Received: 27 September 2021 | Revised: 3 July 2022 | Accepted: 8 August 2022

DOI: 10.1111/desc.13315

Developmental Science WILEY

RESEARCH ARTICLE

# Encouraging pointing with the right hand, but not the left hand, gives right-handed 3-year-olds a linguistic advantage

Katherine H. Mumford[1] | Suzanne Aussems[2] | Sotaro Kita[2]

[1]School of Psychology, University of Birmingham, Birmingham, UK

[2]Department of Psychology, University of Warwick, Coventry, UK

**Correspondence**
Suzanne Aussems, Department of Psychology, University of Warwick, CV4 7AL Coventry, UK.
Email: s.aussems.1@warwick.ac.uk

This work was conducted as part of the PhD of Katherine H. Mumford. It was supported by a PhD studentship from the Economic and Social Research Council, which she held at the University of Birmingham (United Kingdom). She is currently based at BC Family Hearing Resource Society, Victoria, British Columbia, Canada.

## Abstract

Previous research has shown a strong positive association between right-handed gesturing and vocabulary development. However, the causal nature of this relationship remains unclear. In the current study, we tested whether gesturing with the right hand enhances linguistic processing in the left hemisphere, which is contralateral to the right hand. We manipulated the gesture hand children used in pointing tasks to test whether it would affect their performance. In either a linguistic task (verb learning) or a non-linguistic control task (memory), 131 typically developing right-handed 3-year-olds were encouraged to use either their right hand or left hand to respond. While encouraging children to use a specific hand to indicate their responses had no effect on memory performance, encouraging children to use the right hand to respond, compared to the left hand, significantly improved their verb learning performance. This study is the first to show that manipulating the hand with which children are encouraged to gesture gives them a linguistic advantage. Language lateralization in healthy right-handed children typically involves a dominant left hemisphere. Producing right-handed gestures may therefore lead to increased activation in the left hemisphere which may, in turn, facilitate forming and accessing lexical representations. It is important to note that this study manipulated gesture handedness among right-handers and does therefore not support the practice of encouraging children to become right-handed in manual activities.

**KEYWORDS**
gesture, language lateralization, linguistic advantage, right-handed pointing, verb learning, vocabulary development

### Research Highlights

- Right-handed 3-year-olds were instructed to point to indicate their answers exclusively with their right or left hand in either a memory or verb learning task.
- Right-handed pointing was associated with improved verb generalization performance, but not improved memory performance.

- Thus, gesturing with the right hand, compared to the left hand, gives right-handed 3-year-olds an advantage in a linguistic but not a non-linguistic task.
- Right-handed pointing might lead to increased activation in the left hemisphere and facilitate forming and accessing lexical representations.

## 1 | INTRODUCTION

Verb learning is challenging for young children (Gentner, 1978). Unlike nouns, which often refer to concrete objects (e.g., *shoe*), verbs often refer to abstract actions (e.g., the woman is *jumping*) (Gentner, 1981, 1982). Three-year-old children typically struggle to extend the meaning of a novel verb beyond the context in which it was originally learnt (Aussems & Kita, 2021; Imai et al., 2005, 2008; Kantartzis et al., 2011; Kersten & Smith, 2002). For example, Kantartzis et al. (2011) presented 3-year-old children with videos of actors performing unusual manners of human locomotion (e.g., a small shuffling movement, with straight arms rigidly at the side and legs moving very slightly). An experimenter labelled these training events with novel verbs (e.g., "Look, he is *blicking*"). Children were then asked to extend each novel verb to one of two videos in a two-alternative forced-choice test (e.g., "Which one is *blicking*?"). One video showed a novel actor performing the movement from the training event (correct extension) and the other video showed the actor from the training event performing a novel movement (incorrect extension). Children performed at chance in this task, suggesting that they did not map the verbs to the actions the actors performed and, as a result, did not learn the novel verb meanings. Some have suggested that 3-year-olds may consider both the action and the actor as important components of a verb's meaning, which may be why children perform at chance in this generalization test (e.g., Aussems & Kita, 2021; Imai et al., 2005, 2008; Kantartzis et al., 2011; Kersten & Smith, 2002). The current study investigates whether producing gestures during a verb learning task improves children's performance.

Spontaneous gesture production influences the speaker's linguistic processing (see Kita et al., 2017, for a review). For example, allowing speakers to gesture spontaneously, compared to restricting their gestures, has been shown to help speakers retrieve words when these words are on the tip of their tongue. When adults were asked to name low-frequency words (e.g., *kaleidoscope*) based on the definitions of those words, they were more successful when they were allowed to gesture during the lexical retrieval task than a control group of adults who were prohibited from gesturing (Frick-Horbury & Guttentag, 1998). Similarly, when 6-to-8-year-old children were asked to name images of common objects (e.g., *umbrella*), they correctly named more objects when they were allowed to gesture during the picture-naming task than a control group of children who were prohibited from gesturing (Pine et al., 2007). Furthermore, spontaneous gesture production, compared to gesture prohibition, influences the content of speech. For example, when 5-to-7-year-old children were allowed to gesture spontaneously while explaining their answers to Piagetian conservation problems, they referred to the physical features of the task objects in front of them more often than when they were prohibited from gesturing (Alibali & Kita, 2010). Thus, spontaneous gesture production improves linguistic processing in both children and adults.

Instructed gesture production also facilitates linguistic processing in children. For example, when learning a novel word, children who are instructed to produce an iconic gesture depicting the word referent learn the word meaning better. Iconic gestures are hand movements that bear resemblance to the meaning of spoken words (McNeill, 1985, 1992). When 4-to-5-year-old children were taught novel verbs (e.g., *ratching*) for actions on objects (e.g., twisting a knob on an object), they generalized these verbs better to novel objects when they were instructed to produce iconic gestures (e.g., a twisting hand movement in the air) modelled by an experimenter rather than merely observing the experimenter's gestures (Wakefield et al., 2018). Children also benefit from producing iconic gestures when learning a second language. When 4-to-5-year-old French children were asked to reproduce gestures modelled by an adult experimenter (e.g., depicting *rabbit* ears with both hands) while learning English words (e.g., *rabbit*), they memorized the words (e.g., *rabbit*) better than children who were taught the same words with the help of pictures (e.g., an image of a *rabbit*) (Tellier, 2008). Thus, producing iconic gestures depicting the word referents helps retain the word meanings. However, it is not clear if instructing children to produce gestures that do not encode any aspect of word referents, for example, pointing gestures, can also facilitate word learning. It is possible that pointing gestures produced with the right hand facilitate word learning because of the functional organization of the two brain hemispheres.

### 1.1 | Functional lateralization of the brain for language and gesture

The left and right hemispheres of the brain control different cognitive processes. The left hemisphere is dominant in language skills. Language processes such as vocabulary learning (Mills et al., 2005; Su et al., 2018) and grammar acquisition (Qi et al., 2019) are typically controlled by the left hemisphere. The right hemisphere is dominant in pragmatic skills. Language processes such as understanding how others use language in humorous (e.g., for *jokes* see Coulson & Williams, 2005) and non-literal ways (e.g., for *metaphors* see Anaki et al., 1998) are typically controlled by the right hemisphere. This division of labor between the left and right hemispheres is the same for most individuals, but especially for those individuals who are right-handed. For this reason, we only included right-handed children in the current study, and we assume that most right-handed children are developing left-lateralized language skills (Dehaene-Lambertz et al., 2002; Holowka & Petitto, 2002).

Each brain hemisphere controls motor processes on the contralateral side of the body. The left hemisphere typically controls the muscle movements of the right side of the body and the right hemisphere typically controls the muscle movements of the left side of the body. Consequently, right-handed gestures are mostly controlled by the left hemisphere and left-handed gestures are mostly controlled by the right hemisphere. If language and gesture production processes are interlinked with each other (McNeill, 1985, 1992), then the hemispheric dominance for language should be related to which hand is dominant for gesture production.

Gesture production in adults is, indeed, influenced by which hemisphere is dominant in controlling language (Kimura, 1973a, 1973b; Kita & Lausberg, 2008; Lausberg et al., 2007). Even left-handed adults show more right-handed gesturing than would be expected from their manual handedness alone, if their language is lateralized to the left hemisphere (Kimura, 1973b). Furthermore, this right-hand bias is weaker (i.e., the left hand is gesturally more active) when adults talk about metaphorical mappings behind expressions such as “spill the beans” (i.e., “beans” represent secrets and “spilling” represents disseminating information) (Kita et al., 2007). This is because producing metaphorical speech activates pragmatic processes in the right hemisphere (Taylor & Regard, 2003), which triggers left-handed gestures and weakens the right-hand gesture bias.

Furthermore, manipulating with which hand to produce gestures can positively impact performance in a linguistic task. In a study with adult participants, in which the gesture hand was manipulated, left-hand gesturing led to better explanations for metaphorical mappings than right-hand gesturing or gesture prohibition (Argyriou et al., 2017). Thus, the causal nature of the relationship between the gesture hand and linguistic task performance has been shown in adults. To our knowledge, no analogous relationship has been shown in children. The current study investigated the relationship between gesture handedness and linguistic processing in children who were administered a word learning task.

## 1.2 | Right-handed pointing and vocabulary development

Right-handed pointing gestures are associated with faster vocabulary development in both infants and toddlers (e.g., Cochet et al., 2011; Esseily et al., 2011; Mumford & Kita, 2016; Vauclair & Imbault, 2009). For example, in a longitudinal observational study of infants between 13 and 21 months of age, Cochet et al. (2011) reported that an infant’s vocabulary spurt (i.e., rapid vocabulary growth around 18–24 months of age also known as the ‘naming explosion’) is accompanied by an increase in right-handed pointing gestures. Furthermore, in a lab-based pointing task with objects placed out of reach, 14-month-old infants who preferred to use their right hand for pointing to the objects understood and produced significantly more words than infants who preferred to use their left hand for pointing (Esseily et al., 2011). Mumford and Kita (2016) extended this work by showing that preferences for right-handed pointing and receptive vocabulary are positively correlated in 10-to-12-month-olds after controlling for age and vocalizations, ruling out activation of the left hemisphere due to vocalization or general age-related maturation as explanations for this relationship. In all above-mentioned studies, the hand infants use for pointing was compared to the hand they use for object manipulation. There was no relationship between the hand used for manual actions (e.g., instrumental actions performed with the hands such as grasping an object) and vocabulary development. Furthermore, Vauclair and Imbault (2009) showed that not only right-handers but also left-handers and ambidextrous infants and toddlers between 10 and 40 months old tend to use their right hand for pointing during the vocabulary spurt. Taken together, these findings suggest that there may be a special link between right-handed pointing and vocabulary development, which is independent from controlled motor actions such as object manipulation. Although the strong positive association between right-handed gesturing and vocabulary development is well-established (e.g., Cochet et al., 2011; Esseily et al., 2011; Mumford & Kita, 2016; Vauclair & Imbault, 2009), the causal nature of this relationship remains unclear.

## 1.3 | The current study

The current study investigated whether right-handed 3-year-olds perform a verb learning task better when they are instructed to use right-handed pointing to respond. We predicted a right-hand benefit because the movements of the right gesture hand are controlled by the left hemisphere, which is typically dominant for vocabulary development (Mills et al., 2005; Su et al., 2018). To rule out the possibility that any performance differences between the right-hand and left-hand groups in the verb learning task are due to dexterity or control (i.e., right-handed children may be able to produce more precisely coordinated movements with their right hand than with their left hand), we also administered a memory (control) task (i.e., a task in which children are tested on their recognition memory for scenes). There should be no advantage of gesture hand in this non-linguistic memory task because this type of memory is typically processed in both hemispheres (Ofen et al., 2012).

The verb learning task tests children’s ability to infer the meaning of a novel verb when it is introduced with a video-recorded scene showing the referent action, and to use the inferred meaning representation in a subsequent linguistic judgement task. Specifically, children were taught a novel manner of motion verb with a video showing an actor performing the referent action, and then asked if the verb can be applied to novel scenes in which either a different actor performs the same action (correct) or the same actor performs a different action (incorrect). Thus, this task tests whether children can form the correct semantic representation of a verb and generalize it to novel scenes.

The memory task tests children's ability to retain and recognize scenes. Specifically, children were shown videos from the same set of stimuli in the memory task as the children in the verb learning task. They were then asked which video they had seen previously, either an identical video (correct), or a video of the same actor as before performing a different action (incorrect). The key difference between the two tasks is that the verb learning task was a linguistic task and the memory task was a non-linguistic task. Crucially, only the verb learning task required establishing a new lexical representation and subsequently accessing that representation.

### 1.4 | Predictions

In both tasks, children were instructed to point to their answers with either exclusively their left or right gesture hand. All children were right-handed for practical actions (e.g., drawing) as determined by two handedness tasks. There are three main hypotheses. First, we predicted an interaction effect between gesture hand (left vs. right) and task type (memory vs. verb learning) on children's performance, such that the advantage of pointing with the right hand (compared to pointing with the left hand) should be larger in the verb learning task than in the memory task. Second, we predicted that there should be an advantage of pointing with the right hand compared to pointing with the left hand in the verb learning task. Third, we predicted that there should be no such advantage in the memory task. In addition, we predicted that children should perform above chance in the memory task (in both gesture hand conditions) in line with previous research (Aussems & Kita, 2019). Furthermore, we predicted that children who were instructed to point with their left hand should not perform significantly different from chance in the verb learning task, because previous studies have shown that children's baseline performance is at chance (e.g., Aussems & Kita, 2021; Imai et al., 2005, 2008; Kantartzis et al., 2011; Kersten & Smith, 2002). Finally, we expected children to perform above chance when pointing with the right hand in the verb learning task, because right hand movements are expected to activate the left hemisphere, which typically controls the language processes involved in word learning.

## 2 | METHOD

The stimuli, raw data, and analysis script are available via the Open Science Framework (https://osf.io/5ur2m/).

### 2.1 | Design

The experiment had a 2×2 between-subject design. The independent variables were the gesture hand with which children were instructed to respond (right vs. left) and the type of task (linguistic vs. non-linguistic). The dependent variable was children's performance which was operationalized as a binary variable (0 = incorrect, 1 = correct). There were seven test trials in each task. We coded children's verb learning performance as follows: when children pointed at the same-action video, which was the correct extension of a given novel verb, they were given a score of 1, and when they pointed at the same-actor video, which was the incorrect extension of a novel verb, they were given a score of 0. We coded children's memory performance as follows: when children pointed at the identical video, which was the correct answer, they were given a score of 1, and when they pointed at the video that showed the same actor performing a different action, which was the incorrect answer, they were given a score of 0. Total scores in both the verb learning task and memory task thus ranged from 0 to 7.

### 2.2 | Participants

Participants were recruited via nurseries in Warwickshire and the surrounding areas in England. Informed caregiver consent was obtained for all child participants. The sample size was determined based on the time and resources available to conduct this study. The final sample included 131 children (52 girls, 79 boys) between 36 and 47 months old ($M$ = 41.68 months, $SD$ = 3.30). A total of 33 children (15 girls, 18 boys) completed the verb learning task in the right-hand condition and 36 children (12 girls, 24 boys) in the left-hand condition, and 32 children (13 girls, 19 boys) completed the memory task in the right-hand condition and 30 children (12 girls, 18 boys) in the left-hand condition. The participants' gender ($\chi^2(3) = 1.08$, $p = 0.782$) and age in months ($F(3, 127) = 0.55$, $p = 0.647$) did not differ significantly between the four conditions.

An additional 29 children were tested but excluded due to a side bias (i.e., exclusively pointing to answers shown on one side of the screen) ($N = 10$), partial completion of the task because of distraction ($N = 3$), not following the instruction for which hand to use to respond in all but one trial ($N = 1$), developmental language disorder (as indicated in their nursery record, $N = 7$), and manual left-handedness (i.e., dominant left hand in two handedness tasks) ($N = 8$). It is important to note that we did not measure cerebral dominance for language in this study, but we only included right-handed participants in the analysis, as determined by two handedness tasks.

### 2.3 | Handedness tasks

Before the experimental manipulation was introduced, children's handedness was assessed using two tasks: an unscrewing-a-lid task and a drawing task. First, in the unscrewing-a-lid task, children were asked to retrieve a small ball from a cylindrical container with a lid loosely screwed on. The dominant hand was coded as the one used to hold the lid while unscrewing it. Second, in the drawing task, children were asked to draw a circle on a page using a marker. The dominant hand was coded as the one used to hold the marker while drawing. For both tasks, the stimulus materials were set up before children arrived at the table for testing and were presented at the midline of the child.

Children's handedness was coded by hand choice in both tasks (one trial each). The number of children in the final sample in each category was as follows: 25 children were coded as left-handed in the unscrewing-a-lid task and as right-handed in the drawing task; eight children were coded as right-handed in the unscrewing-a-lid task and as left-handed in the drawing task; 98 children were coded as right-handed in both tasks. Please note that eight children who were coded as left-handed in both handedness tasks were excluded from the final sample and that children who performed at least one handedness task with their right hand were considered right-handed. Children who performed one handedness task with their right hand and one with their left hand were included in the sample, because language is left-lateralized in 95%–99% of right-handed individuals and in approximately 70% of left-handed individuals (Corballis, 2014).

## 2.4 | Procedure

Participants were tested individually in a quiet corner of their nursery. The same experimenter tested all children in the study. All children first completed the two handedness tasks followed by the main experiment task (i.e., memory or verb learning) and received a sticker for their participation.

### 2.4.1 | Main experiment tasks

Before the practice trials began, children in all conditions were told that they needed to hide one of their hands and to do this they should put it behind their back (demonstrated by the experimenter). Children were reminded of this instruction throughout the tasks, and it was noted if they ever forgot and responded with the other hand.

**Practice Trials**. There were four practice trials in total, for which the stimuli used for all children were identical. The practice trials were designed to familiarize the children with the pointing procedure and to boost their confidence. Stimuli were presented to the participants on a 20-inch PC monitor. In the first three practice trials, children were encouraged to point to one of two familiar objects (e.g., "*Which is the shoe?*"). In the fourth practice trial, children were familiarized with the structure of the main experiment task. First, children were shown a video of a woman running. Children in the verb learning conditions heard the experimenter say, "*Look, she's running*" and children in the memory conditions heard her say "*Wow, look at her!*." Children were then shown the same video again on the next screen alongside a new video of a man jumping. Children in the verb learning conditions were asked "*Which one is running?*" and children in the memory conditions were asked "*Which video is the same as before?*" Children were encouraged to point at their answer with the instructed gesture hand.

**Stimuli**. The stimuli were taken from Mumford and Kita (2010) and were made up of 28 video clips, ranging from 4 to 8 sec each. All the video clips depicted either a male actor or female actor performing an unusual manner of movement (i.e., a novel way of moving from one location to another that cannot readily be described using an English word). There were four male actors and three female actors. There were 14 unusual manners of locomotion (detailed descriptions in Appendix A). The direction of movement was balanced by flipping the original video clips horizontally using video editing software, which created a larger set of stimulus videos in which half the time the actors moved from left to right, and half the time from right to left. The 28 original video clips were organized into seven groups containing four video clips each: a male actor and a female actor each performing two different unusual manners of movement. The two actors in a group performed each action similar to each other, such that the same verb could be applied to both video clips.

The seven novel verbs taught were *daxing*, *larping*, *blicking*, *tooding*, *stumming*, *pimming*, and *krading*. These novel words follow the rules of the English language and are commonly used in verb learning studies (e.g., Aussems & Kita, 2021; Aussems et al., 2022; Childers, 2011; Maguire et al., 2008; Mumford & Kita, 2014; Naigles & Kako, 1993; Roseberry et al., 2009).

**Test Trials**. In the verb learning conditions, children were told that the experimenter was going to teach them some new words. Children were then taught seven novel verbs (one per trial). Each trial consisted of two stages: training and test. Figure 1 shows still images from a single trial of the verb learning task. Each test occurred immediately after the training, before moving on to the next verb. During the training stage, children saw a video clip of either a male actor or a female actor moving in a novel manner. They were told: "*Look, she (or he) is NOVEL VERB-ing!*." The video clip and the training sentence were then repeated. During the test stage, children saw two videos playing simultaneously, side-by-side, and were asked "*Which one is NOVEL VERB-ing?*" One video showed a new actor (of the opposite gender as in training) performing the same action as in training (correct) and the other video showed the same actor as in training now performing a different action (incorrect). To perform well in this task, children thus had to extend the verb to a novel actor who performed the same action as the actor in the training event. Children were required to use the instructed gesture hand to point to their answer. If children tried to point to both videos at test with the instructed gesture hand, they were reminded they could only pick only one answer and the question was repeated. Children's final choice, indicated by a pointing gesture, was written down by the experimenter.

The memory task followed the same procedure as the verb learning task, using the same stimulus set of 28 videos, apart from the following. The only differences with the verb learning task were the utterances produced by the experimenter and the target video shown at test. During the training stage, children heard the experimenter say "*Wow, look at her (or him).*" The video and the training sentence were repeated. During the test stage, children saw a video identical to the training video (correct) and a video of the same actor now performing a different action (incorrect). The experimenter asked the children, "*Which video is the same as before?*" and children were required to use the instructed gesture hand to point to their choice. To perform well in this task, children thus had to recognize the actions shown in the training events. Figure 2 shows still images from a single trial of the memory task.

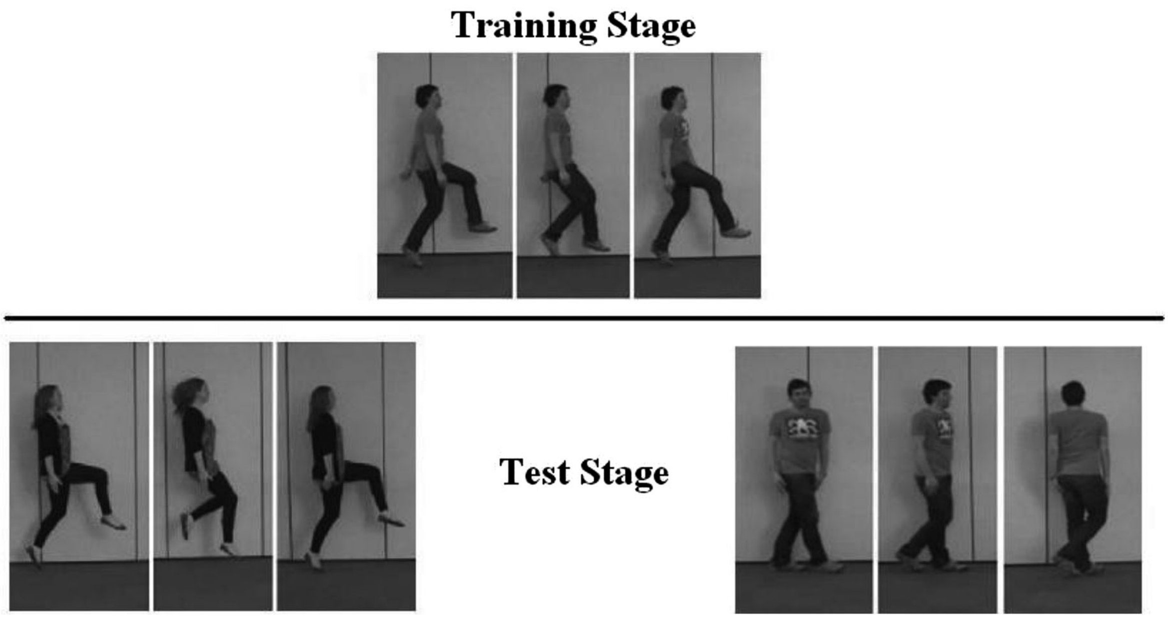


**FIGURE 1** Still images of a training and two test videos from a single trial in the verb learning task. Note. The video clip in the training stage was played twice, then disappeared, and immediately the two video clips in the test stage were shown side-by-side in the two-alternative choice task. In this example, the target is shown on the left and the distractor on the right in the test stage

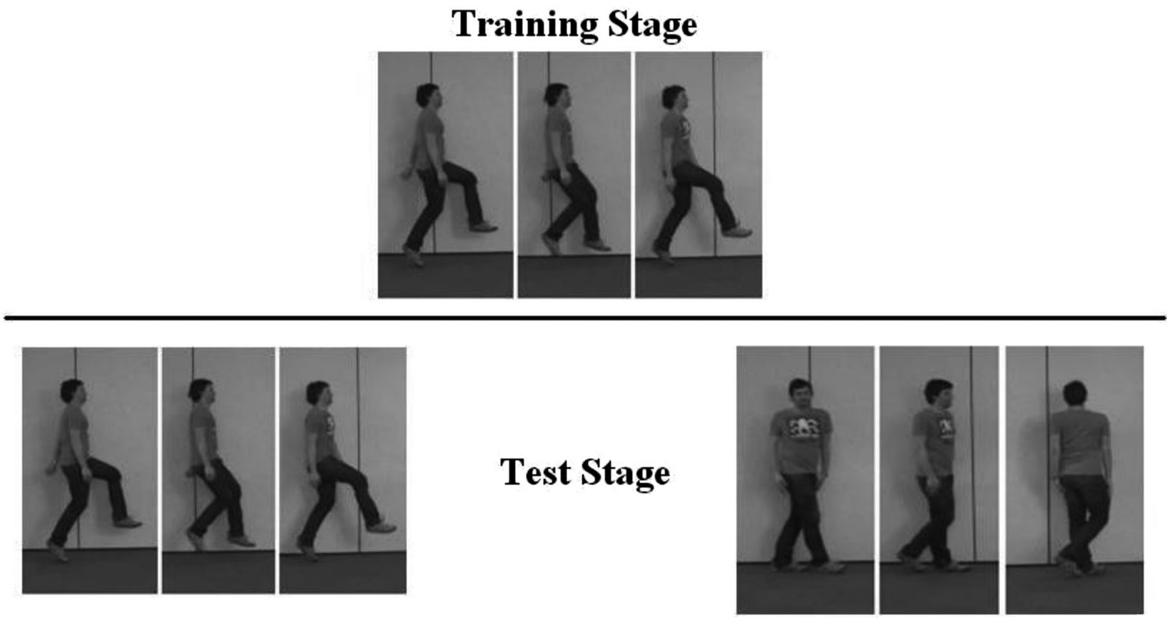


**FIGURE 2** Still images of a training and two test videos from a single trial in the memory task. Note. The video clip in the training stage was played twice, then disappeared, and immediately the two video clips in the test stage were shown side-by-side in the two-alternative choice task. In this example, the target is shown on the left and the distractor on the right in the test stage

## 2.5 | Counterbalancing and randomization

Children were pseudo-randomly assigned to one of the four conditions before the experimenter met them, whilst taking care to balance child gender and age. The four conditions were rotated in each nursery to control for factors that may have co-varied with nurseries such as socio-economic status and any unwanted lateral stimulation during testing. For half of the children in each condition, the experimenter sat on their right-hand side and for the other half she sat on their left-hand side.

Children were administered a version of the main experiment task in which the following factors were counterbalanced. There were eight versions of the experiment in which the 28 unique video clips were divided into groups of four to create seven trials. Each group of four videos included a female actor and a male actor performing the same two actions. The actions were organized in pairs (see Appendix A), and which action was presented in the training stage was counterbalanced between experiment versions. The direction of movement (from left to right or right to left) of the actors in the video clips of a single trial (i.e., both training and test stage) was counterbalanced. The side on which the target appeared in the test stage (left or right) was also counterbalanced. Care was taken to balance the number of male actors and female actors in the video clips included in each experiment version, although this was never exactly equal because there was an uneven number of trials. The experiment versions for the memory and the verb learning task were identical, apart from the following. The video clip shown in the training stage was always the same between experiment versions for the memory task and the verb learning task, as well as the distractor in the test stage, but the target in the test stage differed (see Figures 1 and 2).

## 2.6 | Data analysis

The binary dependent variable (either correct or incorrect responses in each trial) was analyzed with mixed-effect logistic regression models, using the *glmer* function from the *lme4* package (Bates et al., 2015) and the R statistical analysis software (R Core Team, 2020). All models were constructed using main effect and interaction terms for the independent variables gesture hand and task type and a random effect for participant. To evaluate the significance of a main effect or interaction effect, two models, one including and one excluding the effect of interest, are compared using a likelihood ratio test (i.e., chi-square) using the *Anova* function from the *car* package (Fox & Weisberg, 2019). When the chi-square test is significant, we conclude that the inclusion of a main effect or interaction effect increases the fit of the model to the data significantly (e.g., the model that includes the interaction effect is a better fit than a model that excludes the interaction effect). The built-in *confint()* function (R Core Team, 2020) was used to compute 95% confidence intervals around the regression coefficients of each effect.

Finally, for the chance comparisons, the dependent variable of children's average performance was operationalized as a proportion by dividing the total number of correct answers of each child by the total number of valid trials of each child. The average performances of children in each condition were compared with chance (test value: 0.5) using the built-in *t*-test*()* function in R (R Core Team, 2020). The effect size used was Cohen's *d* (Cohen, 1998), which was calculated and interpreted using the *rstatix* package (Kassambara, 2021).

# 3 | RESULTS

Sixty-one trials out of the total of 917 trials (131 children × 7 trials) were excluded from the analysis for the following reasons: 57 trials (from 39 participants, range 1–3 trials per child) were excluded because the children did not follow the experimenter's instruction for which hand to use to point at their answer (i.e., children responded with the wrong hand in 55 trials and with both hands in two trials), one trial from one participant because the child selected a video before the two videos had started to play, and three trials from three participants (one trial per child) because the children did not select a video at all. The analyses reported below are conducted over the remaining 856 trials.

## 3.1 | The effects of gesture hand and task type on performance

Figure 3 shows children's average performance by gesture hand and task type. Children's performance (correct vs. incorrect) in each trial was entered into a mixed-effect logistic regression analysis with gesture hand (left vs. right) and task type (memory vs. verb learning) as fixed effects and participant as a random effect. A summary of the mixed-effect logistic regression analysis output can be seen in Table 1. To assess the significance of the fixed effects, the full regression model which included the effect of interest (i.e., main effect or interaction effect) was compared with another model which excluded this effect, using a likelihood ratio test (chi-square). The main effect of gesture hand on performance was not statistically significant, $\chi^2(1) = 1.43$, $p = 0.232$. The main effect of task type on performance was statistically significant, $\chi^2(1) = 6.64$, $p = 0.001$, where children who were administered the memory task ($M = 0.65$, $SD = 0.25$) outperformed children who were administered the verb learning task ($M = 0.54$, $SD = 0.26$). The interaction effect of gesture hand and task type on performance was not statistically significant, $\chi^2(1) = 2.99$, $p = 0.084$.

## 3.2 | The effects of gesture hand on performance within each task

To test whether there was a right-hand pointing advantage in the verb learning task, but no such advantage in the memory task, we ran two planned comparisons of interest. First, we created a subset of the data which only included the memory task. We then ran a mixed-effect logistic regression analysis on this subset of the data, with gesture hand as a fixed factor and participant as a random factor, to compare the performances of children who were encouraged to point with their right hand and children who were encouraged to point with their left hand. To assess the fixed effect of gesture hand on performance, we compared the full regression model which included the fixed effect of gesture hand to another model that excluded it, using a likelihood ratio test (chi-square). The main effect of gesture hand on performance was not statistically significant for the memory task, $\chi^2(1) = 0.19$, $p = 0.662$. Children who were encouraged to point with their right hand ($M = 0.64$, $SD = 0.26$) did not remember more scenes than children who were encouraged to point with their left hand ($M = 0.67$, $SD = 0.26$), $b = -0.15$, $SE = 0.34$, $z = -0.44$, 95% CI $b$ [−0.84, 0.53]. Second, we created a subset of the data which only included the verb learning task. In the same way, we then compared the performances of children who

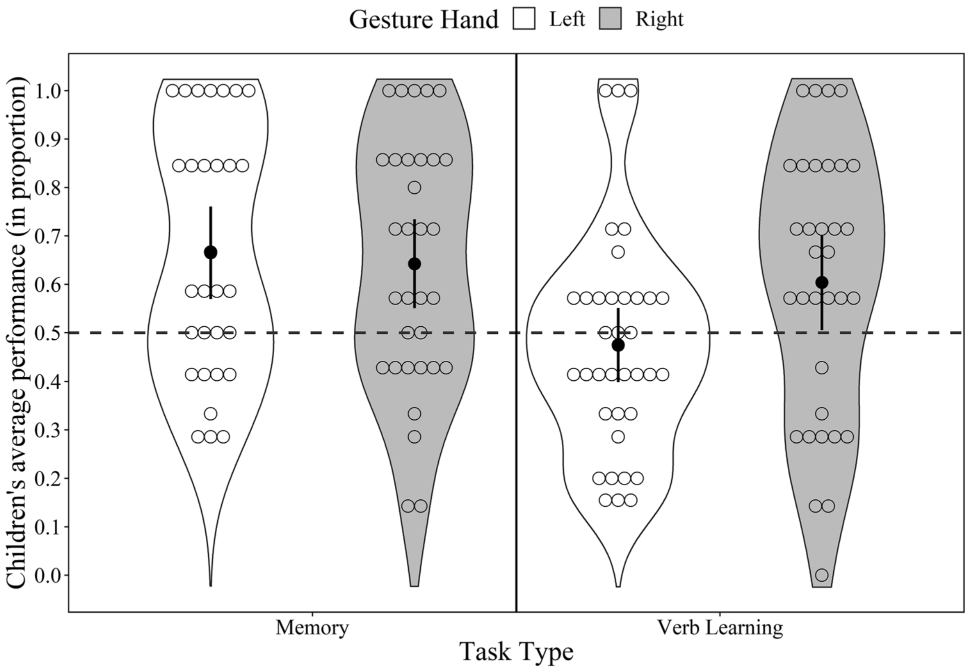


**FIGURE 3** Children's average performance (in proportion) by gesture hand and task type. Note. Children's average performance is on the *y*-axis (in proportion). Task type is on the *x*-axis, with the memory task on the left panel and the verb learning task on the right panel. White violins represent children who were encouraged to point with their left hand and grey violins represent children who were encouraged to point with their right hand. The average performance by condition is represented by a filled black circle in each violin. Error bars represent 95% confidence intervals around the means. Unfilled circles represent average performances of individual children. The dashed horizontal line represents chance level (0.5)

**TABLE 1** Model parameters of the full mixed-effect logistic regression model

| Fixed effects | *b* | *SE* | *z* | *LL* | *UL* |
|---|---|---|---|---|---|
| (Intercept) | 0.82*** | 0.23 | 3.60 | 0.38 | 1.29 |
| Gesture Hand (Left vs. Right) | −0.14 | 0.31 | −0.46 | −0.76 | 0.48 |
| Task type (Memory vs. Verb learning) | −0.92** | 0.30 | −3.04 | −1.52 | −0.33 |
| Gesture hand * Task type (Left – Memory vs. the other 3 conditions) | 0.73 | 0.42 | 1.73 | −0.10 | 1.59 |

*Note*. *b* = *b* estimates; *SE* = standard error around the *b* estimates; *z* = *z*-test value; *LL* = lower limit and *UL* = upper limit of the 95% confidence intervals around the *b* estimates. Model specification: glmer (performance ~ gesture hand * task type + (1 | participant). Dummy coding was used for the fixed effects, and the reference level is indicated in parentheses for each effect. $^{**}p < 0.01$., $^{***}p < 0.001$.

were encouraged to point with their right hand and children who were encouraged to point with their left hand. The main effect of gesture hand on performance was statistically significant for the verb learning task, $\chi^2(1) = 4.52$, $p = 0.033$. Children who were encouraged to point with their right hand ($M = 0.60$, $SD = 0.28$) generalized more verbs successfully than children who were encouraged to point with their left hand ($M = 0.48$, $SD = 0.23$), $b = 0.57$, $SE = 0.27$, $z = 2.14$, 95% CI $b$ [0.05, 1.13].

Additionally, we visualized children's performance trial-by-trial (see Figure B1 in Appendix B) to explore whether performance improved over trials, especially in the right-hand verb learning condition. The graph shows a steady increase from chance level to above chance level performance in the early trials of the verb learning task in the right-hand condition, and this pattern seems weaker in the same trials of the verb learning task in the left-hand condition. Furthermore, the right-hand benefit in the verb learning task was visible in each of the seven trials (see B2 in Appendix B). The graph shows that the right-hand benefit started just above chance in the first trial and became stronger in the following trials. There was no analogous trial-by-trial right-hand benefit visible in the memory task.

### 3.3 | Chance comparisons

The average performances of children in each condition (see Figure 3) were compared to chance (0.5) using one-sample *t*-tests (two-tailed) to assess whether the children reliably remembered the scenes and learnt the verbs. In the memory task, children who were encouraged to use their left hand to point (0.67) performed significantly above chance, $t$ (29) = 3.54, $p$ = 0.001, 95% CI [0.57, 0.76]. The magnitude of this effect was moderate (Cohen's $d$ = 0.65). Similarly, children who were encouraged to use their right hand to point in the memory task (0.64) performed significantly above chance, $t$ (31) = 3.16, $p$ = 0.004, 95% CI [0.57, 0.76]. The magnitude of this effect was moderate (Cohen's $d$ = 0.56). In the verb learning task, children who were encouraged to use their left hand to point (0.48) performed at chance, $t$ (35) = −0.67, $p$ = 0.510, 95% CI [0.40, 0.55]. The magnitude of this effect was negligible (Cohen's $d$ = −0.11). Finally, children who were encouraged to use their right hand to point in the verb learning task (0.60) performed significantly above chance, $t$ (32) = 2.15, $p$ = 0.040, 95% CI [0.51, 0.70]. The magnitude of this effect was small (Cohen's $d$ = 0.37).

### 3.4 | Exploratory correlation between children's task performance and age in months

We calculated an exploratory Pearson's correlation between children's task performance and age in months. The older the children were, the better they performed in the tasks (memory or verb learning), $r$ (131) = 0.39, $p$ < 0.001, 95% CI [0.23, 0.53] (see Figure C1 in Appendix C).

## 4 | DISCUSSION

This study investigated whether the gesture hand that right-handed 3-year-olds are instructed to respond with influences their performance in a linguistic or a non-linguistic task. Specifically, we examined whether encouraging right-handed 3-year-olds to point with their right gesture hand in a (linguistic) verb learning task, compared to a (non-linguistic) memory task, would give them an advantage. Our first hypothesis was that there would be a larger advantage of pointing with the right hand, compared to pointing with the left hand, in the verb learning task than in the memory task. The interaction between the gesture hand with which children were instructed to point (left or right) and the type of task (verb learning or memory) was not statistically significant and thus our first hypothesis was not supported by the data. The results revealed a trend that was in line with our prediction, such that the advantage of pointing with the right hand, compared to pointing with the left hand, was descriptively larger in the verb learning task than in the memory task. Our second hypothesis was that there would be an advantage of pointing with the right hand, compared to pointing with the left hand, in the verb learning task. In line with the second hypothesis, children who were encouraged to use their right hand to point to their answers in the verb learning task outperformed children who were encouraged to use their left hand to point. Our third hypothesis was that there would be no right-hand benefit in the memory task. In line with the third hypothesis, children who were encouraged to use their right hand to point to their answers in the memory task did not outperform children who were encouraged to use their left hand to point. Taken together, there was an advantage of using the right hand to point in the verb learning task but not in the memory task, although the lack of an interaction effect in our omnibus model suggests that the magnitude of this right-hand advantage in the linguistic task was relatively small compared to the non-linguistic (control) task.

Further comparisons of the children's performances to chance corroborated this conclusion. As expected, children performed above chance in the memory task, indicating that most children retained and recognized the scenes. In the verb learning task, children who were instructed to use their right hand to respond performed above chance, indicating that most children successfully learnt the novel verb meanings, whereas children who were instructed to point with their left hand in the verb learning task performed at chance. Pointing with the right hand thus gave right-handed 3-year-old children a small linguistic advantage compared to pointing with the left hand in the verb learning task. Furthermore, the children in the memory task performed above chance (in line with Aussems & Kita, 2019) and equally well in the left- and right-hand conditions; therefore, the right-hand advantage in the verb learning task was not simply due to a right-hand advantage in manual dexterity or control (i.e., the ability to produce precisely coordinated movements with the right hand). We suggest that the left lateralization of language processing gives rise to the linguistic advantage for pointing with the right hand.

This study is the first to show that encouraging right-handed children to respond with the right gesture hand, compared to the left gesture hand, in a verb learning task facilitates children's verb learning. Previous studies have found positive correlations between right-handed gesturing and vocabulary development (Cochet et al., 2011; Esseily et al., 2011; Mumford & Kita, 2016; Vauclair & Imbault, 2009), but the directionality of this association was not clear. By manipulating the gesture hand with which children were instructed to respond in a linguistic task, while controlling for the children's handedness, this study offers the first preliminary evidence for the directionality of this association. Encouraging children to point with their right hand may help children to learn verbs better.

The study builds on research showing that language lateralization and the hand used for gesturing are associated (e.g., Kimura, 1973a, 1973b; Lausberg et al., 2007). It is also consistent with research showing that encouraging adult participants to use the left hand for gesturing led to better performance in a metaphor task, which engaged the right hemisphere (Argyriou et al., 2017). The findings are in line with research showing that producing gesture influences linguistic processing in children (Alibali & Kita, 2010; Pine et al., 2007; Tellier, 2008; Wakefield et al., 2018) and adults (Frick-Horbury & Guttentag, 1998; Kita et al., 2017).

### 4.1 | Possible mechanisms

There are two mechanisms that could explain why right-handed pointing showed a performance advantage over left-handed pointing in the verb learning task. The first mechanism is related to *forming* lexical representations and the second mechanism is related to *accessing* lexical representations. These two mechanisms are not mutually exclusive and may work in tandem to aid children's verb learning.

The first mechanism is that *forming* lexical representations may be easier when gesturing with the right hand. The right hand is contralateral to the left hemisphere, which is where language is typically processed in the brain. Previous research has shown neural overlap between gesture and language processing (e.g., Kimura, 1973a, 1973b; Kita & Lausberg, 2008; Willems et al., 2007; Skipper et al., 2007). The current study supports the idea that producing right-handed gestures increases activation in the left hemisphere, which controls language processes such as vocabulary learning (Indefrey & Cutler, 2004; Knecht et al., 2000). So, how did the right-hand gesture benefit work? In the verb learning task, children likely formed an initial verb-referent mapping in the training stage. However, gesture was not manipulated until the test stage. Children's representation of the novel verb could be updated in the test stage, in which they see a second novel exemplar of the referent action. This updating may happen while planning and executing the pointing gesture, so this is where gesture could affect the lexical representation. This idea that children update their lexical representations when they are presented with new information is in line with the multiple-exemplar literature (e.g., Childers, 2011; Haryu et al., 2011). In addition, children in the right-hand verb learning condition used the right hand in seven consecutive trials, and thus may have maintained left hemisphere activation (see Figure B1 and B2 in Appendix B). This increased activation may also make it easier for children to form a lexical representation of a novel word's referent, resulting in a better performance in the verb learning task. Though the children did not produce a pointing gesture when the experimenter presented a novel word and its referent, the remaining activation from the previous trial may have facilitated the new formation of a lexical representation of a novel word. Consistent with this idea, people performed better in a metaphor task, which activates the right hemisphere (Taylor & Regard, 2003), when gesturing with the left hand (Argyriou et al., 2017). Thus, gesturing with the hand contralateral to the hemisphere that is involved in the type of linguistic task helps participants to form linguistic representations.

The second mechanism is that *accessing* lexical representations may be easier when gesturing with the right hand. Since the left hemisphere is typically dominant in the processing and storing of lexical items (see Indefrey & Cutler, 2004, for a review), gesturing with the right hand may result in easier access to lexical representations. Consistent with this idea, people perform better in a word retrieval task when they are tapping their finger than when they are not moving their hands, possibly due to activation of the key areas in the brain involved in motor movements and speech production (Ravizza, 2003). This account is also consistent with the finding that split brain patients used the left hand to produce shrugs, which often have an emotional connotation (Lausberg et al., 2007). This hand preference may stem from the fact that the left hand has easier access to emotion representation in the right hemisphere (e.g., Blonder et al., 1991). Thus, if children are left-lateralized for language, right-handed gestures may lead to better verb generalization performance due to access to relevant linguistic representations in the left hemisphere. Even though the initial representations of the novel verbs that children just learnt are not fully consolidated, accessing these representations in the left hemisphere may be easier when right-handed pointing activates this part of the brain.

## 4.2 | Limitations

One limitation of this study is that the memory task was easier for 3-year-old children than the verb learning task. This difference in task difficulty may be a possible confound for the pattern of results observed in this study. Specifically, the difficulty of the verb task might have led to a better performance with the right hand simply because using the left (non-dominant) hand would have been an "extra burden" and hence hindered children's performance. In other words, the at-chance performance in the verb learning task, of those children who were instructed to point with their left hand, could be interpreted as a decreased performance, compared to the above-chance performance of those children who were instructed to point with their right hand. However, this is unlikely because previous research suggests that children typically perform at chance in this type of verb generalization task even when children can respond with the gesture hand of their choice (e.g., Aussems & Kita, 2021; Imai et al., 2005, 2008; Kantartzis et al., 2011; Kersten & Smith, 2002).

A second limitation of this study is that the cognitive demand of the two tasks may have differed. In the memory task, children were required to process one video in the training stage, which was then shown again in the test stage, along with one novel video. In the verb learning task, children were required to process one video in the training stage, and two novel videos in the test stage. Thus, there was a difference in the cognitive processing demand between the two types of tasks. This possible confound could have influenced the performance difference between the verb learning and memory tasks.

A third limitation of this study is related to the children's adherence to the experimental manipulation. Right-handed children were instructed to point to their answers exclusively with their left hand or their right hand, which may have been counterintuitive to how they would normally respond. There were several trial exclusions because children did not follow the experimenter's instruction and pointed with the wrong hand. In those cases, the trial in which they pointed with the wrong hand was excluded, but if the children adhered to the manipulation in the following trials, then these trials were still included to prevent too much data loss. This is a factor that could have weakened our manipulation, especially considering that left hemisphere activation may have been "disrupted," or perhaps, not maintained throughout the task, due to a switch in gesture hand. A closer investigation of how many children did not adhere to the manipulation revealed that the numbers were very similar between the verb learning (left-hand condition, $N = 17$, right-hand condition, $N = 4$) and memory tasks (left-hand condition, $N = 13$, right-hand condition, $N = 4$). Although children found it more difficult to follow the left-hand instruction than the right-hand instruction, this pattern was the same for the memory and verb learning tasks. It is therefore unlikely that any differences between the memory and verb learning tasks are best explained by differences in how well children followed the instructions.

## 4.3 | Future research

This study focused on right-handed children, because they typically show left-hemispheric language lateralization even at a young age (Dehaene-Lambertz et al., 2002; Holowka & Petitto, 2002). We predict the same pattern of results in left-handed and ambidextrous children with left-hemispheric language dominance. This is because the special link between right-handed pointing and vocabulary development is independent from manual object manipulation (Cochet et al., 2011; Esseily et al., 2011; Mumford & Kita, 2016; Vauclair & Imbault, 2009). It is important to note that the incidence of atypical language lateralization (i.e., no dominant left hemisphere for language processing) in left-handed and ambidextrous children is much higher than in right-handed children (Szaflarski et al., 2012). So, to investigate whether this pattern holds in these groups, a future study should first use neurophysiological methods (e.g., fMRI) to measure hemispheric language dominance.

Furthermore, part of our explanation for the right-hand gesture benefit in this study is based on increased left hemisphere activation. Future studies could measure brain activity in the left hemisphere during linguistic tasks, using non-invasive functional near-infrared spectroscopy (fNIRS). This optical imaging technique that measures changes in blood flow in the brain has been used successfully with young children (e.g., Smith et al., 2020). In a future experiment, children could be instructed to use either their right or left hand to gesture while learning words. If right-handed gesturing leads to increased left hemisphere activation, there should be an increased blood flow to the regional brain areas involved in language processing. In combination with behavioral data, such an fNIRS study could strengthen our developmental theory of a linguistic advantage via right-handed gesturing.

Finally, whereas the current study focused on children with typical language development, future studies could focus on (neurodivergent) children who show signs of atypical language development. For example, children with developmental language disorder (DLD), who often have difficulty acquiring new words, and consequently develop poorer vocabulary skills than their typically developing peers (McGregor et al., 2013). Given that DLD children's early vocabulary skills are predictors of their later reading (Snowling et al., 2020) and writing skills (Dockrell et al., 2007), early intervention could potentially make a big and positive impact in this population. Furthermore, neurodivergent children (e.g., children who have been diagnosed with ADHD, autism, or dyslexia) also experience difficulties with linguistic processes. For example, children with ADHD can struggle with language comprehension and pragmatics (i.e., how to use language in context) (Bruce et al., 2006). Potentially, ADHD children may benefit from simple interventions that encourage them to use their right hand to gesture during language learning tasks (for left hemisphere activation), and their left hand during pragmatic tasks (for right hemisphere activation). Finally, if the hand children use to respond influences performance in neurodivergent populations, it may be useful to note the hand children use to respond in linguistic assessments, to establish the most accurate profile of children's language abilities.

## 5 | CONCLUSION

This is the first study to manipulate children's gesture hand to investigate its relationship to verb learning. Encouraging right-handed children to use their right hand to point in a verb learning task gave them a linguistic advantage over right-handed children who were encouraged to point with their left hand. No such advantage of gesture hand was found in a non-linguistic memory task. Pointing with the right hand may be important for verb learning because producing right-handed gestures activates the left hemisphere, which is important for forming and accessing lexical representations.

To avoid any misinterpretation of our findings, it is important to emphasize that we investigated the relationship between gesture and verb learning and *not* handedness and verb learning. This study only included children who were right-handed as determined by two handedness assessments. It therefore does not support, in any way, the practice of encouraging left-handed children to use their right hand for manual activities.

## CONFLICT OF INTEREST

The authors declare no conflicts of interest.

## ETHICS STATEMENT

The study protocol received full ethical approval.

## DATA AVAILABILITY STATEMENT

The stimuli, raw data, and analysis script are available via: http://osf.io/5ur2m

## ORCID

*Suzanne Aussems* https://orcid.org/0000-0002-0781-5849

*Sotaro Kita* https://orcid.org/0000-0002-0088-3654

## REFERENCES

Alibali, M. W., & Kita, S. (2010). Gesture highlights perceptually present information for speakers. *Gesture*, *10*(1), 3–28. https://doi.org/10.1075/gest.10.1.02ali

Anaki, D., Faust, M., & Kravetz, S. (1998). Cerebral hemispheric asymmetries in processing lexical metaphors. *Neuropsychologia*, *36*, 353–362. https://doi.org/10.1016/S0028-3932(97)00110-3

Argyriou, P., Mohr, C., & Kita, S. (2017). Hand matters: Left-hand gestures enhance metaphor explanation. *Journal of Experimental Psychology: Learning Memory and Cognition*, *43*(6), 874–886. https://doi.org/10.1037/xlm0000337

Aussems, S., & Kita, S. (2019). Seeing iconic gestures with action events facilitates children's memory of these events. *Child Development*, *90*(4), 1123–1137. https://doi.org/10.1111/cdev.12988

Aussems, S., & Kita, S. (2021). Seeing iconic gesture promotes first- and second-order verb generalization in preschoolers. *Child Development*, *92*(1), 124–141. https://doi.org/10.1111/cdev.13392

Aussems, S., Mumford, K. H., & Kita, S. (2022). Prior experience with unlabeled actions promotes 3-year-old children's verb learning. *Journal of Experimental Psychology: General*, *151*(1), 246–262. https://doi.org/10.1037/xge0001071

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

Blonder, L. X., Bowers, D., & Heilman, K. M. (1991). The role of the right hemisphere in emotional communication. *Brain*, *114*(3), 1115–1127. https://doi.org/10.1093/brain/114.3.1115

Bruce, B., Thernlund, G., & Nettelbladt, U. (2006). ADHD and language impairment. *European Child & Adolescent Psychology*, *15*, 52–60. https://doi.org/10.1007/s00787-006-0508-9

Childers, J. (2011). Attention to multiple events helps two-and-a-half-year-olds extend new verbs *First Language*, *30*(1), 3–22. https://doi.org/10.1177/2F0142723710361825

Cochet, H., Jover, M., & Vauclair, J. (2011). Hand preference for pointing gestures and bimanual manipulation around the vocabulary spurt period. *Journal of Experimental Child Psychology*, *110*(3), 393–407. https://doi.org/10.1016/j.jecp.2011.04.009

Cohen, J. (1998). *Statistical power analysis for the behavioral sciences*. 2nd ed. Lawrence Erlbaum Associates.

Corballis, M. C. (2014). Left brain, right brain: facts and fantasies. *PLoS Biology*, *12*(1): e1001767. https://doi.org/10.1371/journal.pbio.1001767

Coulson, S., & Williams, R. F. (2005). Hemispheric asymmetries and joke comprehension. *Neuropsychologia*, *43*(1), 128–141. https://doi.org/10.1016/j.neuropsychologia.2004.03.015

Dehaene-Lambertz, G., Dehaene, S., & Hertz-Pannier, L. (2002). Functional neuroimaging of speech perception in infants. *Science*, *298*(5600), 2013–2015. https://doi.org/10.1126/science.1077066

Dockrell, J. E., Lindsay, G., Connelly, V., & Mackie, C. (2007). Constraints in the production of written text in children with specific language impairments. *Exceptional Children*, *73*(2), 147–164. https://doi.org/10.1177/001440290707300202

Esseily, R., Jacquet, A. Y., & Fagard, J. (2011). Handedness for grasping objects and pointing and the development of language in 14-month-old infants. *Laterality*, *16*, 565–585. https://doi.org/10.1080/1357650X.2010.499911

Fox, J., & Weisberg, S. (2019). *An R companion to applied regression* (3rd edition). Sage. Retrieved from: https://socialsciences.mcmaster.ca/jfox/Books/Companion/

Frick-Horbury, D., & Guttentag, R. E. (1998). The effects of restricting hand gesture production on lexical retrieval and free recall. *American Journal of Psychology*, *11*(1), 43–62. https://doi.org/10.2307/1423536

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). Erlbaum.

Haryu, E., Imai, M., & Okada, H. (2011). Object similarity bootstraps young children to action-based verb extension. *Child Development*, *82*, 674–686. https://doi.org/10.1111/j.1467-8624.2010.01567.x

Holowka, S., & Petitto, L. A. (2002). Left hemisphere cerebral specialization for babies while babbling. *Science*, *297*(5586), 1515. https://doi.org/10.1126/science.1074941

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*(2), 340–355. https://doi.org/10.1111/j.1467-8624.2005.00849_a.x

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

Indefrey, P., & Cutler, A. (2004). Prelexical and lexical processing in listening. In M. Gazzaniga (Ed.), *The cognitive neurosciences III* (pp. 759–774). MIT Press.

Kantartzis, K., Imai, M., & Kita, S. (2011). Japanese sound-symbolism facilitates word learning in English-speaking children. *Cognitive Science*, *35*(3), 575–586. https://doi.org/10.1111/j.1551-6709.2010.01169.x

Kassambara, A. (2021). rstatix: Pipe-friendly framework for basic statistical tests. R Package retrieved from: https://cran.r-project.org/web/packages/rstatix/index.html

Kersten, A. W., & Smith, L. B. (2002). Attention to novel objects during verb learning. *Child Development*, *73*(1), 93–109. https://doi.org/10.1111/1467-8624.00394

Kimura, D. (1973a). Manual activity during speaking-I. Right-handers. *Neuropsychologia*, *11*(1), 45–50. https://doi.org/10.1016/0028-3932(73)90063-8

Kimura, D. (1973b). Manual activity during speaking-II. Left-handers. *Neuropsychologia*, *11*(1), 51–55. https://doi.org/10.1016/0028-3932(73)90064-X

Kita, S., & Lausberg, H. (2008). Generation of co-speech gestures based on spatial imagery from the right hemisphere: Evidence from split-brain patients. *Cortex*, *44*(2), 131–139. https://doi.org/10.1016/j.cortex.2006.04.001

Kita, S., Alibali, M. W., & Chu, M. (2017). How do gestures influence thinking and speaking? The gesture-for-conceptualization hypothesis. *Psychological Review*, *124*(3), 256–266. https://doi.org/10.1037/rev0000059

Kita, S., de Condappa, O., & Mohr, C. (2007). Metaphor explanation attenuates the right-hand preference for depictive co-speech gestures that imitate actions. *Brain and Language*, *101*(3), 185–197. https://doi.org/10.1016/j.bandl.2006.11.006

Knecht, S., Drager, B., Deppe, M., Bobe, L., Lohmann, H., Floel, A., Ringelstein, E. B., & Henningsen, H. (2000). Handedness and hemispheric language dominance in healthy humans. *Brain*, *123*(12), 2512–2518. https://doi.org/10.1093/brain/123.12.2512

Lausberg, H., Zaidel, E., Cruz, R. F., & Ptito, A. (2007). Speech-independent production of communicative gestures: Evidence from patients with complete callosal disconnection. *Neuropsychologia*, *45*(13), 3092–3104. https://doi.org/10.1016/j.neuropsychologia.2007.05.010

Maguire, M., Hirsh-Pasek, K., Golinkoff, R., & Brandone, A. (2008). Focusing on the relation: Fewer exemplars facilitate children's initial verb learning and extension. *Developmental Science*, *11*(4), 628–634. https://doi.org/10.1111/j.1467-7687.2008.00707.x

McGregor, K. K., Oleson, J., Bahnsen, A., & Duff, D. (2013). Children with developmental language impairment have vocabulary deficits characterized by limited breadth and depth. *International Journal of Language & Communication Disorders*, *48*(3), 307–319. https://doi.org/10.1111/1460-6984.12008

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*. University of Chicago Press.

Mills, D. L., Plunkett, K., Prat, C., & Schafer, G. (2005). Watching the infant brain learn words: Effects of vocabulary size and experience. *Cognitive Development*, *20*(1), 19–31. https://doi.org/10.1016/j.cogdev.2004.07.001

Mumford, K. H., & Kita, S. (2010). *Helping hands: Recognising iconicity in gestures and its advantage during verb acquisition*. Unpublished master's thesis, University of Birmingham, England.

Mumford, K. H., & Kita, S. (2014). Children use gesture to interpret novel verb meanings. *Child Development*, *85*(3), 1181–1189. https://doi.org/10.1111/cdev.12188

Mumford, K. H., & Kita, S. (2016). At 10–12 months, pointing gesture handedness predicts the size of receptive vocabularies. *Infancy*, *21*(6), 751–765. https://doi.org/10.1111/infa.12138

Naigles, L., & Kako, E. (1993). First contact in verb acquisition: Defining a role for syntax. *Child Development*, *64*(6), 1665–1687. https://doi.org/10.2307/1131462

Ofen, N., Chai, X. Q. J., Schuill, K. D. I., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2012). The development of brain systems associated with successful memory retrieval of scenes. *Journal of Neuroscience*, *32*(29), 10012–10020. https://doi.org/10.1523/JNEUROSCI.1082-11.2012

Pine, K. J., Bird, H., & Kirk, E. (2007). The effects of prohibiting gestures on children's lexical retrieval ability. *Developmental Science*, *10*(6), 747–754. https://doi.org/10.1111/j.1467-7687.2007.00610.x

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. URL https://www.R-project.org/

Ravizza, S. (2003). Movement and lexical access: Do non-iconic gestures aid in retrieval? *Psychonomic Bulletin & Review*, *10*, 610–615. https://doi.org/10.3758/BF03196522

Roseberry, S., Hirsh-Pasek, K., Parish-Morris, J., & Golinkoff, R. M. (2009). Live action: Can young children learn verbs from video? *Child Development*, *80*(5), 1360–1375. https://doi.org/10.1111/j.1467-8624.2009.01338.x

Qi, T., Schaadt, G., & Friederici, A. D. (2019). Cortical thickness lateralization and its relation to language abilities in children. *Developmental Cognitive Neuroscience*, *39*, 100704. https://doi.org/10.1016/j.dcn.2019.100704

Smith, E. G., Condy, E., Anderson, A., Thurm, A., Manwaring, S. S., Swineford, L., Gandjbakhche, A., & Redcay, E. (2020). Functional near-infrared spectroscopy in toddlers: Neural differentiation of communicative cues and relation to future language abilities. *Developmental Science*, *23*(6), e12948. https://doi.org/10.1111/desc.12948

Snowling, M. J., Hayiou-Thomas, M. E., Nash, H. M., & Hulme, C. (2020). Dyslexia and developmental language disorder: Comorbid disorders with distinct effects on reading comprehension. *Journal of Child Psychology and Psychiatry*, *61*(6), 672–680. https://doi.org/10.1111/jcpp.13140

Skipper, J. I., Goldin-Meadow, S., Nusbaum, H. C., & Small, S. L. (2007). Speech associated gestures, Broca's area and the human mirror system. *Brain and Language*, *101*(3), 260–277. https://doi.org/10.1016/j.bandl.2007.02.008

Su, M., Thiebaut de Schotten, M., Zhao, J., Song, S., Zhou, W., Gong, G., McBride, C., Ramus, F., & Shu, H. (2018). Vocabulary growth rate from preschool to school-age years is reflected in the connectivity of the arcuate fasciculus in 14-year-old children. *Developmental Science*, *21*(5), e12647. https://doi.org/10.1111/desc.12647

Szaflarski, J. P., Rajagopal, A., Altaye, M., Byars, A. W., Jacola, L., Schmithorst, V. J., Schapiro, M. B., Plante, E., & Holland, S. K. (2012). Left-handedness and language lateralization in children. *Brain Research*, *18*(1433), 85–97. https://doi.org/10.1016/j.brainres.2011.11.026

Taylor, K. I., & Regard, M. (2003). Language in the right cerebral hemisphere: Contributions from reading studies. *News in Psychological Sciences*, *18*(6), 257–261. https://doi.org/10.1152/nips.01454.2003

Tellier, M. (2008). The effect of gestures on second language memorisation by young children. *Gesture*, *8*(2), 219–235. https://doi.org/10.1075/gest.8.2.06tel

Vauclair, J., & Imbault, J. (2009). Relationship between manual preferences for object manipulation and pointing gestures in infants and toddlers. *Developmental Science*, *12*(6), 1060–1069. https://doi.org/10.1111/j.1467-7687.2009.00850.x

Wakefield, E. M., Hall, C., James, K. H., & Goldin-Meadow, S. (2018). Gesture for generalization: Gesture facilitates flexible learning of words for actions on objects. *Developmental Science*, *21*(5), e12656. https://doi.org/10.1111/desc.12656

Willems, R. M., Özyürek, A., & Hagoort, P. (2007). When language meets action: The neural integration of gesture and speech. *Cerebral Cortex*, *17*(10), 2322–2333. https://doi.org/10.1093/cercor/bhl141

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Mumford, K. H., Aussems, S., & Kita, S. (2022). Encouraging pointing with the right hand, but not the left hand, gives right-handed 3-year-olds a linguistic advantage. *Developmental Science*, e13315. https://doi.org/10.1111/desc.13315