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How gesture works to change our minds

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Abstract

When people talk, they gesture. We now know that these gestures are associated with learning—they can index moments of cognitive instability and reflect thoughts not yet found in speech. But gesture has the potential to do more than just reflect learning—it might be involved in the learning process itself. This review focuses on two non-mutually exclusive possibilities: (1) The gestures we see others produce have the potential to change our thoughts. (2) The gestures that we ourselves produce have the potential to change our thoughts, perhaps by spatializing ideas that are not inherently spatial. The review ends by exploring the mechanisms responsible for gesture's impact on learning, and by highlighting ways in which gesture can be effectively used in educational settings.

In all cultures and at all ages, speakers move their hands when they talk—they gesture. Even congenitally blind individuals who have never seen anyone gesture move their hands when they talk (Iverson & Goldin-Meadow, 1998), suggesting that gesturing is a robust part of speaking. The question this review asks is whether these gestures can be harnessed to promote learning.

Although gesture may seem like hand waving, in fact, it conveys substantive information, often information that is not found in the speaker's words. For example, consider a child who is shown two rows of checkers. The child is first asked to verify that the two rows have the same number of checkers and is then asked whether the rows still have the same number after one row is spread out. The child says "no" and justifies his response by saying, "They're different because you moved them." But at the same time, the child produces the following gestures—he moves his finger between the first checker in row 1 and the first checker in row 2, then the second checker in rows 1 and 2, and so on. In his gestures, the child is demonstrating an understanding of one-to-one correspondence, a central concept underlying the conservation of number, which does not appear in his speech (Church & Goldin-Meadow, 1986).

Two additional points are worth noting about gesture: (1) The information conveyed uniquely in a learner's gestures is often accessible *only* to gesture; that is, it is encapsulated knowledge not yet accessible to speech (Goldin-Meadow, Alibali & Church, 1993). (2) Learners who produce gestures that convey information not found in their speech when explaining a task are ready to learn that task—when given instruction in the task, they are

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more likely to profit from that instruction than learners whose gestures convey the same information as their speech, whether the learners are children (Church & Goldin-Meadow, 1986; Perry, Church & Goldin-Meadow, 1988; Pine, Lufkin & Messer, 2004) or adults (Perry & Elder, 1997; Ping et al., 2013).

Gesture can thus reflect the state of a learner's knowledge. But evidence is mounting that gesture can do more than display what learners know and can play a role in changing what learners know.

The gestures learners see can change their minds

Learners are more likely to profit from instruction when it is accompanied by gesture than when that same instruction is not accompanied by gesture (Church, Ayman-Nolley & Mahootian, 2004; Perry, Berch & Singleton, 1995; Valenzeno, Alibali & Klatzky, 2003), even when the gestures are not directed at objects in the immediate environment (Ping & Goldin-Meadow, 2008). Gesture has been found to be particularly helpful in instruction when it conveys a correct strategy for solving a math problem that is different from the (also correct) strategy conveyed in the accompanying speech (Singer & Goldin-Meadow, 2005).

But the gestures that teachers spontaneously use with their children are not always helpful. Take the following interchange that occurred when a teacher was asked to teach a child mathematical equivalence. The teacher had asked the child to solve the problem 7+6+5=__ +5 and the child put 18 in the blank, using an incorrect "add-numbers-to-equal-sign" strategy to solve the problem. In her speech, the teacher made it clear to the child that he had used this strategy: she said "so you got this answer by adding these three numbers". However, in her gestures, she produced an "add-all-numbers" strategy: she pointed at the 7, the 6, the 5 on the left side of the equation *and* the 5 on the right side of the equation. After these gestures, the teacher went on to try to explain how to solve the problem correctly but, before she could finish, the child offered a new solution—23—precisely the number you get if you add up all of the numbers in this problem. The teacher was genuinely surprised at her student's answer, and was completely unaware of the fact that she herself might have given him the idea to add up all of the numbers in the problem. A teacher's gestures can lead the child astray. The larger point, however, is that the gestures teachers produce have an impact on what learners take from their lessons and may therefore have an effect on learning.

The gestures we see are influential in other situations as well. For example, it is well-known that the details of an event recalled by an eye-witness can be influenced by the way in which an interviewer poses the question (e.g., Ceci, 1995). Targeted questions—"What color was the hat he was wearing?"—can mislead witnesses in a way that open-ended questions—"What else was he wearing"—do not. But if an open-ended question is accompanied by a gesture (for example, a hat-donning gesture), it is just as likely to evoke a hat response when there were no hats involved as a targeted question that explicitly draws attention to a hat (Broaders & Goldin-Meadow, 2010). Seeing gesture can affect how we think about things.

The gestures learners produce can change their minds

The gestures that learners themselves produce can also have an impact on learning. To determine whether gesture can affect learning, we need to teach learners to gesture in particular ways. If learners can extract meaning from their gestures, they should be sensitive to the particular movements in those gestures and learn accordingly. Alternatively, all that may matter is that learners move their hands. If so, they should learn regardless of which gestures they produce. To investigate these alternatives, Goldin-Meadow, Cook and Mitchell (2009) manipulated gesturing during a math lesson. They found that children required to produce *correct* gestures learned more than children required to produce *partially correct* gestures, who learned more than children required to produce *no* gestures. This effect was mediated by whether, after the lesson, the children added information to their spoken repertoire that they had conveyed uniquely in their gestures during the lesson (and that the teacher had not conveyed at all). The findings suggest that the gestures learners produce can have an impact on what they learn.

Gesturing not only helps children learn in the short-term, but it also makes learning last. Cook, Mitchell, and Goldin-Meadow (2008) taught some children a strategy for solving math problems in speech alone, some the same strategy in gesture alone, and a third group the strategy in both speech and gesture. The children produced the words and/or gestures they were taught throughout a lesson in how to solve the problems. Children in all three groups improved an equal amount after the lesson, but only the children who gestured during the lesson (either alone or with speech) retained what they had learned a month later. Gesturing, but not speaking, thus solidified the knowledge gained during instruction, again suggesting that gesturing can play a cause roled in learning.

The gestures learners produce can influence the course of learning. But if teachers need to invent gestures for each concept they hope to teach, it may be difficult to scale gesture up so that it can be used as a general teaching tool. What would happen, however, if we just told learners to gesture and provided no information as to how to gesture? Broaders, Cook, Mitchell and Goldin-Meadow (2007) asked children to explain how they solved a set of math problems with no instructions about what to do with their hands. They then asked the children to solve a second set of comparable problems and divided the children into three groups: some were told to move their hands as they explained their solutions to this second set of problems; some were told not to move their hands; and some were given no instructions about their hands. Children who were told to gesture on the second set of problems added strategies to their repertoires that they had not previously produced; children who were told not to gesture and children given no instructions did not. Most of the added strategies were produced in gesture and not in speech and, surprisingly, most were correct. In addition, when later given instruction, the children who had been told to gesture and had added strategies to their repertoires profited from the instruction and learned how to solve the math problems. Being told to gesture thus encouraged children to express ideas that they had previously not expressed, which, in turn, led to learning. Doing gesture can affect how we take in new information.

How does gesture change learners' minds?

Gestures are produced in space and could emerge from visuospatial thinking. Speakers are, in fact, likely to gesture when talking about things that are spatial or imageable (Alibali, Heath & Meyers, 2001; Beattie & Shovelton, 2002, Krauss, 1998) and when conveying information that has been acquired visually as opposed to verbally (Hostetter & Hopkins, 2002). Indeed, the mathematics domain that we have focused on here has its roots in space. But can gesture have an impact on learning even in a non-spatial domain?

Beaudoin-Ryan and Goldin-Meadow (2013) used the same paradigm as Broaders et al. (2007) to explore whether gesturing when reasoning about a moral dilemma helps children profit from a lesson in moral reasoning. It did—children who were told to gesture were more likely to take multiple points of view into account in their speech after the lesson than children who were told not to gesture or than children who were given no instructions about their hands. Gesturing allows learners to take ideas that are not inherently spatial and lay them out in space, thus "spatializing" them. The learners can then make use of spatial mechanisms (Newcombe, 2010) that they would not necessarily have used had they not gestured.

Gesturing might promote learning because it is itself a physical action, or because it uses physical action to represent abstract ideas (Goldin-Meadow & Beilock, 2010). Novack, Congdon, Hermani and Goldin-Meadow (2013) taught children a strategy for solving math problems that was instantiated in one of three ways: (1) in the physical action children performed on objects, (2) in a concrete gesture miming that action, or (3) in an abstract gesture. All three types of hand movements helped children learn how to solve the problems on which they were trained. However, only gesture led to success on problems that required generalizing the knowledge gained, with abstract gesture producing the highest rates of learning on generalization problems. The results provide evidence that gesture promotes transfer of knowledge better than action, and suggest that the beneficial effects gesture has on learning may reside in the features that differentiate it from action.

How can gesture be recruited in educational settings?

There are at least three ways that gesture can be put to better use in educational settings. First, teachers can be encouraged to examine their own gestures to make sure that those gestures are, at the least, not conveying ideas that could mislead their students. They might even think about how the ideas they want to teach can be displayed in the manual modality and then produce those gestures during their lessons.

Second, learners can be encouraged to gesture when they explain a problem. The gestures they produce are likely to display their cutting-edge understanding of the problem, not yet evident in their speech. These gestures can then serve as a diagnostic that teachers can use to figure out what their students know and what they are ready to learn.

Finally, encouraging students to gesture about a problem may activate whatever implicit ideas they have about that problem, which, in turn, may make them more open to instruction

in the problem. Encouraging particular types of gestures can even introduce new ideas into the student's repertoire.

In sum, the spontaneous gestures we produce when we talk are not mindless hand waving. They not only reflect thought, but they also have the potential to change thought in both listeners and speakers. Gesture thus offers a tool that learners (and researchers) can use to make new discoveries about the mind.

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