data set with group and blocks of three trials as predictors. The main effect of group was significant (β = −.97, p = .035, 95% CI [−1.91, −.08]), but not the main effect of blocks of three trials (β = −.14, p = .600, 95% CI [−.67, .39]), or the interaction (β = .03, p = .875, 95% CI [−.30, .35]). Thus, there is no evidence for the alternative explanation that the interactive gesture group performed worse because the same three interactive gestures were repeated.

Finally, we investigated whether each group performed better than chance in the two blocks. Children's proportions of correct answers on the verb generalization task were entered into one-sample Wilcoxon Signed Rank tests (two-tailed) with a test value of .5. Children in the iconic manner gesture group performed significantly better than chance in Block 1, Z = −3.70, p < .001, r = .76, and Block 2, Z = −2.70, p = .007, r = .55, but children in the interactive gesture group did not perform significantly different from chance in Block 1, Z = −.07, p = .943, r = .01, and Block 2, Z = −.81, p = .417, r = .17.

Discussion

The iconic gesture benefit in Block 1 indicates that seeing iconic gestures promotes children's first-order generalization of individual locomotion verbs to novel events. The continuing iconic gesture benefit in Block 2 shows that seeing iconic gestures promotes children's second-order generalization of locomotion verbs, because all the actors, actions, and novel verbs in Block 2 were different from those in Block 1, and none of the interactive gestures depicted any aspect of the verb referents. Thus, from the iconic gestures in Block 1, children must have deduced the general knowledge that the verbs in our study describe manners of locomotion, and they used this knowledge to learn a new set of verbs belonging to this subcategory in Block 2, in which all children saw interactive gestures.

Experiment 2

Experiment 2 investigates the long-term benefit of seeing iconic gestures on second-order generalization.

Methods and Materials

Design

The design was the same as in Experiment 1, but we introduced a 1-week delay between the two blocks of the experiment task.

Participants

The data were collected between April 12 and the May 16, 2017. As in Experiment 1, the sample

included 48 typically developing children (26 girls, 22 boys) between 35 and 50 months old (M = 42.98, SD = 3.87). An additional two children were tested but excluded from the analysis because they were unavailable for the second testing moment (N = 1) or diagnosed with a speech and language disorder (N = 1). None of the children had participated in Experiment 1 and the nurseries differed between experiments. Participants were recruited via two public nurseries and one Early Years Teaching Center in the West-Midlands and Warwickshire (United Kingdom). A total of 45 children was tested 7 days apart, two children 8 days apart, and one child 9 days apart. Six percent of the children had a racial background other than White (4% Asian, 2% Black). There were 13 girls and 11 boys in each group. Children's age in months did not differ between the two groups, $F(1, 46)$ = 0.38, p = .539. Informed parental consent was obtained for all participants. All children were exposed to the English language for at least 70% of the time and English was the primary language spoken at home (as indicated by their caregivers). Participating nurseries received a book voucher.

Materials

The materials were the same as in Experiment 1.

Randomization and Counterbalancing

Randomization and counterbalancing were the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1 (see Figure 1), apart from the following. We introduced a 1-week delay between the two blocks of the experiment task. Children performed the warm-up trials again when they were presented with Block 2 after the 1-week delay to familiarize them with pointing to both sides of the screen.

Data Analysis

The data were analyzed in the same way as in Experiment 1.

Results

The middle panel of Figure 2 shows children's performance on the verb generalization trials (in proportion) in Experiment 2 organized by group and block. The same analysis was used as in Experiment 1. The main effect of group on verb generalization performance was significant, $\chi^2(2)$ = 11.18, p = .004, but not the main effect of block, $\chi^2(2)$ = 1.24, p = .539, or the interaction, $\chi^2(1)$ = 1.10, p = .294. Overall, children who saw iconic gestures in Block 1 and interactive gestures in Block 2 generalized more verbs to same-action events than children who saw interactive gestures in both blocks (β = −.98, p = .001, 95% CI [−1.58, −.40]).

To further investigate our predictions, we used the same analysis as in Experiment 1. First, children in the iconic manner gesture group (M_{prop} = 0.77, SD = 0.42) generalized significantly more verbs to novel events in Block 1 than children in the interactive gesture group (M_{prop} = 0.62, SD = 0.49), β = −.81, p = .009, 95% CI [−1.47, −.21]. Second, children in the iconic manner gesture group (M_{prop} = 0.81, SD = 0.39) also significantly generalized more verbs to novel events in Block 2 than children in the interactive gesture group (M_{prop} = 0.59, SD = 0.49), β = −1.24, p = .001, 95% CI [−2.08, −.49].

Finally, we calculated comparisons with chance for each group in the same way as in Experiment 1. Children in the iconic manner gesture group performed significantly better than chance in Block 1, Z = −3.80, p < .001, r = .78, and Block 2, Z = −4.06, p < .001, r = .83, and children in the interactive gesture group did not perform significantly different from chance in Block 1, Z = −1.96, p = .050, r = .40, and Block 2, Z = −1.54, p = .123, r = .31.

Discussion

As in Experiment 1, the results show that seeing iconic gestures promotes first-order generalization of individual verb meanings (Block 1) and second-order generalization of the subcategory of verbs describing locomotion verbs (Block 2), even after a 1-week delay.

Experiment 3

Experiment 3 investigates whether iconic gestures depicting verb referents are better for promoting first- and second-order verb generalization than path-tracing gestures iconically depicting the actors' lateral path by tracing their movement from the left to the right side on the computer screen, and at the same time, drawing children's attention to the stimulus events.

Methods and Materials

Design

The design was the same as in Experiment 1, but we introduced path-tracing gestures as a control in the first block of the task instead of interactive gestures (see Figure 1). A path-tracing gesture involved an index-finger point that traced the actor's location (i.e., path) on the computer screen as they moved across the length of a scene (from left to right). Each path-tracing gesture was produced as long as actors were moving across the scene, just like the iconic manner gestures. Thus, both iconic manner and path-tracing gestures were dynamic in nature. Path-tracing gestures directed children's attention to the center of the center of the stimulus events, and they were produced approximately at belly button height of each actor. A video recording that illustrates how the path-tracing gestures were produced in relation to the stimulus events can be viewed via the Open Science Framework (osf.io/3jx4b).

Participants

The data were collected between November 28, 2018 and January 21, 2019. As in Experiments 1 and 2, the sample included 48 typically developing children (25 girls, 23 boys) between 36 and 50 months old ($M = 43.24$, $SD = 4.54$). An additional eight children were tested, but excluded from the analysis because they pointed only to answers on the one side of the screen in test trials ($N = 1$), were not compliant (e.g., covered their face with their arm during the task, $N = 1$), did not finish all the trials ($N = 1$), were too old on the day of testing ($N = 2$), or did not meet the English language requirements ($N = 3$). Participants were recruited via two public nurseries and two Early Years Teaching Centers in Warwickshire (United Kingdom) and from the database of families interested in taking part in language development research with their child at the University of Warwick. The nurseries where the data for this experiment were collected partly overlapped with Experiments 1 and 2, but none of the children had participated in these previous experiments. Twelve percent of the children had a racial background other than White (8% Asian, 4% Black). There were 13 girls and 11 boys in the iconic manner gesture group and 12 girls and 12 boys in the interactive gesture group. Children's age in months did not differ between the two groups, $F(1, 46) = 1.19$, $p = .281$, nor did their gender $\chi^2(1) = 0.08$, $p = .773$. Informed parental consent was obtained for all participants. All children were exposed to the English language for at least 70% of the time and English was the primary language spoken at home (as indicated by their caregivers). Participating nurseries received a book voucher and children who took part in the research lab received a toy and a certificate.

Materials

The materials were the same as in Experiments 1 and 2.

Randomization and Counterbalancing

Randomization and counterbalancing were the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, apart from the following. The experimenter now produced path-tracing gestures (at a distance of approximately 10 cm off the computer screen) that traced the actors' location on the screen during the movement (i.e., their path from left to right) in Block 1 for the control group, instead of interactive gestures (see Figure 1). In the same way as in Experiments 1 and 2, all children were taught novel verbs with interactive gestures in Block 2.

Data Analysis

The data were analyzed in the same way as in Experiments 1 and 2.

Results

The right panel in Figure 2 shows children's performance on the verb generalization trials (in proportion) in Experiment 3 organized by group and block. The same analysis was used as in Experiments 1 and 2. The main effect of group on verb generalization performance was significant, $\chi^2(2) = 6.27$, $p = .043$, but not the main effect of block, $\chi^2(2) = 3.56$, $p = .169$, or the interaction, $\chi^2(1) = 0.34$, $p = .559$. Overall, children in the iconic manner gesture group generalized more verbs to same-action events than children in the path-tracing gesture group ($\beta = -.70$, $p = .013$, 95% CI [-1.28, $-.14$]).

To further investigate our predictions, we compared performances between the two groups in Blocks 1 and 2 in the same way as in Experiments 1 and 2. First, children in the iconic manner gesture

group (M_{prop} = 0.75, SD = 0.43) generalized significantly more verbs to same-action events in Block 1 than children in the path-tracing gesture group (M_{prop} = 0.63, SD = 0.48), β = −.57, p = .038, 95% CI [−1.13, −.03]. Second, children in the iconic manner gesture group (M_{prop} = 0.68, SD = 0.47) generalized significantly more verbs to same-action events in Block 2 than children in the path-tracing gesture group (M_{prop} = 0.51, SD = 0.50), β = −.79, p = .016, 95% CI [−1.50, −.15].

Finally, we calculated comparisons with chance for each group in the same way as in Experiments 1 and 2. Children in the iconic manner gesture group performed significantly better than chance in Block 1, Z = −3.96, p < .001, r = .81, and Block 2, Z = −2.59, p = .010, r = .53, and children in the path-tracing gesture group did not perform significantly different from chance in Block 1, Z = −1.94, p = .052, r = .40, or in Block 2, Z = −.42, p = .676, r = .09.

Discussion

As in Experiments 1 and 2, the results show that iconic gestures encoding the verb referents (i.e., manners of locomotion) promoted first-order generalization of individual verb meanings (performances in Block 1) and second-order generalization of verbs that belong to the subcategory of locomotion verbs (performances in Block 2), in comparison to path-tracing gestures that encoded the actors' lateral path. This indicates that iconic gestures promote verb learning when they encode verb referents, and that just drawing children's attention to the stimulus events with path-tracing gestures is not sufficient to bring about such benefits.

General Discussion

This study has four key findings. First, preschool-aged children who learned novel locomotion verbs while seeing iconic gestures depicting the verb referents in a first block of trials extended those verbs significantly more often to novel events than children who saw interactive gestures (Experiments 1 and 2) or path-tracing gestures (Experiment 3). Thus, seeing iconic gestures that depict verb referents promotes *first-order generalization* of locomotion verbs. Second, children who saw iconic gestures during verb learning outperformed children who saw interactive gestures (Experiments 1 and 2) and path-tracing gestures (Experiment 3) in a second block of trials in which all children saw interactive gestures and learned a new set of different novel

verbs. Crucially, the actors and actions shown in the stimulus events and the novel verbs used to label these events in Block 2 were completely novel to the children (i.e., the children did not encounter them in Block 1). Thus, seeing iconic gestures that depict verb referents promotes *second-order generalization* of locomotion verbs. In other words, iconic gestures that depicted individual verb meanings helped children to *deduce new abstract knowledge* about a subcategory of verbs that describes manners of human locomotion. Third, children used this knowledge to generalize a new set of novel verbs of the same subcategory 1 week later (Experiment 2), demonstrating that seeing iconic gestures has a lasting beneficial effect on second-order verb generalization. Fourth, children who saw iconic gestures depicting the verb referents (i.e., manners of locomotion) outperformed children who saw path-tracing gestures that encoded the actors' lateral path of movement but did not encode the verb referent (Experiment 3). That is, gestures that encoded the referents of novel verbs promoted first- and second-order generalization of the verbs better than gestures that iconically encoded other aspects of the events (i.e., paths) irrelevant to verb meaning. Furthermore, just drawing children's attention to the stimulus events with path-tracing gestures was not sufficient to promote the two types of verb generalization.

Seeing Iconic Gesture Promotes First-Order Generalization of Locomotion Verbs

Our finding that seeing iconic gestures promotes first-order generalization of verbs describing manners of locomotion is consistent with studies showing that iconic gestures promote this type of generalization when children learn verbs describing object manipulations (Mumford & Kita, 2014; Wakefield et al., 2018). For instance, Mumford and Kita (2014) showed that iconic gestures guided 3-year-old children's attention to components of action events that could be considered as verb referents (i.e., manners, end-states), which influenced children's interpretations of verbs that describe object manipulations. Moreover, Wakefield et al. (2018) demonstrated that iconic gestures helped 4- and 5-year-old children to generalize verbs that describe object manipulations based on the sameness of action alone, without including the object that was acted upon in their representations of verb meanings. This study extends their findings to verbs that describe manners of locomotion.

In line with Mumford and Kita (2014), we show in Experiment 3 that the type of information

encoded in iconic gesture matters. In their study, they showed that iconic gestures encoding manners of manipulating objects led children to favor a manner interpretation over an end-state interpretation in the verb learning task. In our third experiment, children who saw iconic gestures that encoded verb referents outperformed children who saw path-tracing gestures that encoded the actors' lateral movement in the first- and second-order generalization trials. The path-tracing gestures in this experiment had an iconic component; that is, they traced the path of the actors as they moved across the length of a scene (from left to right). As actors always moved from left to right in the stimulus events, this iconic component did not encode information useful for the two-alternative forced-choice generalization trials (in which both videos showed actors moving from left to right). The difference between the two groups thus shows that iconic gestures encoding information useful for learning improves children's generalization performance. In our case, iconic gestures that depicted the referents of the novel verbs, namely the manners of locomotion helped children more than path-tracing gestures that traced the actors' path but did not encode the verb referents. Thus, only iconic gestures with a meaningful relationship with the verb referents promoted first-order generalization of these verbs.

How did iconic gestures promote first-order generalization of locomotion verbs? We argue that iconic gestures help children to focus on manners of locomotion in a schematic manner (e.g., Chu & Kita, 2008; de Ruiter, 2000; Goldin-Meadow, 2015; Kita, 2000; Kita et al., 2017; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Novack & Goldin-Meadow, 2016). Schematization by gesture is a form of abstraction—iconic gestures that depict actions strip away event components that are irrelevant to verb meaning (e.g., actors), while maintaining the components that are relevant to verb meaning (e.g., locomotion). Schematic representations of action events in iconic gestures can thus help children to single out the manners of locomotion in the stimulus events. This enabled children to generalize a verb to a novel event in which the same manner of locomotion was performed by a different actor (i.e., first-order generalization).

Seeing Iconic Gestures Promotes Second-Order Generalization of Locomotion Verbs

The current finding on second-order generalization goes beyond the existing literature in three important ways. First, seeing gesture promotes abstract *linguistic* knowledge in children, just as seeing iconic gestures promotes abstract *nonlinguistic* knowledge about mathematical equivalence (Cook et al., 2013). Second, in Cook et al.'s study, gestures and the concurrent speech both directly encoded the abstract knowledge that the two sides of equations must be equal, but, in our study, iconic gestures encoded individual verb meanings, not general knowledge about the subcategory of locomotion verbs, and speech did not express this abstract linguistic knowledge either. Nevertheless, the iconic gestures in our study helped children to deduce abstract linguistic knowledge about locomotion verbs. Thus, iconic gestures helped children to generate *new* abstract knowledge about this subcategory of verbs. This suggests that the benefit of iconic gesture in word learning has a *more profound* impact than previously assumed (Goodrich & Hudson Kam, 2009; McGregor et al., 2009; Mumford & Kita, 2014; Wakefield et al., 2018). Third, the effect of seeing iconic gestures persists even after 1 week. Thus, the *lasting benefit* of seeing iconic gesture on abstract knowledge in the nonlinguistic domain (e.g., the mathematical domain in Cook et al., 2013) extends to the linguistic domain.

How did iconic gestures promote abstract knowledge about the meanings of locomotion verbs? We argue that repeated schematization of action events guided by iconic gestures helped children to deduce general semantic properties of verbs from the same subcategory, which all describe locomotion. As such, iconic gestures tuned children's attention to manners of locomotion. This enabled children to map novel verbs of the same subcategory (i.e., locomotion verbs) to referents of the same type (i.e., manners of locomotion) on first encounter.

Two Routes to Second-Order Generalization

This study uncovered a new route to second-order generalization of novel verbs. When learning verbs, seeing an iconic gesture depicting the verb referent led to second-order generalization. This route is distinct from what Smith et al. (2002) showed: when learning nouns, being taught the same noun for two distinct objects with the same shape led to second-order generalization.

Although the two routes are distinct from each other, there is one important similarity. Both routes provide children with repeated opportunities to integrate two representations, which leads to new knowledge and highly tuned attention. When children hear a novel verb and see an accompanying

iconic gesture plus a video showing an action event, they can use iconic gesture as a schematic "template" to identify the referent action in the event. In other words, iconic gestures help children to attend to the essential component in the event relevant for verb meaning. As children repeatedly experience this schematization process, they develop the general knowledge that manner of locomotion is likely to be the referent of a novel verb and their attention is tuned to the manner of locomotion even when they do not see an iconic gesture. In case of the noun learning paradigm in Smith et al. (2002), when children hear the same novel noun in the presence of two distinct objects with the same shape, they compare the two objects and extract the shared property, namely shape. As children repeatedly experience this comparison, they develop the general knowledge that shape is important when a noun refers to a solid object, and their attention is tuned to shape when learning a novel object label (Smith et al., 2002). In these two cases, speech-gesture combinations and the use of an object label for two different same-shaped objects guide children as to what representations to focus on. Repeated integration of two relevant representations leads to abstract knowledge about word meaning and tunes children's attention so that the word referent is readily selected from a rich array of event information.

Gesture Observation and Gesture Production

Our findings that seeing iconic gestures promotes first-order and second-order generalization in children are in line with findings from gesture production research. In a study by Chu and Kita (2011), adults were better at solving mental rotation problems when they were encouraged to gesture than adults who were prohibited from gesturing. This finding shows that adults gained problem-specific knowledge from gesturing, which is equivalent to our finding that seeing gesture facilitates first-order generalization in word learning. Importantly, the beneficial effect of encouraging adults to gesture in a mental rotation task also carried over to a subsequent paper folding task (another spatial visualization task), in which gesturing was prohibited. This finding suggests that gesture production helped participants to generate problem-general knowledge which they could apply even to other types of spatial visualization problems. This is equivalent to our finding that seeing iconic gesture promotes second-order verb generalization.

Lasting Beneficial Effect of Iconic Gesture on Word Learning

Our finding that there was a lasting beneficial effect of iconic gesture on second-order generalization is consistent with studies that showed a delayed beneficial effect of iconic gesture on first-order generalization. Seeing iconic gesture facilitated first-order generalization of novel verbs referring to object manipulations 24 hr after training (Wakefield et al., 2018) and first-order generalization of the word *under* (e.g., "the boat is *under* the bridge") 2 or 3 days after training (McGregor et al., 2009). These findings show that iconic gestures have a lasting beneficial effect on first-order generalization. Gesture is likely to facilitate first-order generalization, because gesture highlights components of an event that promote abstract learning while leaving out details that could tie learning to a specific context (Goldin-Meadow, 2015). As such, gesture helps to create a schematic representation that is "light-weight" (Kita et al., 2017) and may therefore be easier to maintain in the memory and lead to lasting beneficial effects.

Why is Seeing Iconic Gesture Good for Learning?

Seeing iconic gestures help learners generate both linguistic and nonlinguistic abstract knowledge. We suggest that three properties of iconic gestures play a key role in this process. First, iconic gestures represent information in a schematic manner, which leads to efficient communication (Kita et al., 2017) and to generalizable knowledge (Goldin-Meadow, 2015). In teaching contexts, iconic gestures can convey only the essential information children need for the task. For mathematical problems, in an equation, for instance, gestures represent each side of the equation without focusing on specific values or the plus sign (Cook et al., 2013), and for verb learning in this study, they focus on the action component of an event while stripping away irrelevant details (e.g., the actor's clothes, background). Second, iconic gestures are *representational* actions in the sense that they stand for something else (Novack & Goldin-Meadow, 2016). Iconic gesture as a symbol is "removed" from the referent, and this symbolic distancing (Werner & Kaplan, 1963) may promote abstract understanding. Third, iconic gestures are typically produced in ways semantically coordinated with speech (Kita & Özyürek, 2003; McNeill, 1985, 1992). Thus, when children receive information in speech-gesture combinations, they may naturally tend to ground information in speech to spatio-motoric information in gesture

(Kelly, Özyürek, & Maris, 2010; Novack & Goldin-Meadow, 2016; Valenzeno, Alibali, & Klatzky, 2003). This may be especially helpful when speech directly encodes abstract knowledge (e.g., Cook et al., 2013; Valenzeno et al., 2003).

Iconicity and Verb Acquisition

Children's verb production seems to be related to their iconic gesture production developmentally. For example, English-speaking children show an increase in iconic gesture production between 22 and 26 months of age, precisely the period during which they also show an increase in verb production (Özçalışkan, Gentner, & Goldin-Meadow, 2014). Furthermore, Turkish-speaking children start producing iconic gestures on average around 23 months of age (Furman, Küntay, & Özyürek, 2014), which is earlier than what is reported for English-speaking children (Özçalışkan & Goldin-Meadow, 2011). Furman et al. (2014) suggest that this may be because Turkish-speaking children start using more verbs earlier than English speaking children. Verbs and iconic gestures may be linked in production because they both require the ability to individuate action components in a complex scene and conceptualize the relationship among various components (such as actor, action, object, instrument, etc.)

Once children's iconic gesture comprehension is established, it can further bootstrap verb learning. By age 3, children can reliably identify the referents of iconic gestures that depict actions (Hodges et al., 2018; Marentette & Nicoladis, 2011; Namy, 2008; Stanfield et al., 2014; Tolar et al., 2008). This study and previous studies (Goodrich & Hudson Kam, 2009; Mumford & Kita, 2014; Wakefield et al., 2018) showed that seeing iconic gestures helps 3-year-olds learn novel verbs.

In the preschool years, children can also benefit other types of iconic cues in verb learning. For example, 3-year-olds perform better in verb generalization tasks when the form and meaning of the verbs are sound symbolically congruent (i.e., the verbs sound like what they mean; Imai et al., 2008; Kantartzis, Imai, & Kita, 2011; Yoshida, 2012). Thus, 3-year-olds' sophisticated symbolic understanding allows them to use cues such as iconic gestures and sound symbolism to bootstrap their lexical development (Imai & Kita, 2014).

Limitations

The study is limited in two ways: only a certain type of verb referents and a certain type of iconic

gestures were investigated. First, the verbs in this study described locomotion manners. Previous research has shown that iconic gestures can promote first-order generalization of change-of-state verbs (e.g., Mumford & Kita, 2014) and object manipulation verbs (e.g., Mumford & Kita, 2014; Wakefield et al., 2018), but it is not clear if iconic gestures can also promote second-order generalization of these verb types. Second, the iconic gestures in this study were all "observer viewpoint gestures" (McNeill, 1992), in which the gesturing hands represented something other than hands (e.g., feet, legs, body). Thus, it remains unclear if "character viewpoint gestures" (McNeill, 1992) used in previous research (e.g., Mumford & Kita, 2014; Wakefield et al., 2018), in which the gestural hand movement represents hand movement, have the same beneficial effects on verb learning and generalization as observer viewpoint gestures. This is because hand-to-leg gestures are further removed from their referent than hand-to-hand gestures in terms of symbolic distance (Werner & Kaplan, 1963). As such, it may be easier for children to recognize the resemblance between an iconic hand gesture that depicts a hand movement and the actual hand movement (e.g., throwing a ball) than between an iconic hand gesture that depicts a leg movement and the actual leg movement (e.g., kicking a ball). This may facilitate first-order generalization. In contrast, gestures further removed from their referents may require more abstract processing and this may, in turn, be beneficial for second-order generalization. These are important questions for future research.

Conclusions

Many of the co-speech gestures adults produce daily are iconic gestures that depict verb referents (Remland, 2016). Nevertheless, the real-world benefit of seeing iconic gestures on children's verb learning has not been clear, because people do not produce an iconic gesture with every utterance. However, we show that seeing iconic gestures during verb learning has a far-reaching and lasting impact when they depict the verb referents; they improve children's subsequent verb learning even when iconic gestures are not present. More specifically, seeing iconic gestures depicting verb referents not only promotes generalization of the verbs whose referents are depicted by the accompanying iconic gestures (first-order generalization), but also improves subsequent generalization of similar novel verbs of the same subcategory whose referents are *not* depicted by iconic gestures (second-order

generalization). In other words, iconic gestures depicting individual verb referents can help children figure out not only *what* aspect of an event a particular verb refers to, but also *how* to learn verbs that belong to a certain subcategory (e.g., locomotion verbs). Furthermore, the beneficial effect of seeing iconic gesture on verb generalization persists after 1 week. Thus, iconic gestures depicting verb referents play a much bigger role in verb learning than was previously thought.

References

Anderson, R., & Freebody, P. (1979). Vocabulary Knowledge. In J. Guthrie (Ed.), *Reading comprehension and education* (pp. 77–117). Neward, DE: International Reading Association.

Aussems, S., & Kita, S. (2017). Seeing iconic gestures while encoding events facilitates children's memory of these events. *Child Development*, *90*, 1123–1137. https://doi.org/10.1111/cdev.12988

Aussems, S., Kwok, N., & Kita, S. (2017a). GestuRe and ACtion Exemplar (GRACE) video database: Stimuli for research on manners of human locomotion and iconic gestures. *Behavior Research Methods*, *50*, 1270–1284. https://doi.org/10.3758/s13428-017-0942-2

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

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. https://doi.org/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. https://doi.org/10.18637/jss.v067.i01

Bavelas, J., Chovil, N., Lawrie, D., & Wade, A. (1992). Interactive gestures. *Discourse Processes*, *15*, 469–490. https://doi.org/10.1080/01638539209544823

Behrend, D. (1990). The development of verb concepts: Children's use of verbs to label familiar and novel events. *Child Development*, *61*, 681–696. https://doi.org/10.2307/1130953

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. https://doi.org/10.1037/a0013157

Chu, M., & Kita, S. (2011). The nature of gesture's beneficial role in spatial problem solving. *Journal of Experimental Psychology: General*, *140*, 102–116. https://doi.org/10.1037/a0021790

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

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.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using GPower 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Forbes, J., & Farrar, M. (1993). Children's initial assumptions about the meaning of novel motion verbs: Biased and conservative? *Cognitive Development*, *8*, 273–290. https://doi.org/10.1016/S0885-2014(93)80002-B

Forbes, J., & Farrar, M. (1995). Learning to represent word meaning: What initial training events reveal about children's developing action verb concepts. *Cognitive Development*, *10*, 1–20. https://doi.org/10.1016/0885-2014(95)90016-0

Furman, R., Küntay, A., & Özyürek, A. (2014). Early language-specificity of children's event encoding in speech and gesture: Evidence from caused motion in Turkish. *Language, Cognition and Neuroscience*, *29*, 620–634. https://doi.org/10.1080/01690965.2013.824993

Gentner, D. (1978). On relational meaning: The acquisition of verb meaning. *Child Development*, *49*, 988–998. https://doi.org/10.2307/1128738

Gentner, D. (1981). Some interesting differences between verbs and nouns. *Cognition and Brain Theory*, *4*, 161–178.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.), *Language development: Language, cognition, and culture* (pp. 301–334). Hillsdale, NJ: Erlbaum.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity and early word learning. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). New York, NY: Cambridge University Press.

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

Goodrich, W., & Hudson Kam, C. (2009). Co-speech gesture as input in novel verb learning. *Developmental Science*, *12*, 81–87. https://doi.org/10.1111/j.1467-7687.2008.00735.x

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

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. https://doi.org/10.1111/j.1467-8624.2005.00849_a.x

Imai, M., & Kita, S. (2014). The sound symbolism boot-strapping hypothesis for language acquisition and language evolution. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*. https://doi.org/10.1098/rstb.2013.0298

Imai, M., Kita, S., Nagumo, M., & Okada, H. (2008). Sound symbolism facilitates early verb learning. *Cognition*, *109*, 54–65. https://doi.org/10.1016/j.cognition.2008.07.015

Kantartzis, K., Imai, M., & Kita, S. (2011). Japanese sound symbolism facilitates word learning in English-speaking children. *Cognitive Science*, *35*, 575–586. https://doi.org/10.1111/j.1551-6709.2010.01169.x

Kelly, S., Özyürek, A., & Maris, E. (2010). Two sides of the same coin: Speech and gesture mutually interact to enhance comprehension. *Psychological Science*, *21*, 260–267. https://doi.org/10.1177/0956797609357327

Kersten, A., & Smith, L. B. (2002). Attention to novel objects during verb learning. *Child Development*, *73*, 93–109. https://doi.org/10.1111/1467-8624.00394

Kita, S. (2000). How representational gestures help speaking. In D. McNeill (Ed.), *Language and gesture* (pp. 162–185). Cambridge, UK: Cambridge University Press.

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

Kita, S., & Özyürek, A. (2003). What does cross-linguistic variation in semantic coordination of speech and gesture reveal?: Evidence for an interface representation of spatial thinking and speaking. *Journal of Memory and Language*, *48*, 16–32. https://doi.org/10.1016/S0749-596X(02)00505-3

Marentette, P., & Nicoladis, E. (2011). Preschoolers' interpretations of gesture: Label or action associate? *Cognition*, *121*, 386–399. https://doi.org/10.1016/j.cognition.2011.08.012

McGregor, K., Rohlfing, K., Bean, A., & Marschner, E. (2009). Gesture as a support for word learning: The case of *under*. *Journal of Child Language*, *36*, 807–828. https://doi.org/10.1017/S0305000908009173

McNeill, D. (1985). So you think gestures are nonverbal? *Psychological Review*, *92*, 350–371. https://doi.org/10.1037/0033-295X.92.3.350

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

Morgan, P., Farkas, G., Hillemeier, M., & Scheffner Hammer, C. (2015). 24-month-old children with larger oral vocabularies display greater academic and behavioral functioning at kindergarten entry. *Child Development*, *86*, 1351–1370. https://doi.org/10.1111/cdev.12398

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

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

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. https://doi.org/10.1177/0956797613518351

Novack, M., & Goldin-Meadow, S. (2016). Gesture as representational action: A paper about function. *Psychonomic Bulletin & Review*, *24*, 652–656. https://doi.org/10.3758/s13423-016-1145-z

Özçalışkan, Ş., Gentner, D., & Goldin-Meadow, S. (2014). Do iconic gestures pave the way for early verbs? *Applied Psycholinguistics*, *35*, 1143–1162. https://doi.org/10.1017/S0142716412000720

Özçalışkan, Ş., & Goldin-Meadow, S. (2011). Is there an iconic gesture spurt at 26 months? In G. Stam & M. Ishino (Eds.), *Integrating gestures: The interdisciplinary nature of gesture*. Amsterdam, The Netherlands: John Benjamins.

R Development Core Team. (2011). *R: A language and environment for statistical computing*. Vienna, Austria. Retrieved from http://www.R-project.org

Remland, M. (2016). *Nonverbal communication in everyday life* (4th ed.). West Chester, PA: Sage.

Roseberry, S., Hirsh-Pasek, K., Parish-Morris, J., & Golinkoff, R. (2009). Live action: Can children learn verbs from video? *Child Development*, *80*, 1360–1375. https://doi.org/10.1111/j.1467-8624.2009.01338.x

Rosenthal, R. (1994). Parametric measures of effect size. In H. Cooper & L. V. Hedges (Eds.), *The handbook of research synthesis* (pp. 231–244). New York, NY: Russell Sage Foundation.

Rowe, M., Raudenbusch, S., & Goldin-Meadow, S. (2012). The pace of vocabulary growth helps predict later vocabulary skill. *Child Development*, *83*, 508–525. https://doi.org/10.1111/j.1467-8624.2011.01710.x

Smith, L. B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science*, *13*, 13–19. https://doi.org/10.1111/1467-9280.00403

Stanfield, C., Williamson, R., & Özçalışkan, Ş. (2014). How early do children understand gesture–speech combinations with iconic gestures? *Journal of Child Language*, *41*, 462–471. https://doi.org/10.1017/S0305000913000019

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

Valenzeno, L., Alibali, M. W., & Klatzky, R. (2003). Teachers' gestures facilitate students' learning: A lesson in symmetry. *Contemporary Educational Psychology*, *28*, 187–204. https://doi.org/10.1016/S0361-476X(02)00007-3

Wakefield, E., Hall, C., James, J., & Goldin-Meadow, S. (2018). Gesture for generalization: gesture facilitates

flexible learning of words for actions on objects. *Developmental Science*, *21*, e12656. https://doi.org/10.1111/desc.12656

Werner, H., & Kaplan, B. (1963). *Symbolic formation. An organismic-developmental approach to language and the expression of thought*. New York, NY: Wiley.

Yoshida, H. (2012). A cross-linguistic study of sound symbolism in children's verb learning. *Journal of Cognition and Development*, *13*, 232–265. https://doi.org/10.1080/15248372.2011.573515

Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Table S1. Exploratory Correlations Between Children's Age in Months and Verb Generalization Performance (in Proportion) by Experiment, Gesture Condition, and Block

Appendix

Table A1

List of Video Files Taken from the GRACE Video Data Base (Aussems et al., 2017a, 2017b). The Iconic Gesture Column Lists Video Files of Examples of Iconic Gestures Produced Live by an Experimenter During the Task. The Training Exemplar Column Lists Video Files Shown in the Training Phase and the Target Exemplar and Distractor Exemplar Columns List Video Files Shown Side by Side in the Test Phase. All Videos are Available in MP4 Format Via http://wrap.warwick.ac.uk/78493/

Iconic gesture	Training exemplar	Target exemplar	Distractor exemplar
00F_flicking	11F_flicking	10M_flicking	11F_dragging
00F_scurrying	10F_scurrying	04M_scurrying	10F_groining
00F_grapevining	07F_grapevining	12M_grapevining	07F_shuffling
00F_bowing	06M_bowing	12F_bowing	06M_skating
00F_folding	02M_folding	08F_folding	02M_dropping
00F_creeping	07M_creeping	03F_creeping	07M_crisscrossing
00F_swinging	13F_swinging	05M_swinging	13F_skipping
00F_twisting	04F_twisting	01M_twisting	04F_stomping
00F_marching	06F_marching	09M_marching	06F_wobbling
00F_overstepping	03M_overstepping	09F_overstepping	03M_mermaiding
00F_trotting	08M_trotting	05F_trotting	08M_hopping
00F_turning	11M_turning	01F_turning	11M_hopscotching

Note. In the following order, the files names contain a reference to an individual (numbers 0–13), the individual's gender (F = female, M = male), and a short-hand label for the iconic gesture (Column 1) or manner of locomotion (Columns 2–4).