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Taking a Hands-on Approach to Learning

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Abstract

When people talk, they gesture. These gestures often convey substantive information that is related, but not always identical, to the information conveyed in speech. Gesture thus offers listeners insight into a speaker's unspoken cognition. But gesture can do more than reflect cognition—it can play a role in changing cognition and, as a result, contribute to learning. This article has two goals: (a) to make the case that gesture can promote growth early in development when children are learning language and also later in development when children learn about math, and (b) to explore the implications of these findings for practice—how gesture can be recruited in everyday teaching situations by parents and teachers. Because our hands are always with us and require little infrastructure to implement in teaching situations, gesture has the potential to boost learning in *all* children and thus perhaps reduce social inequalities in achievement in language and math.

Keywords

gesture, language learning, math learning, gesture–speech mismatch, teacher training, parent advising

Tweet

Because our hands are always with us, gesture has the potential to boost learning in *all* children and thus reduce inequalities in achievement in language and math.

Key Points

- When people talk, they gesture, and these gestures can convey substantive information that is related, but not always identical, to the information conveyed in speech.
- Gesture thus offers listeners insight into a speaker's unspoken cognition.
- But gesture can do more than reflect cognition—it can change cognition early in development when children are learning language and also later in development when children learn about math.
- These findings have implications for practice because our hands are always with us and gesture requires little infrastructure to implement in teaching situations.
- Gesture thus has the potential to boost learning in *all* children and perhaps reduce inequalities in achievement in language and math.

Introduction

The social inequality in achievement in language and math begins before children enter school and persists despite reforms to classroom instruction (Duncan et al., 2007; Hart & Risley, 1995; National Research Council, 2012). One way to combat this inequality is to develop strategies that teachers can use to even out the differential inputs that children from lower versus higher achieving family backgrounds typically receive at home. Another approach is to tackle the differences in input early in development before children come to school. But following either approach requires understanding the factors that influence learning at home and at school, and determining whether any of these factors is easily manipulable.

Consider a behavior that typically goes unnoticed—the gestures people produce when they talk. Gesture has the potential to affect learning while fitting seamlessly into everyday practices in the classroom and the home. Gestures are movements of the hand that accompany speech and, as such, are actions. The actions people do during, or in relation to, a task have been found to affect processing and remembering that task (e.g., Calvo-Merino, Glaser, Grezes, Passingham, & Haggard, 2005; Casile & Giese, 2006; Chao & Martin, 2000; Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004; James & Swain, 2011; Longcamp, Tanskanen, & Hari, 2006; Pulvermüller, 2001). For example, people are more likely to recall an action if they have performed the action than if they have read a verbal description of the action (Engelkamp & Zimmer, 1989; Nilsson, 2000). Producing (Cook, Mitchell, & Goldin-Meadow, 2008; Goldin-Meadow, Cook, & Mitchell, 2009) or even observing (Singer & Goldin-Meadow, 2005) task-relevant gesture while learning a task

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has also be found to facilitate success on that task. In this sense, gesture can function like action.

But gesture differs from action in a number of respects. First, gestures do not have a direct effect on the world; for example, producing a *rotate* gesture while mentally rotating an object does not actually reposition the object; only physically rotating the object has this effect. Second, although gestures, particularly iconic gestures, resemble actions, gestures vary in how closely they mirror the actions they represent; for example, a *rotate* gesture produced with a C-shaped hand simulating how the object would be held if it were rotated resembles the actual act of rotating more closely than a *rotate* gesture produced with a pointing hand. Gesture can focus attention on particular components of an action.

Gesture thus has the potential to play a unique role in learning as it is an action and can exploit the effects that action has on cognition (cf. Beilock, Lyons, Mattarella-Micke, Nusbaum, & Small, 2008). At the same time, gesture *refers* to the world and does not directly influence it; it can thus selectively highlight components of action that are relevant to a particular situation. As a result, gesture's contribution to learning may be as a stepping-stone in the transition from concrete action to abstract thought.

The first goal of this article is to make the case that gesture plays a role in learning—it can promote growth early in development when children are first learning language and also later in development (once language has been learned) when children are learning other topics like math. The gestures speakers spontaneously produce when they talk often convey substantive information that is related, but not always identical, to the information conveyed in that talk. Gesture thus offers listeners (parents, teachers, clinicians, researchers) insight into a speaker's unspoken cognition. But gesture can do more than reflect cognition—it can play a role in changing cognition and, as a result, contribute to learning. The second goal of the article is to explore the implications of these findings for practice—more specifically, to explore how gesture can be recruited in everyday teaching situations by parents and teachers. Gesture could be included as a topic in both parent advising and teacher training with an eye toward making communication more effective for learners.

Gesture Promotes Learning

Learning Language

Well before children produce their first words, they use their hands to communicate (Acredolo & Goodwyn, 1988; Bates, 1976)—they point at things to draw attention to those things, they wave *bye-bye*, they raise their outstretched hands to ask to be picked up, and so on. These gestures are not just a way for children to communicate when they do not yet have words to do the job—the gestures seem to set the stage for language development. For example, the number of different items to which a child points at 14 months is a good predictor of the size of that child's spoken vocabulary approximately 3 years later, at age 54 months. In fact, child gesture at 14 months can account for some of the variance in predicting vocabulary prior to school entry that has been attributed to socioeconomic status. Moreover, parent gesture at 14 months predicts child gesture at 14 months, which, in turn, predicts vocabulary size at 54 months (Rowe & Goldin-Meadow, 2009). The pointing gestures children produce early in development are thus a harbinger of things to come in speech.

Not only does the number of distinct pointing gestures a child produces early in development predict the size of the child's vocabulary at school entry, but these points also predict which words are likely to soon enter that child's vocabulary (Iverson & Goldin-Meadow, 2005). For example, a child who points at dogs but does not yet say the word "dog" will very likely learn to produce the word "dog" within a few months. Moreover, a child's early gesture + word combinations predict when that child will begin producing word + word combinations. Consider a child who is at the one-word stage and does not yet combine words into strings. The child does, however, combine gestures and words and uses these combinations to express sentence-like ideas; for example, a point at a box combined with the word "open" to request mom to open the box; or a point at a hat combined with the word "mama" to indicate that the hat is mom's. This child is very likely to produce his first two-word utterance (e.g., "open box" or "mama hat") within a few months—more likely than a child who has not yet produced gesture + word combinations of this sort (Iverson & Goldin-Meadow, 2005; Özçalişkan & Goldin-Meadow, 2005). Children's early gestures thus foreshadow their subsequent language development (see also Bavin et al., 2008; Goodwyn & Acredolo, 1993).

The gestures that children spontaneously produce provide a lens through which caregivers can detect which children are ready to take their next linguistic steps. But spontaneous gesture cannot tell us whether gesture is playing a causal role in a child's ability to take that step. To determine whether gesturing can change a learner's mind, researchers need to manipulate the gestures that the learner produces.

One study did just that (LeBarton, Raudenbush, & Goldin-Meadow, 2015). The experimenter went into young toddlers' homes once a week for 7 weeks, beginning when the children were 16 months old. During the first .5 hr of every visit, the children interacted with their primary caregivers. During the second .5 hr, the experimenter showed the children picture books and produced labels for the pictures. One group heard only the experimenter's words (e.g., "Do you see the dress?"). Another group saw the experimenter point at the picture as she produced the label (e.g., "Do you see the dress?" while pointing at the dress). A third group not only saw the experimenter point at and label the dress, but was also instructed to point at the dress (e.g., "Do you see the dress?" while pointing at the dress, followed by "can you do this?").

The first question was—would this manipulation increase the number of points children in the third group produced (relative to the other two groups) not only when they were interacting with the experimenter, but also when they were interacting with their caregivers? The answer was "yes"—telling children to point gets them pointing even when not directly told to use their hands. The second question was—did this increase in pointing gestures bring with it an increase in spoken words? Again the answer was "yes"—children in the third group (who were instructed to gesture) produced significantly more words in a naturalistic interaction with their caregiver at the end of the study than children in the other two groups (who were not instructed to gesture). Telling children to point can increase the rate at which they learn words.

In addition to pointing, children in the early stages of language learning produce iconic gestures, which portray features of the objects or actions they represent (Acredolo & Goodwyn, 1988; Iverson, Capirci, & Caselli, 1994; Özçalişkan, Gentner, & Goldin-Meadow, 2014). For example, a child might pantomime hammering to comment on the action that is being done with a hammer. These iconic gestures can also play a role in word learning. One study taught toddlers novel words for novel actions (Wakefield, Hall, James, & Goldin-Meadow, 2018). The children were told either to produce a gesture for an action while learning a nonsense word for that action or to produce the action itself while learning the word. Children learned the words equally well whether they produced a gesture for an action or the action itself during instruction. However, they were better at generalizing the words they had learned to a new situation if they had learned the words through gesture rather than action. For example, a child who learned the word "leeming" on an orange toy was better able to extend "leeming" to a purple toy that afforded the same action if the child had learned the word through gesture rather than action. The gestures children produce can play a role in shaping the words they learn.

Learning Math

Once they are fluent language users, children begin to use their hands in other types of learning situations. This review focuses on math learning for two reasons. First, students often struggle in math classes because mathematical concepts build on each other; once a student falls behind in a math class, the student often has difficulty catching up in subsequent classes. Not only do delays of this sort decrease the student's likelihood of succeeding in other science, technology, engineering, and mathematics (STEM) courses, but they can also affect the student's academic success more broadly (Adelman, 2006; Allensworth & Easton, 2005; Department of Education, 1997; Hansen, 2014). Second, gesture is spontaneously used in math classrooms (Alibali et al., 2014; Flevares & Perry, 2001; Richland, Zur, & Holyoak, 2007)—students gesture when asking questions or describing their solutions to math problems (Alibali & Nathan, 2012), and teachers gesture, particularly when students do not understand a concept in a math lesson (Alibali, Nathan, et al., 2013). Gesture is thus a naturally used tool that students and teachers both use to represent and manipulate mathematical notions.

But does gesture play a role in math learning? As in language learning, the gestures children spontaneously produce in a math lesson can provide insight into their understanding of the lesson that is not evident in their speech. Consider a child explaining her answers to a mathematical equivalence problem, $5 + 7 + 3 = \_\_ + 3$. The child puts 15 in the blank and says she solved the problem by adding up all of the numbers on the left side of the equation. At the same time, she produces a *grouping* gesture—she puts a V-hand under the 5 + 7 and then points at the blank. Her gestures suggest that she has more knowledge about how to solve this problem than her speech reveals—she seems to know (albeit not necessarily consciously) that adding the two numbers on the left side of the equation that are unique and putting the sum in the blank is another way to solve the problem.

Indeed, when children who produce these so-called gesture–speech mismatches are given instruction in mathematical equivalence, they are likely to learn how to solve the problem correctly—more likely than children who do not produce gesture–speech mismatches on the problem (Alibali & Goldin-Meadow, 1993; Perry, Church, & Goldin-Meadow, 1988; see also Goldin-Meadow, Shield, Lenzen, Herzig, & Padden, 2012, for evidence that deaf children who produce gesture–*sign* mismatches are more likely to profit from instruction in mathematical equivalence than deaf children who do not produce gesture–sign mismatches).

Again as in language learning, determining whether gesture can change a learner's mind requires manipulating the gestures that the learner produces. One experiment taught a group of children the *equalizer* strategy in speech ("I want to make one side of the problem equal to the other side") and told the children to produce it on each problem in the lesson (Cook et al., 2008). Another group was taught the same words along with gestures instantiating the equalizer strategy (sweep the left hand under the left side of the equation, and then the right hand under the right side of the equation) and told to produce both during the lesson. A third group was taught only the hand movements and told to produce them during the lesson. Children in all three groups profited from the math lesson, but those who gestured during the lesson (with or without speech) were more likely to retain what they had learned than those who produced only speech. Gesturing makes learning last.

Gesturing during math learning also encourages children to generalize what they learn to novel instances, and (as in word learning) promotes generalization better than acting on concrete manipulatives (Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014). One group of children was taught to produce the *equalizer* strategy in speech and the *grouping* strategy in gesture. Another group was taught to say the same words but to produce actions on plastic numbers that instantiated the *grouping* strategy (the children were told to pick up the first two plastic numbers on the left side of the equation and hold them under the blank on the right side of the equation). Children in both groups learned how to solve the problems on which they were taught (problems like 5 + 7 + 3 = __ + 3). But children who gestured rather than acting directly on plastic numbers were more likely to generalize what they had learned to problems in a new format (e.g., 5 + 7 + 3 = 5 + __ with the blank in a new position; or 5 + 7 + 3 = __ + 4 with no duplicated numbers on the two sides of the equation). Children who gestured during the lesson were able to extend the knowledge they had gained and, in this sense, had achieved a deeper understanding of mathematical equivalence than children who acted on objects during the lesson.

Implications for Practice: Recruiting Gesture in Everyday Teaching and Learning Situations

Using Gesture to Diagnose and Assess

The gestures learners produce often reveal cutting-edge knowledge that the learners are not yet able to display in their speech (or their problem solutions). Gesture thus has the potential to alert the people who interact with child-learners to the fact that those learners might know more than they can say. This information could then be used to get an accurate assessment of the learner's knowledge state (more accurate than without gesture), and perhaps to diagnose children whose learning has gone awry.

As an example, early gesture can identify which children with early unilateral focal brain injury are likely to remain delayed with respect to vocabulary development and which children are likely to progress into the typical range. Children with brain injury who produced a repertoire of gestures at 18 months that was comparable to the repertoire of gestures produced by typically developing 18-month-old children were subsequently within the typical range of spoken language development at 22, 26, and 30 months. In contrast, children with brain injury whose gesture production at 18 months was below the typical range continued to show delays in vocabulary development at 22, 26, and 30 months (Sauer, Levine, & Goldin-Meadow, 2010; see also Luyster, Kedlec, Carter, & Tager-Flusberg, 2008; Smith, Mirenda, & Zaidman-Zait, 2007; Thal, Tobias, & Morrison, 1991). Early gesture can tell clinicians who really needs intervention.

The insights into a child's knowledge state provided by gesture are, of course, useful to listeners only if those listeners can glean meaning from the child's gestures. Indeed, ordinary people (teachers and nonteachers alike) can infer meaning from the gestures children produce on tasks testing conservation of quantity (Goldin-Meadow, Wein, & Chang, 1992) or mathematical equivalence (Alibali, Flevares, & Goldin-Meadow, 1997; Goldin-Meadow & Sandhofer, 1999) in an experimental situation. Even in naturalistic teaching situations, teachers recognize (although not necessarily consciously) when a child is producing a mismatching gesture—they respond differently than they do to a child who does not produce mismatching gestures (Goldin-Meadow & Singer, 2003). Moreover, the changes teachers spontaneously make when they respond to a child who produces mismatches (as opposed to a child who produces only matches) turn out to be just right for teaching mathematical equivalence (Singer & Goldin-Meadow, 2005). These findings suggest that teachers can use a child's gestures as a useful guide to how to best teach that child.

Parents too can make use of child gesture when deciding what to say next to their children. Parents are not likely to be making conscious use of their child's gesture to assess the child's state. Nevertheless, the parent may respond to the child's cutting-edge gestures with the kind of input that could help the child progress to the next step. For example, when a child who does not know the word "dog" points at a dog, her parent could respond by saying, "yes, that's a dog," thus providing just the input that the child needs to learn this word. In fact, it turns out that when a mother translates her child's gesture into a word, that word is particularly likely to enter the child's spoken vocabulary within a few months—more likely than when mother does not translate the child's gesture (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007).

Parents can also play a role in helping children transition from gesture + word combinations to word + word utterances. Mothers respond differently to their children's early gesture + word combinations—they produce longer sentences when responding to combinations that can easily be translated into a sentence (e.g., point at bird + "nap") than to combinations that offer less opportunity for expansion (e.g., point at bird + "bird"). Maternal sentences are longest when mother incorporates information from both the word *and* the gesture that the child produced; for example, in this case, she responds with a sentence containing six words, "The bird is taking a nap." Note that mother could have produced a six-word sentence if she had focused only on the child's words—she could have said, "Do you want to nap now?" But maternal sentences that take information from only one modality, or that take no information from the child, tend to be short (Goldin-Meadow et al., 2007). Moreover, children whose mothers produce many gesture-to-word translations tend to be first to produce two-word utterances, suggesting that targeted responses to children's gestures have the potential to play a role in helping children take their first step into multiword combinations.

Gesture thus offers a window onto a learner's developing skills that teachers and parents can, and do, exploit.

Using Gesture to Teach

Gesture can be effectively recruited in teaching situations in at least three ways.

First, encourage learners to gesture. For example, show them how to move their hands when explaining how to solve a math problem (Cook et al., 2008; Goldin-Meadow et al., 2009) or learning a new word (Wakefield et al., 2018). Initially, these hand movements may be nothing more than rote actions, produced with little comprehension. However, over time, children who make progress in learning the math problem begin to alter the form of their rote hand movements, changing them so that they look more like the gestures produced by people who know how to solve the problem (Mangelsdorf, Cook, & Goldin-Meadow, 2018). The learners' hand movements become true gestures and thus provide yet another signal that they are making progress.

Note, however, that this process is difficult to "scale-up" if teaching every concept requires knowing the optimal gestures for a learner to produce. Happily, this type of planning may not be necessary. Merely telling children to move their hands can get them to gesture in effective ways. In one study, children were told that the next time they solved a new set of mathematical equivalence problems, they should "move their hands" when explaining their solutions (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). Children who were encouraged to gesture in this way not only increased the number of gestures they produced, but they also began to produce problem-solving strategies in gesture that they had never produced before—and many of those strategies would lead to correct solutions if implemented. In other words, encouraging children to gesture brought out implicit knowledge that the children seemed unable or unwilling to express prior to being told to gesture. Moreover, when later given a math lesson, children who had been encouraged to gesture were more likely to learn mathematical equivalence than children who had not been encouraged to gesture. Bringing out a child's implicit knowledge about mathematical equivalence via gesture makes them ready to profit from instruction in the concept.

Second, encourage teachers to pay attention to the gestures that their students produce. One study attempted to teach adults, who were not trained investigators, to understand information conveyed through children's hand gestures (Kelly, Singer, Hicks, & Goldin-Meadow, 2002). Adults saw videotapes of children solving conservation of quantity problems and indicated on a questionnaire whether a child had expressed a particular problem-solving strategy; some of the strategies were expressed in speech but others were expressed only in gesture. The adults saw explanations from 15 children in the pretest, and the same explanations in a different order in the posttest. Between pretest and posttest, adults were given a 5-min break and were randomly assigned to one of four conditions: (a) No instruction: Adults were not told anything about gesture during the break. (b) Hint: Adults were told that hand gestures often convey important information not found in speech. (c) General instruction: Adults were shown a 5-min instructional tape on how to interpret hand gestures in general; examples used on the tape did not come from conservation. (d) Specific instruction: Adults were shown a 5-min instructional tape focusing on examples in the context of conservation and, in fact, used examples that the adults had seen in the pretest and would be seeing on the posttest. All three groups who had received instruction about gesture noticed more explanations that the children conveyed uniquely in gesture (i.e., not in speech) on the posttest than on the pretest. Adults receiving the Hint and General instruction about gesture did not differ from one another, but did differ from both the No-instruction and the Specific-instruction groups. Not surprisingly, instruction about the specific gestures that the adults would see on the videotape resulted in the best performance. Nevertheless, merely giving adults a hint to pay attention to gesture, or general instruction about how to look at gesture, was sufficient to boost their ability to "read" child gesture. It does not take much to increase an adult's ability to glean information from gesture that is not expressed in speech.

Third, encourage parents and teachers to gesture. When told about the importance of gesture for student learning, teachers increased the amount of gesturing they did during instruction (Alibali, Young, et al., 2013). A simple intervention—merely telling teachers that gesture can help students learn—appears to be sufficient to change teacher behavior. And teacher gesture begets child gesture—children are more likely to produce gesture themselves if they are exposed to an experimenter who gestures (Cook & Goldin-Meadow, 2006). Parents can also be encouraged to gesture. When shown a 5-min instructional video on the importance of early pointing (*Pointing to Success*), parents increased their gestures and those increases led to increases in child gesture and vocabulary (Rowe & Leech, 2018). In fact, merely letting parents watch the experimenter gesture to their child and encourage the child to gesture led parents in the child-gesture condition of the LeBarton et al. (2015) study to increase their gesturing when they later interacted with the child. Increasing gesture in parents and teachers can be quick and inexpensive and thus has the potential to be widely used.

Our Hands Are Always With Us

A good teaching tool is one that can be implemented broadly. If a tool is difficult to use, it is unlikely to be adopted. If the tool is costly, it may not be accessible to underprivileged communities (see Wakefield & Goldin-Meadow, 2018). It thus matters that gestures are ubiquitous, naturally produced, and universally accessible in both homes and schools. Not only is gesture used naturally, but its use can, with little effort, be increased in children (Broaders et al., 2007), parents (Rowe & Leech, 2018), and teachers (Alibali, Young, et al., 2013). Adults can be instructed to model gestures and to ask children to produce gestures of their own, a practice that might be particularly beneficial for children from lower socioeconomic homes who tend to produce fewer spontaneous gestures than children from higher socioeconomic homes (Rowe & Goldin-Meadow, 2009). In addition, because children who have impairments in language often use gesture to compensate for their disabilities (Evans, Alibali, & McNeil, 2001), harnessing gesture may benefit not only typically developing children, but also children with special needs in classrooms and one-on-one assessment situations.

However, two caveats need to be considered. Gesture is a powerful tool that can be used to promote learning (as illustrated here), but it can also be used to mislead. For example, when interviewing witnesses, good practice has it that the examiner ask only open-ended questions ("What else was the musician wearing") rather than targeted questions ("What color was the hat that the musician was wearing"). But witnesses will respond that the musician was wearing a hat even when he was not *if* the examiner produces a *donning-hat* gesture along with his open-ended question—and they do so just as often as if the examiner had produced a targeted question focusing attention on the hat ("What color was the hat he was wearing"; Broaders & Goldin-Meadow, 2010). As another example, an inadvertent gesture produced by a teacher can mislead a student. Consider a teacher who is trying to teach a child how to solve the problem $4 + 5 + 7 = \_\_ + 7$, but points at all four numbers in the problem without pausing at the equal sign. In response, the child offers 23 as the answer, which is the sum of the four numbers to which the teacher pointed (Goldin-Meadow & Alibali, 2012). Gesture can change minds and must be used with care.

The second caveat is that gesture may not always be *the* optimal tool. Although gesture often leads to more flexible learning than actions on objects, sometimes action experience may be more effective than gesture. Because action on objects is concrete, it may be more useful than gesture when first learning a concept (cf. Goldstone & Son, 2005). For example, manipulatives can provide students with a physical representation of a concept, allowing them to off-load some of the mental effort involved in learning (Lillard, 2005). When students are struggling with a new concept, manipulatives can thus provide a rudimentary understanding of the concept, which can then be expanded through gesture. Using action and gesture to complement each other creates an ideal learning situation for certain concepts.

To conclude, although certainly not a panacea, gesturing has the potential to improve learning with little cost. We can put gesture into the hands of children by simply telling them to gesture or by modeling gesture for them. An increase in child gesture can then improve learning in two ways—it can give parents and teachers insight into the child's cutting-edge (albeit implicit) thoughts and it can help the child consolidate those thoughts and make them more explicit. We can also put gesture into the hands of parents and teachers, again by simply telling them to gesture or by modeling gesture for them. Adult gesture not only increases child gesture, but it also has the potential to express imagistic ideas that may be easier to convey (and grasp) in the manual modality than in the oral modality (Goldin-Meadow, 2003; McNeill, 1992). Letting parents and teachers know that gesture can have positive effects on learning outcomes is a first step in putting this ubiquitous and easily accessible tool to optimal use.

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