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Children Use Gesture to Interpret Novel Verb Meanings.

Katherine H. Mumford and Sotaro Kita

Author Note

Katherine H. Mumford, Sotaro Kita, School of Psychology, University of Birmingham, Birmingham, B15 2TT, United Kingdom.

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Correspondence concerning this article and its underlying research materials should be addressed to Katherine H. Mumford, at KHM907@bham.ac.uk.

When people speak, they often spontaneously produce gestures. Gestures play complex and important roles in communication (Hostetter, 2011; Kendon, 1994). We investigated how gestures by adults influence children's word learning. Among various types of gestures, the current paper will focus on iconic gestures. These are gestures that, either in hand shape or movement, depict action, movement or shape based on similarity between the gestural form and referent (McNeill, 1985).

The Problem of Verb Learning

Children learning English typically begin to use nouns before they use verbs (e.g. Goldin-Meadow, Seligman & Gemlan, 1976, Bornstein, Cote, Maital, Painter, Park, Pascual et al, 2004). Experimental studies showed that 3-year-old children, for example, struggle to generalise new verbs outside of the context in which it was first encountered (e.g. Imai, Haryu & Okada, 2005) especially if features of the context are novel (e.g. Kersten & Smith, 2002). It has been argued that it is difficult for children to pin-point what aspect of a complex scene is the referent of a novel word in an ostensive word-learning situation (e.g. Genter, 1982). This is commonly known as "Quine's (1960) problem". Although this problem is traditionally associated with noun acquisition, the same issues arise with verb learning too. Gentner (1982) argues that nouns are easier to learn than verbs, since they have a more transparent mapping to the perceptual world. In contrast verbs have less transparent mappings; children have to extract and package various aspects of the relations between objects (Gentner, 1982). Verbs often refer to complex actions, including various participants and objects (Imai et al, 2005) as well as varying outcomes. Further, the referents are often dynamic and fleeting (e.g. an action). Gleitman and Gleitman (1992) describe several problems children face when learning verbs, including how the word is often not heard at the time of the event itself and how some verbs cannot be seen at all (e.g.

internal states '*to know*'). They also highlight how complex the contexts are when verbs are heard, and the difficulty in trying to understand which feature the verb is expressing (Gleitman & Gleitman, 1992). Despite these difficulties, in real life, children this age appear to have begun to comprehend and produce verbs (e.g. Goldin-Meadow et al, 1976). The discrepancy between experimental and real-life learning situations may arise because real-life situations may provide a richer set of contextual cues, such as speech-accompanying gestures. The current study investigated whether co-speech gestures can bias children's interpretation of a novel verb towards either a manner verb (such as '*to kick*') or a change-of-state verb (such as '*to break*').

Manual Actions and Word Learning

Adults' body movements can influence children's word learning performance. Manipulative actions made upon novel objects, when learning a novel label, influence children's understanding of what novel labels refer to. For example, Kobayashi (1997) found that, when teaching novel words, actions which highlighted shape (e.g. rolling a glass egg) or material (e.g. looking through the glass egg) helped children to assign labels to particular properties of objects. Further, these actions helped children to pinpoint a particular aspect of an object better than a pointing gesture. (Kobayashi, 1998). Similarly, O'Neill and colleagues (2002) taught children novel adjectives, and found that actions made upon objects, which highlighted texture, helped children to identify the meaning of these words.

Gestures and Word Learning

Iconic gestures have been shown to support word learning for a range of word types in both first (McGregor, Rohlfing, Bean, & Marschner, 2009; Goodrich & Kam, 2009) and second language acquisition (Tellier, 2007, 2008). Clark and Estigarribia (2011) found that when adults teach 3-year-olds new words, adults use gestures (as well as object manipulation) to indicate

parts of a novel object and to describe actions and functions. McGregor and colleagues (2009) taught 2-year-old children the preposition term '*under*' through the modelling of objects, either with or without iconic gestures. Results showed that infants who had seen iconic gestures had built a more robust and abstract representation of '*under*'. It has been suggested that iconic gestures may relieve cognitive load by making the meaning of a word more salient, leading to more efficient word learning (e.g. McGregor et al, 2009; Goldin-Meadow, 2000). However, as McGregor and colleagues' (2009) study used only one gesture condition, it remains unclear if gesture simply benefited learning by making the task more interactive and engaging. Research has also shown that 3-year-old children can use information from iconic gestures to map a novel verb to a novel scene (Goodrich & Kam, 2009). The scenes used in the Goodrich and Kam's (2009) study, however, were complex, involving different toys and actions, and children were not required to generalise the novel verbs to novel situations. It remains unclear, therefore, if children can use iconic gestures to zero-in on a particular aspect within a scene as the referent of novel verbs, which allows them to correctly generalise the verbs to novel situations. In other words, it remains unclear whether iconic gestures can help children solve Quine's (1960) problem, with respect to verb learning.

Current Study

The current study investigated the hypothesis that iconic gestures help children map a novel word to a particular feature within a novel complex scene, and therefore generalise the verb based on this feature. Around 26 months, children begin to demonstrate some understanding of iconic gestures (Namy, 2008; Namy, Campbell & Tomasello, 2004). Therefore, the current study tested 3 year old children. We taught children ambiguous novel verbs, where the referent of the novel verb could be the action in the video (manner verb interpretation) or the end state

(change-of-state verb interpretation). Teaching was accompanied by iconic gestures highlighting the manner, the end state or by no gestures. Children were then asked to generalise the novel verb to a scene in which either the end state was constant but the manner was novel, or the manner was constant and the end state was changed. The children were asked to point to one of the two scenes, presented side-by-side on the computer screen. We predicted that children's interpretation of ambiguous novel verbs should align with information encoded in gestures. That is, gesture can facilitate word learning because gesture guides children's attention to a specific aspect of a complex scene, which is the intended referent of the word.

Method

Participants

The study included 120 3-year-old children (57 females and 63 males) between the ages of 36 and 47 months (M= 41.48 months, SD= 3.13). Participants were recruited from nurseries in Warwickshire, England, and received a sticker in return for their participation. Testing took place in a quiet area of their nursery. Participants were randomly assigned into one of three gesture conditions (manner gesture, end state gesture or no gesture). There were no significant differences in age (measured in months) between the gesture groups. Six of the children were acquiring at least two languages (end state gesture group: 2 children; manner gesture group: 1 child; no gesture group: 3 children). Although information about socio-economic status (SES) was not taken, the gesture groups were equally represented within each nursery in order to control for influences of SES.

Nineteen children were excluded from the analysis: one for attentional problems, and 18 for a side bias (all responses selected videos on one side). This left the following number of

participants in each group: end state gesture group- 32, manner gesture group- 36, no gesture group- 33.

Materials

The study used 20 short video clips (8-11seconds) as exemplars of novel verbs. The videos all depicted an actor's hand manipulating objects in different ways to bring about a clear end state (e.g. placing sections of black material to create a 'cloud' shape on a white background). See the supplementary materials for all the video stimuli.

The video clips were organised into five video groups. Within each group, the materials manipulated by the actions were the same. Each group consisted of two different manners, each resulting in two different end states. This resulted in four videos per group. For example, one video group consisted of the following four videos: Video 1) placing sections of material to create a 'cloud' shape, Video 2) placing sections of material to create horizontal stripes, Video 3) pushing sections of material using the index finger to create a 'cloud' shape, Video 4) pushing sections of material using the index finger to create horizontal stripes. Each child was tested on each of the five video groups once. Thus, there were five trials in total. As an example, when Video 1 from a given video group was used as the training video for a given child, then, at test, Video 2 was the same-manner video and Video 3 was the same-end-state video (both from the same video group). Video 4 would not be presented to this child. The video used for training was counterbalanced across participants, such that all videos appeared equally often as the training video, and as the same-manner and same-end-state videos at test. Further, the video groups were presented in a rotated order, such that across participants all video groups appeared equally often in the 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and final trial.

The five novel verbs used in the study were *Dax*, *Larp*, *Stum*, *Tood* and *Blick.* These were randomised such that one verb did not always accompany one particular video group.

Iconic gestures

There were two types of iconic gestures: manner and end state. Manner gestures depicted the manner shown in the video and, therefore, depicted the action of the hand in the video, regardless of the state that action brought about. End state gestures depicted the shape or lines formed in the video, regardless of how that state was brought about. All gestures were produced live by the experimenter (See supplementary materials for video recordings demonstrating some of the gestures used).

Stimuli pre-test

A pre-test was conducted to ensure that children could match the iconic gestures to their referents in a two-way forced choice task (full details in the supplementary material 1). Fourteen 3-year-olds (7 females, M= 40.94months, SD=3.28) who did not take part in the main experiment, matched the iconic gestures to the correct video above chance (.5), (the proportion of trials with a correct choice: M = .660, SD = 0.145, $t(13) = 4.137$, p=.001). Further, the performance did not significantly differ between end state and manner gestures ($t(13)$=.416, p>.05).

Procedure

Stimuli were presented on a 20” screen linked to a computer. The study started with four practice trials, in which participants were asked to identify familiar objects from two static images. Practice trials were designed to familiarise children with pointing to the screen and to boost their confidence. As there was no practice of pointing to videos, participants were not

primed to attend to a particular aspect of the video (e.g. end state or manner) before the experimental phase.

The study then moved on to the experimental phase, which consisted of five trials. Each experimental trial consisted of two stages: training and testing (see Figure 1). In the training phase participants saw a video clip of an actor performing the target action and heard the training sentence '*Look! She's (novel verb)-ing it!*'. Both the video clip and the training sentence were then repeated. For children in the manner gesture group, as the experimenter said the training sentence, she also produced a gesture that depicted the manner seen in the video. For children in the end state gesture group, as the experimenter said the training sentence, she also produced a gesture that depicted the end state in the video. Children in the no iconic gesture condition just heard the sentence. The experimenter sat next to participants at 45° so they could see the child and the videos. The experimenter always looked at the child as she produced the sentences/ gestures.

In the test phase participants saw two videos, side-by-side, playing simultaneously and looped. Participants were asked '*Which one's (novel verb)-ing it?*'. Participants were asked to point to their chosen video. One video showed a different manner resulting in the same end state. If children had a change-of-state bias they would select this video. The other video showed the same manner resulting in a different end state. If children had a manner interpretation they would select this video. The test phase was the same for all participants: it did not involve any iconic gestures.

At test, children sometimes tried to point to both videos. In these cases, children were reminded they could only pick one and the question was repeated. Children's final choice, indicated by a pointing gesture, was noted down by the experimenter. If children made a choice,

this was always made clear by them using a pointing gesture, children never made a verbal choice. All choices were noted down in real time by the experimenter, the sessions were not recorded and, therefore, no reliability analysis was conducted.

Figure 1 about here.

Results

Two trials from two separate children (one per child) were removed as the children failed to make a choice.

The dependent variable was the proportion of trials in which the same-manner video (with a different end-state) was selected, out of the total number of trials in which they made a choice (usually 5). Therefore, a score of 1 indicates a pure manner bias (selecting the manner match on every trial), and 0 indicates a pure change-of-state bias (selecting the end state match on every trial). Figure 2 shows the descriptive results obtained.

Figure 2 about here.

Group Level Analysis

First, in order to assess whether gender or order of stimulus videos had had an impact on the performance, an analysis of variance (ANOVA) was conducted with sex, counterbalancing group (the order in which the video groups were presented, and which video within a video group was presented as the training video) and gesture group as the independent variables, and

the proportion of same-manner videos selected as the dependent variable. Neither sex nor counterbalancing group, nor any of their interactions were significant (p>.05 for all).

In order to assess how stable the observed pattern was across stimulus items, we looked at the pattern of results across the ten manners and the ten end states. The trend seen in the main analysis holds well across the manners and end states. See Supplementary Materials 2 for more details.

The proportion of trials with the same-manner video choice were entered into a one-way ANOVA with gesture type as the between subjects variable (3 levels: no gesture, manner gesture and end state gesture) (see Figure 2). The results revealed a significant main effect of gesture type (F (2, 98) = 7.863, p=.001). Additional analysis including age as a covariate found a similar main effect of gesture type, see supplementary materials 3 for more details.

LSD post hoc testing revealed children who saw manner gestures gave significantly more manner bias responses than children who saw no iconic gestures (p=.004) and those who saw end state gestures (p<.001). There was no significant difference between children who saw end state gestures or no gestures. That is, manner gestures made children generalize novel verbs based on manners significantly more often than the baseline (the no gesture group); however, there is no evidence that end-state gestures made children generalise the verbs based on end-states more often than the baseline. Note that if children who were acquiring multiple languages were excluded, the main results did not change. See supplementary materials 4 for details.

Then, the children's performance was compared to chance (.5). Children selected more change-of-state choices than chance when they saw either no gestures (t (32) = -2.633, p=.013) or end state gestures (t (31) = -3.978, p<.001). Children who saw manner gestures showed a trend towards more manner responses than chance, but this was not statistically significant.

Individual Level Analysis

Given that children who saw manner gestures did not perform differently from chance, we investigated the possibility that seeing manner gestures simply led to confusion (and chance performance) rather than a shift towards a manner bias. To do this we looked at the number of children who showed a strong bias in their responses in the three conditions. Children were defined as having a strong bias if they picked the opposite interpretation only once or not at all throughout the experiment. For example, children were defined as change-of-state biased if they only chose the manner interpretation once or never. Children who did not fit into these categories were defined as having no strong bias.

Table 1 about here.

The gesture groups and their response bias were significantly associated (χ^2 = 13.925, *df* = 4, *p*=.008). That is, children in different gesture groups showed different patterns of bias.

Next we tested if certain biases were more common in some gesture groups than others. To do this we reran the chi-squared analyses for each response category (see the columns in Table 1). This compared the observed frequency against the frequency expected if the gesture conditions did not have any impact on biases in response. We inferred the expected frequency based on the total number of children in the three gesture groups: manner gesture n = 36, end-state gesture n = 32, no gesture n = 33. If gesture groups did not have any impact on the biases, then we should expect that the number of children in the three gesture group should be at the ratio of 36:32:33, regardless of the bias groups. For example, the proportion of the manner

gesture group was expected to be .356 = 36 / (36 + 32 + 33). Thus, for the strong manner bias group (n = 18), the expected frequency for the manner gesture group was 18 * .356

First, the group which demonstrated a strong manner biases showed a significant difference between the observed and expected frequencies (χ^2 = 7.55, *df* = 2, *p*=.023). This difference arose because that there were marginally more children than expected with a strong manner bias in the manner group and fewer than expected in the end state gesture group (χ^2 = 3.38, *df* = 1, *p*=.066) and in the no gesture group (χ^2 = 3.6, *df* = 1, *p*=.058).

Next, the group which demonstrated a strong change-of-state bias showed a marginally significant difference between the observed and expected frequencies (χ^2 = 5.7, *df* = 2, *p*=.058). This difference arose because there were more than expected children in the end state gesture group, and fewer than expected children in the manner group (χ^2 = 4.83, *df* = 1, *p*=.028). There were no significant differences when comparing manner and no gesture groups or end state and no gesture groups (*p*>.05 for both).

Finally, we investigated the group of children who did not show a strong bias. The results showed no significant effect (*p*>.05), such the comparable amount of children in each group had no strong bias.

Discussion

Overview of Study

This study investigated the effect of seeing an iconic co-speech gesture on 3-year-old children's ability to learn novel verbs. The results supported the hypothesis that information contained within these gestures can influence children's semantic representations of novel verbs. The results suggest that gestures could guide children's attention to a particular aspect of a complex scene as the referent of a novel verb. Children who saw iconic gestures depicting

manner were more likely to generalise the verb to a new scene with the same action, compared to children who saw no gestures or end state gestures. Children showed a baseline bias (in the no gesture group) towards the end-state interpretation; thus, children who saw manner gestures as a group selected the manner interpretation only at a chance level. This may raise a concern that children in the manner gesture group were simply confused; however, further analysis that classified children based on the bias in their responses did not support this alternative interpretation. Confused children should respond randomly, without any strong manner or change-of-state bias. If manner gestures had confused children, then the children in the manner gesture group should have been over-represented among the children with no strong bias; however, the three gesture groups were equally represented. Moreover, gesturally encoded information led to a higher number of children with a strong bias for the encoded information. That is, among the children with a strong manner bias, the children in the manner gesture group were over-represented, in comparison to those in the no-gesture group and the end-state gesture group. Among the children with a strong end-state bias, children in the end-state gesture condition were over-represented, in comparison to those in the manner-gesture condition. This pattern of results suggests that children in the manner gesture group were more likely to take the action, not the change-of-state, as the critical feature of the complex scene in the video. Thus, we conclude that utilising information contained in iconic co-speech gestures is one way that children can zero-in on a particular aspect of a novel scene as the referent of a novel verb.

Iconic Gestures and Word Learning

The current finding is compatible with other studies that have found that iconic gestures can help children to learn new words (e.g. the preposition '*under*': McGregor et al, 2009; verbs: Goodrich & Kam, 2009; nouns in a second language: Tellier, 2008). The current study, however,

extends the literature by clarifying *how* gestures can aide learning. McGregor and colleagues (2009) found that children in the iconic gesture condition performed better in a word learning task; however, it was unclear if that was because gesture simply increased overall interactivity or engagement in the task. The current results cannot be accounted for by increased overall interactivity or engagement as different gestures had different effects; children were guided by specific information contained in gesture. In addition, although Goodrich and Kam (2009) found that children could use iconic gestures to link a novel verb to a novel scene, it remained unclear what children believed the novel verb referred to exactly, as they were not required to generalise verbs to novel scenes. The current study found that seeing iconic gestures can help children to focus on a particular referent within a complex scene when learning novel verbs, rather than simply associating a verb with the scene in general. The current study has, therefore extended the previous literature in two ways. Firstly, as different gestures influenced children's verb learning differently, that is the gestural content is important, gestures do more than just make the learning environment more engaging. Secondly, gestures can help to select a particular aspect within a complex scene as the referent of a novel verb, which is crucial for generalizing the verb to new situations; gestures do not simply help children to associate a word with a scene in general. That is, using information in iconic gestures may be one way by which children can solve which feature of a scene, a verb is encoding (e.g. Quine, 1960; Gentner, 1982, Gleitman & Gleitman, 1992).

How do iconic gestures help children zero-in on the referent in a complex scene? Gesture is a schematic representation that abstracts away irrelevant aspects of complex scenes. Thus, seeing an iconic gesture along with a complex scene help children pinpoint the relevant information within the complex scene. In other words, iconic gestures help overcome some of

the key difficulties of verb learning; extracting relevant features of a scene and packaging them into a conceptual unit (Gentner, 1982). Iconic gestures may serve a similar function to seeing multiple complex scenes that repeat the referent. When learning a novel verb that can be interpreted either as a manner or a change-of-state verb in the initial exposure, two-and-half year olds could zero-in on the referent after seeing additional complex scenes in which the referent (e.g., either the same manner or the same end-state) remained constant (Childers, 2011). In this situation, children could compare multiple complex scenes and find the common feature, which is likely to be the referent. The comparison of an iconic gesture and the complex scene may bring similar benefits to word learning, but in a more efficient way: exposure to one scene already enables comparison, and the schematic nature of gestural representation makes it easier to find common features. In other words, iconic gestures provide a sketch of abstract semantic representations of verbs, which help children carry out fast mapping (Carey & Bartlett, 1978) of newly encountered verbs and correctly apply the verbs to novel complex scenes later.

Different Types of Iconic Gestures

It is interesting that seeing manner gestures had a large effect on verb learning but end state gestures did not. There are at least three potential explanations for this finding. Firstly, this pattern may reflect a floor effect, as children who saw no gestures showed an end-state interpretation bias, that is interpreting the novel verb as a change-of-state verb. Seeing end state gestures could not increase this bias, while seeing manner gestures had more room to influence interpretations.

The other two accounts suggested here reflect the idea that some types of iconic gestures may have more of an influence than others on word learning. These are both speculative and further work would be needed to distinguish these accounts. Firstly, gestures may have a larger

influence on word learning when the information contained is not compatible with children's natural bias (in this case their natural bias was a change-of-state interpretation). When children see a gesture, which is compatible with their own bias, they may pay little attention to it, as it is only confirming their original understanding. When a gesture contains information incongruent with their natural bias, however, children may pay more attention to it, as this suggests that their original interpretation of the novel word is incorrect. Research has shown that gestures are produced more often when it is potentially more difficult for the listener to comprehend the concurrent speech. For example, adults produce more iconic gestures when they utter an unexpected word (Beattie & Shovelton, 2000). Similarly, 4-year-old children often use iconic gestures to clarify ambiguous concurrent words (Kidd & Holler, 2009). In terms of comprehension, Holle and Gunter's (Experiment 3, 2007) study with adult participants found that gestures boost the activation levels of a subordinate meaning of a homonym, but had little influence on the dominant interpretation of the word. This suggests that, for adults at least, gestures may have more impact when concurrent words should be interpreted against the natural bias for interpretations.

Secondly, the manner and end-state gestures in this study were iconic in different ways and this difference may have led to end state gestures having less influence than manner gestures. We know from the pre-test that there was no difference in children's ability to match the two gesture types to their referents, but there may still be a difference in how well children are able to use them during verb learning. In line with this account is research by O'Reilly (1995), who found that children were able to comprehend gestures where the hand represented an object, better than those where the hand acted as if holding an imaginary object. It appears that children struggle when they must imagine features of the scene being depicted. In the current

study, although there was some imagery required for the manner gestures (e.g. the hand holding or manipulating imaginary materials), the end state gestures arguably required more imagination, for example, the shape outline being traced by the index fingers. This line must have been imagined and remembered in order to understand the referent (e.g. a 'cloud' shape). Although the pre-test revealed children could map the gestures to their video referents, it may have been too cognitively demanding to then use this information during verb learning. It would be an interesting topic for future research to investigate more specifically which types of iconic gestures can influence word learning. It would also be interested to investigate whether iconic gestures can help children to focus on aspects, such as manner, at the expense of other features, such as actors and objects.

Children's Natural Bias

It is interesting to note that children in the current study who saw no gestures tended to interpret the novel verbs as change-of-state verbs, though the natural bias for children's interpretation was not the focus of this study. There is some debate in the literature regarding children's natural biases when learning words that can be either manner verbs or change-of-state verbs. Some studies have found that children often interpret such words as manner verbs (e.g. Forbes & Farrar, 1995), while others have found children to interpret them as change-of-state verbs (e.g. Behrend, 1990). It is an important topic of future study to investigate what features of stimuli and tasks influence the direction of the bias.

General Conclusions

Iconic gestures highlight particular features within a scene and guide children's semantic interpretation of novel words towards the gesturally encoded features. Such gestures may be one of the important contextual cues that children take advantage of in real-life word learning

situations. The result also suggests that iconic gesture is a potentially useful tool for teaching new words to children in educational or clinical settings.

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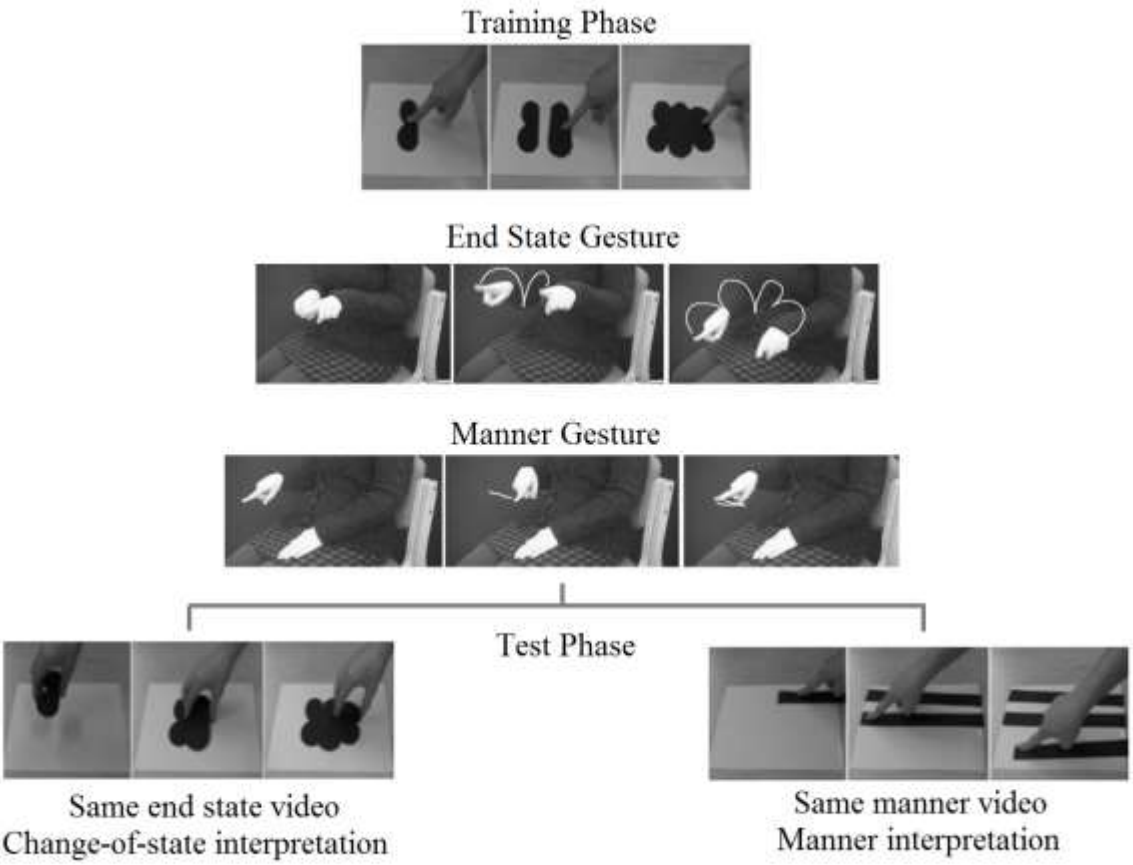

Figure 1. The structure of a single trial. The top photo represents the training video, the central photos depict the corresponding gestures performed live by the experimenter during training (the white line traces the path of the index fingers). The two bottom photos represent the two videos at test and the bottom photos The manner in the training video (top) uses a pointed hand shape and quick side-to-side movements to push shapes into position; the second manner in the left test video is slowly placing shapes down vertically.

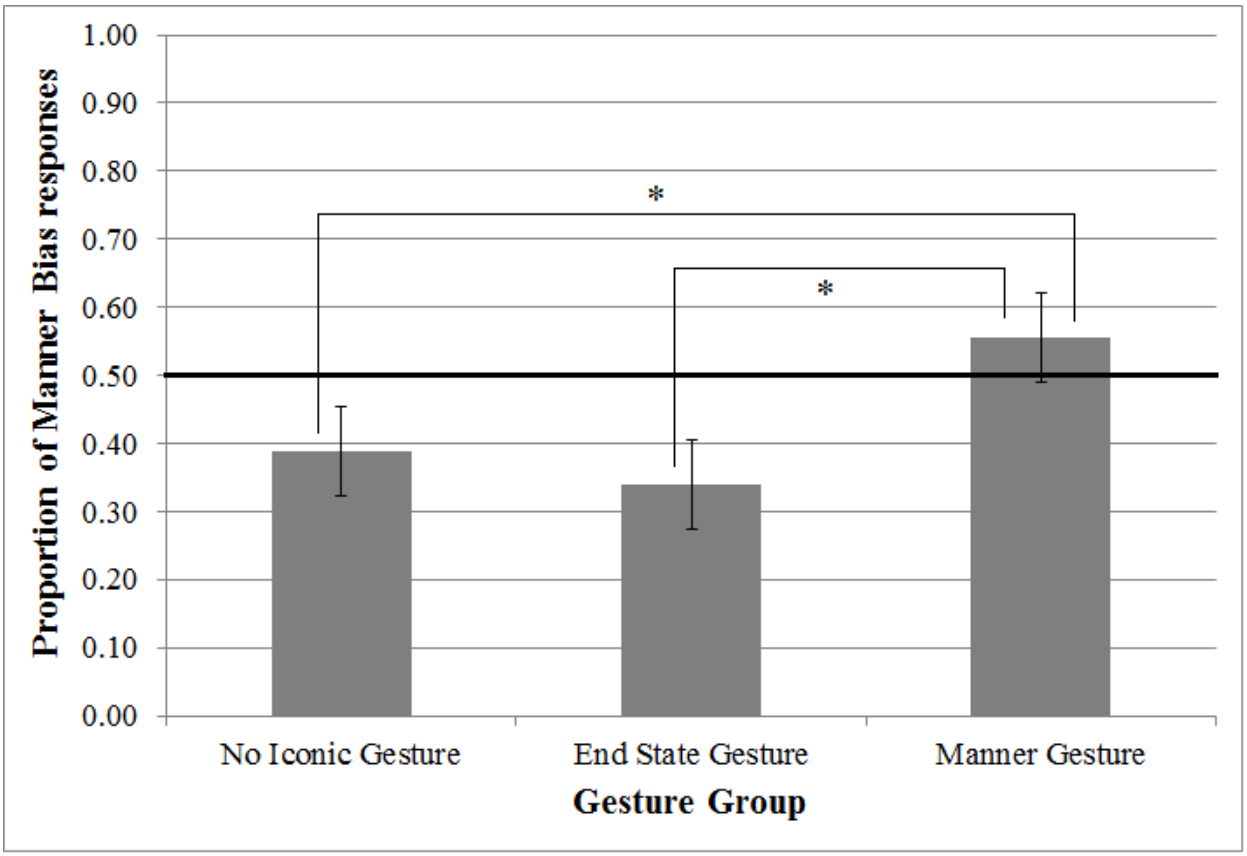

Figure 2. The mean proportion of trials in which the same-manner, different-end state videos were selected (i.e., generalisation of verbs based on manner) in the three gesture conditions. The error bars represent standard error, the thick line represents chance (0.5) and the * represents significance ($p<.01$)

Table 1.

The number of children in the three gesture conditions and in the three response bias groups.

Gesture Group	**Change-of-state Bias**	**No strong bias**	**Manner Bias**
End State	16	13	3
Manner	6	18	12
No Gesture	12	18	3