Primer

Using our hands to change our minds

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Jean Piaget was a master at observing the routine behaviors children produce as they go from knowing less to knowing more about at a task, and making inferences not only about how children understand the task at each point, but also about how they progress from one point to the next. This article examines a routine behavior that Piaget overlooked—the spontaneous gestures speakers produce as they explain their solutions to a problem. These gestures are not mere hand waving. They reflect ideas that the speaker has about the problem, often ideas that are not found in that speaker's talk. Gesture can do more than reflect ideas—it can also change them. Observing the gestures that others produce can change a learner's ideas, as can producing one's own gestures. In this sense, gesture behaves like any other action. But gesture differs from many other actions in that it also promotes generalization of new ideas. Gesture represents the world rather than directly manipulating the world (gesture does not move objects around) and is thus a special kind of action. As a result, the mechanisms by which gesture and action promote learning may differ. Because it is both an action and a representation, gesture can serve as a bridge between the two and thus be a powerful tool for learning abstract ideas.

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INTRODUCTION

Jean Piaget, the renowned developmental psychologist, was a master at observing the routine behaviors children produce as they learn about the world. Here, I examine a routine behavior that Piaget overlooked—the spontaneous gestures we all produce as we talk. These gestures are not mere hand waving. They reflect ideas, often ideas that we do not express in speech. But gesture does more than reflect ideas—it also changes them. Gesture could bring about change because it is an action of the body and thus naturally introduces embodied action into our mental representations (see Oudeyer, What do we learn about development from baby robots?, *WIREs Cogn Sci*, also in the collection How We Develop). I provide evidence for this hypothesis but suggest that it is not the whole story. Gesture is a special kind of action—it is representational and thus more abstract than direct action on objects, which may be why gesture helps us learn.

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GESTURES ARE MORE THAN JUST EMOTIONAL EXPRESSIONS

A student waves her arm wildly when the teacher asks a question. Another tries hard not to make eye contact with the teacher. Both are using their bodies to tell the teacher whether they want to answer the question. These body movements constitute what is typically called 'nonverbal communication.' Many things fall within the realm of nonverbal communication—the home and work environments we create, the distance we establish between ourselves and our listeners, whether we move our bodies, make eye contact, or raise our voices—all of these behaviors collaborate to send messages about us.[1] But these messages, although important in framing a conversation, are not the conversation itself. The student's extended arm or averted gaze does not constitute the answer to the teacher's question—each reflects the student's attitude toward answering the question.

According to Michael Argyle,[2] a social psychologist at the University of Oxford, nonverbal behavior expresses emotion, conveys interpersonal attitudes, presents one's personality, and helps manage turn-taking, feedback, and attention (see also Wundt[3]). Argyle's characterization fits most peoples' intuitions about nonverbal communication. Omitted from Argyle's list, however, is a role for nonverbal behavior in conveying the message itself—it plays a role only in conveying the speaker's attitude toward the message or in regulating the interaction between speaker and listener.

This is the traditional (and intuitive) view. Communication is divided into content-filled verbal and affect-filled nonverbal components. Adam Kendon[4] was among the first to challenge this view. He argued that one form of nonverbal behavior—gesture—cannot be separated from the content of the conversation. David McNeill's groundbreaking studies of gesture and speech followed in 1992,[5] and established that the hand movements we produce when we talk are tightly intertwined with that talk in timing, meaning, and function. To ignore the information conveyed in these hand movements, these gestures, is to ignore part of the conversation.

A variety of behaviors count as gestures. In 1969, Ekman and Friesen[6] made a comprehensive list of them—emotional displays on the face (e.g., a smile or furrowed brow); self-adaptors maintained by habit (e.g., pushing glasses up the nose even when they are perfectly positioned); regulators maintaining the give-and-take between speaker and listener (e.g., head movements or slight changes in body position); culturally specific emblems (e.g., the *thumbs up*); hand movements directly tied to speech that often illustrate the speech (e.g., talking about going upstairs and, at the same time, bouncing the hand upward). This last category, the illustrators, can mark the tempo of speech (a gesture that beats time), point out referents of speech (a pointing gesture), or exploit imagery to elaborate the contents of speech (a circling movement of the hand that could either represent rolling down a hill, an iconic gesture, or time passing, a metaphoric gesture).

My focus here is on illustrators—on deictic, iconic, and metaphoric gestures. Because they are produced along with speech, illustrators are part of an intentional act but, unlike emblems like the *thumbs up*, they rarely come under conscious control. The meaning of an illustrator gesture is constructed in an *ad hoc* fashion in the context of the speech it accompanies. In the earlier example, the bouncing-upward gesture refers to taking the stairs. If that same gesture were produced along with the sentence, 'his salary increases every year,' it would refer instead to yearly incremental increases. Emblems, in contrast, have the same meaning no matter what the speech (they can even be produced without speech)—*thumbs up* means 'things are good' in all contexts. And emblems are held to standards of form. Imagine making the *thumbs up* emblem with the pinky, rather than the thumb—it doesn't work. But making the bouncing-upward gesture with a pointing hand, a flat palm, or even an O-shaped hand appears just fine.

It is precisely because gestures participate in communication, yet are not part of a codified system, that they are of interest to us—they are free to take on forms that speech cannot assume or, for a novice who has not yet mastered a task, forms that the novice cannot yet articulate in speech. Gesture can reflect our unfettered thoughts.

GESTURE OFFERS A WINDOW ONTO OUR THOUGHTS

How do we know that gesture reflects our thoughts? Consider two children who are shown two rows of checkers. The children are first asked to verify that the two rows have the same number of checkers, and are then asked whether the rows still have the same number after one row is spread out. Both children say 'no,' displaying a misunderstanding of what Piaget called conservation of number. Both justify their response by focusing on the fact that the checkers were moved, saying for example, 'They're different because you moved them.'

But the two children differ in the gestures they produce along with their speech. One child spreads her hands out (Figure 1), mimicking the movement that was used to spread the checkers out—she is conveying essentially the same information in gesture and in speech. The other child (Figure 2) moves her 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—she is demonstrating an understanding of one-to-one correspondence, a central concept underlying the conservation of number and one that she does not express in speech (see examples at https://goldin-meadow-lab.uchicago.edu/page/video-gallery#).

Importantly, the two children also differ in how likely they are to profit from a lesson in conservation. The child whose gestures convey different

FIGURE 1 | A nonconserver producing gestures that match her speech. The child says, 'They're different because you spreaded them apart,' while producing a gesture that mimics the experimenter's movements.

FIGURE 2 | A nonconserver producing gestures that do not match her speech. The child says, 'They're different because you moved them,' while indicating in gesture the one-to-one correspondence between the checkers in the two rows.

information from speech (Figure 2) is more likely to learn from the lesson than the child whose gesture conveys the same information as speech[7] (Figure 1). In general, when explaining a task, learners who produce gestures that convey information *not* found in their speech are more likely to benefit from instruction in that task than learners whose gestures convey the same information as their speech—whether the learners are children[8,9] or adults.[10] We know that it isn't gesturing *per se* that signals who the learners will be—both children illustrated in the figures produced gestures. It is the information conveyed in gesture, taken in relation to the information conveyed in the accompanying speech, that tells us who is ready to learn, thus confirming that gesture is a window onto our thoughts.

SEEING THE GESTURES OTHERS PRODUCE CAN CHANGE OUR THOUGHTS

Gesture not only reflects our thoughts—it can play a role in changing those thoughts. We know that gesture can convey substantive information so it's not hard to imagine that we could learn from seeing the gestures that other people produce. But to be certain, we need to manipulate gesture and explore the impact of that manipulation on learning. We can, for example, present a videotape of someone teaching the same lesson twice, once with gesture and once without it. It turns out that learners are more likely to profit from the lesson that contains gesture than the lesson that is gesture-free.[11]

Surprisingly, gesture is particularly helpful in a lesson when it conveys information that *differs* from the information conveyed in speech. When students are given a correct strategy for solving a math problem in gesture, accompanied by a different (and also correct) strategy for solving the problem in speech, they end up being better at solving the problem than when they are given the same two strategies entirely in speech.[12] Having information displayed across two modalities appears to be good for learning.

But gesture is not always a force for good. Take the following exchange that took place when a teacher taught a child mathematical equivalence with respect to addition. The teacher 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 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. The teacher's gestures were misleading. The take-home message is that gesture is powerful, perhaps even more powerful than speech simply because it's under the radar.

Take eyewitness testimony as a second example. The details that a witness reports can be shaped by the way the interviewer poses the question. 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 in the scene as does a targeted question that explicitly draws attention to a hat.[13] An observed gesture can affect how we think about things.

PRODUCING OUR OWN GESTURES CAN CHANGE OUR THOUGHTS

To determine whether the gestures that speakers themselves produce affect their own thinking and learning, we once again need to manipulate gesture and explore the impact of that manipulation.

We can, for example, tell a child during a math lesson to produce movements that instantiate a strategy for correctly solving a mathematical equivalence problem, 2+4+9=__+9. The child produces a V-hand under the 2 and 4 (Figure 3) and points at the blank, *grouping* the two unique numbers on the left side of the equation and putting their sum in the blank. She is asked to produce these movements and also say, 'I want to make one side equal to the other side,' before and after each problem that she attempts to solve. Such a child will learn more than a child told to say the words and produce no movements. We thus know that moving and speaking promotes learning more effectively than does speaking alone.

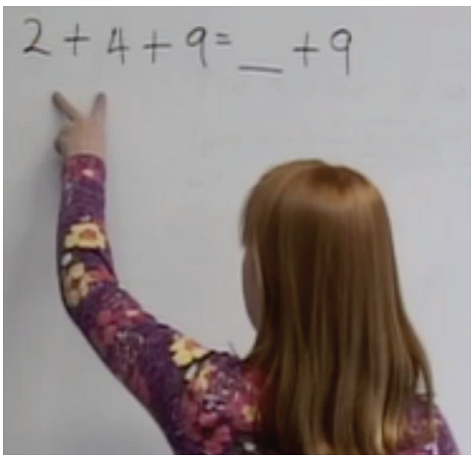

FIGURE 3 | A child taught to produce a fully correct grouping strategy in gesture. The child says, 'I want to make one side equal to the other side,' while producing a V-point under the 2 and 4, the two numbers that can be grouped and summed to give the correct answer; after producing the V-point, the child points at the blank.

To show that it is the *particular* movements children make that matter, we tell another child to produce the V under the 4 and 9 (Figure 4), thus encouraging a partially correct strategy (the V-handshape instantiates *grouping* but of the wrong two numbers), while saying the same words. This child learns less than the child told to use a fully correct strategy in her hands, but more than a child told to produce the words with no hand movements at all.[14] Interestingly, after the lesson when the children are again asked to solve the problems and explain their solutions, the children who produced the *grouping* strategy in gesture during the lesson not only solved the postlesson problems correctly, but also produced grouping for the first time in their spoken explanations. These children were not exposed to grouping during the lesson, as the teacher produced it in neither speech nor gesture (nor did the children produce grouping in speech). The children were able to extract meaning from their own movements.

But if we have to invent gestures for each concept that needs to be taught, it will be difficult to scale gesture up so that it can be used as a general teaching tool. Instead, we could just tell students to gesture, giving them no explicit instruction as to how to move their hands. If we follow this path and tell children to gesture when they explain how they solved a math problem, we find that these children produce new strategies in gesture—and those strategies tend, for the most part, to be correct. When later given instruction, the children profit from that instruction and are more likely to solve the math problems correctly than children who are told not to gesture.[15] Therefore, being told to gesture encourages children to express ideas that they have not yet expressed, which, in turn, leads to learning. Gesturing can affect how we take in new information.

HOW DOES GESTURE CHANGE OUR MINDS?

Gesturing might promote learning because it is a physical action, or because it uses physical action to represent abstract ideas. To distinguish between these two possibilities, we can use magnetic numbers on a board (Figure 5). In particular, we can concretize the grouping strategy by instructing children to pick up the two unique numbers on the left side of the

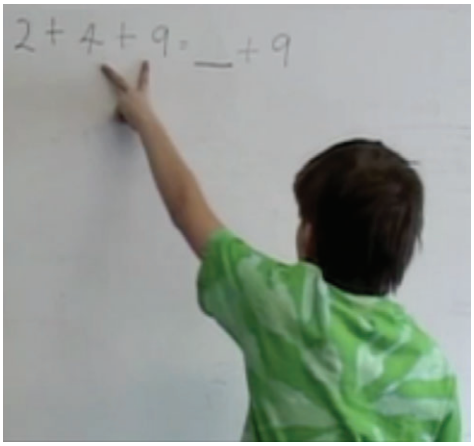

FIGURE 4 | A child taught to produce a partially correct grouping strategy in gesture. The child says, 'I want to make one side equal to the other side,' while producing a V-point under the 4 and 9, two numbers that should *not* be grouped and summed; after producing the V-point, the child points at the blank. The gesture is partially correct in that the V-handshape instantiates grouping and is followed by the point at the blank, which highlights the fact that the equation has two sides.

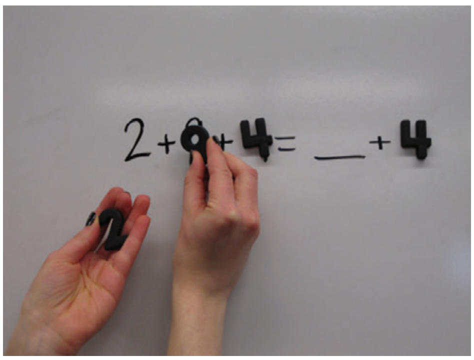

FIGURE 5 | Actions children were taught to produce during a math lesson. Children were instructed to pick up the first two plastic numbers and then hold them under the blank. (Reprinted with permission from Ref 16 Copyright 2014 SAGE Publications)

equation (2 and 9 in 2+9+4=__+4) and hold the numbers under the blank—a physical instantiation of the *grouping* strategy. If we compare how these children do after the lesson to children told only to produce the *grouping* strategy in gesture (Figure 6), we find that both types of hand movements help children solve problems like those on which they were trained. But producing the grouping gesture (as in Figure 6) during a lesson leads to further success on problems that require generalizing the knowledge gained (e.g., 2+9+4=__+6); acting on the relevant numbers (as in Figure 5) does not lead to generalization.[16]

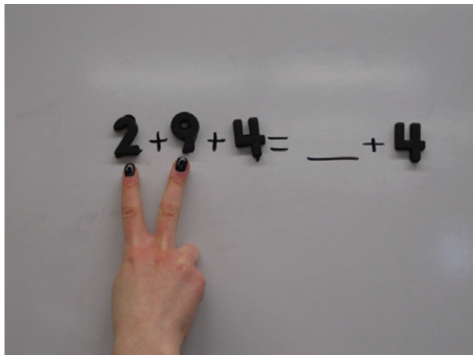

FIGURE 6 | Gestures children were taught to produce during a math lesson. Children were instructed to produce a V-point under the first two plastic numbers and then point at the blank. (Reprinted with permission from Ref 16 Copyright 2014 SAGE Publications)

Therefore, gesture promotes transfer of knowledge better than action, suggesting that the beneficial effects of gesture on learning may reside in the features that differentiate it from action.

HARNESSING GESTURE IN THE CLASSROOM

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

Second, learners can be encouraged to gesture when they explain a problem. The gestures learners produce are likely to display their evolving 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, being encouraged to gesture about a problem may help students to activate whatever implicit ideas they have about that problem. This activation, in turn, may make them more open to further instruction. Encouraging particular types of gestures can even introduce new ideas into the student's repertoire.

CONCLUSION

Speakers gesture in all cultures and at all ages; even congenitally blind individuals who have never seen anyone gesture move their hands when they talk.[17]

Gesturing is thus a robust part of speaking and is decidedly not mindless hand waving. It not only reflects thought but also has the potential to change thought in listeners and in speakers. Gesture is a tool that learners, teachers, and researchers alike can use to make new discoveries about the mind.

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