Talking and Thinking With Our Hands

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ABSTRACT—*When people talk, they gesture. Typically, gesture is produced along with speech and forms a fully integrated system with that speech. However, under unusual circumstances, gesture can be produced on its own, without speech. In these instances, gesture must take over the full burden of communication usually shared by the two modalities. What happens to gesture in this very different context? One possibility is that there are no differences in the forms gesture takes with speech and without it—that gesture is gesture no matter what its function. But that is not what we find. When gesture is produced on its own and assumes the full burden of communication, it takes on a language-like form. In contrast, when gesture is produced in conjunction with speech and shares the burden of communication with that speech, it takes on an unsegmented, imagistic form, often conveying information not found in speech. As such, gesture sheds light on how people think and can even play a role in changing those thoughts. Gesture can thus be part of language or it can itself be language, altering its form to fit its function.*

KEYWORDS—*gesture; sign language; cognitive load; communication; instruction*

Imagine a deaf child whose hearing losses prevent him from acquiring spoken language and whose hearing parents have chosen not to expose him to a signed language. The child is, in effect, deprived of a model for language. We might expect such a child to be unable to communicate. But we would be wrong. Children in such circumstances do communicate: They gesture. For example, when shown a picture of a shovel, one such deaf child produced iconic gestures for *dig*, *snow-falls*, and *pull-on-boots* and pointed outside and downstairs, thus conveying several propositions about snow shovels—how they are used (to dig), when they are used (when it snows and boots are worn), where they are used (outside), and where they are kept (downstairs). For this child, the burden of communication has fallen on gesture and his gestures have risen to the occasion, assuming not only the function of language but also many of its formal features, such as segmentation (producing separate gestures to represent objects and the relations among them), combination (combining those gestures in a structured manner), and recursion (producing more than one proposition within a single gesture sentence; Goldin-Meadow, 2003a).

The gestures that deaf children produce in place of speech stand in sharp contrast to the gestures that hearing speakers produce along with speech. Gestures that accompany speech share the burden of communication with that speech and, interestingly, do not assume a language-like form (McNeill, 1992). These gestures are picture-like in form and rarely combine with one another to create sentence-like gesture strings. Nevertheless, gestures produced with speech are not mere hand-waving. They convey substantive information in their own right and may offer unique insight into a speaker's unspoken thoughts (Goldin-Meadow, 2003b).

My goal in this article is to explore gestures of both types: gestures that turn into language and reveal the basic capacity we have for structured communication, and gestures that work alongside language and shed light on how we think.

WHEN GESTURE BECOMES LANGUAGE

The Resilient Properties of Language

When deaf children are exposed to sign language from birth, they learn that language as naturally as hearing children learn spoken language. However, 90% of deaf children are not born to deaf parents who could provide early access to sign language. Instead, they are born to hearing parents who often choose to expose their children solely to speech. Unfortunately, it is uncommon for deaf children with profound hearing losses to acquire spoken language, even with specialized instruction.

My colleagues and I have studied 10 profoundly deaf children in the United States and 4 in Taiwan. The children's hearing parents had decided to educate them in oral schools where sign

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TABLE 1
The Resilient Properties of Language as Manifested in the Gesture Systems of Deaf Children

Language property	In deaf children's gesture
Words	
Stability	Gesture forms are stable and do not change capriciously with changing situations.
Paradigms	Gestures consist of smaller parts that can be recombined to produce new gestures with different meanings.
Categories	The parts of gestures are composed of a limited set of forms, each associated with a particular meaning.
Arbitrariness	The relation between gesture form and meaning, although essentially transparent (i.e., it is easy to guess the meaning from the form), has arbitrary aspects.
Grammatical functions	Gestures are differentiated by the noun, verb, and adjective grammatical functions they serve.
Sentences	
Underlying frames	Frames organized around the act predicate underlie gesture sentences.
Deletion	Consistent production and deletion of gestures within a sentence mark particular thematic roles.
Word order	Consistent orderings of gestures within a sentence mark particular thematic roles.
Inflections	Consistent inflections on gestures mark particular thematic roles.
Recursion	Complex gesture sentences are created by recursion.
Redundancy reduction	Gestures are produced for redundant semantic elements in complex sentences less often than for nonredundant semantic elements.
Language use	
Here-and-now talk	Gesturing is used to make requests, comments, and queries about the present.
Displaced talk	Gesturing is used to communicate about past, future, and hypothetical events.
Narrative	Gesturing is used to tell stories about self and others.
Self-talk	Gesturing is used to communicate with oneself.
Generic statements	Gesturing is used to make generic statements, particularly about animate objects.
Meta-language	Gesturing is used to refer to one's own and others' gestures.

language was neither taught nor encouraged. The children had made little progress in oral language and, in addition, had not been exposed to sign language. The children thus knew neither sign nor speech.

Nevertheless, these children spontaneously used gestures to communicate. What is particularly surprising is that the children's gestures displayed many of the structural properties of natural language. We have called the linguistic properties that the deaf children introduced into their gesture systems *resilient* properties of language (Table 1). The example at the beginning of this article illustrates two such properties: recursion (the child has expressed several propositions, each dealing with snow shovels, within a single gesture sentence) and displaced communication (the child has described events that are not taking place in the here and now).

Gesture In, Language Out

The deaf children in our studies were not exposed to sign language. They were, however, exposed to the gestures that their hearing parents produced as they spoke. These gestures could have served as input to the children's gesture systems. To explore this possibility, we looked at the gestures that the hearing mothers produced when talking to their deaf children. However, we looked at them not as they were meant to be experienced (i.e., with speech), but as a deaf child would look at them: We turned off the sound and analyzed the mothers' gestures using the same analytic tools that we used to describe the children's gestures. We found that the hearing mothers' gestures did not have language-like structure (e.g., Goldin-Meadow & Mylander, 1998). Thus, the children received as input speech-accompanying gestures that were not language-like in form, but produced as output gestures that resembled language.

Why didn't the resilient properties of language appear in the hearing mothers' gestures? The mothers wanted their deaf children to learn to talk and, as a result, always spoke as they gestured. We hypothesized that the mothers' gestures (like the gestures of all hearing speakers; Kendon, 1980; McNeill, 1992) were integrated with the words they accompanied and thus were not free to assume the language-like properties found in their children's gestures. This hypothesis leads to the following prediction: Adults' gestures should look more like those of the deaf children if they are produced without talking. We tested this prediction experimentally.

Turning Gesturers Into Signers

We asked English-speakers who had no experience with sign language to describe videotaped scenes using their hands and not their mouths. We then compared the resulting gestures to gestures these same adults produced when asked to describe the scenes using speech (Goldin-Meadow, McNeill, & Singleton, 1996). When using gesture with speech, the adults rarely combined gestures into strings, and when they did, those gestures were not consistently ordered (Fig. 1A). In contrast, when using gesture on its own, the adults often combined gestures into

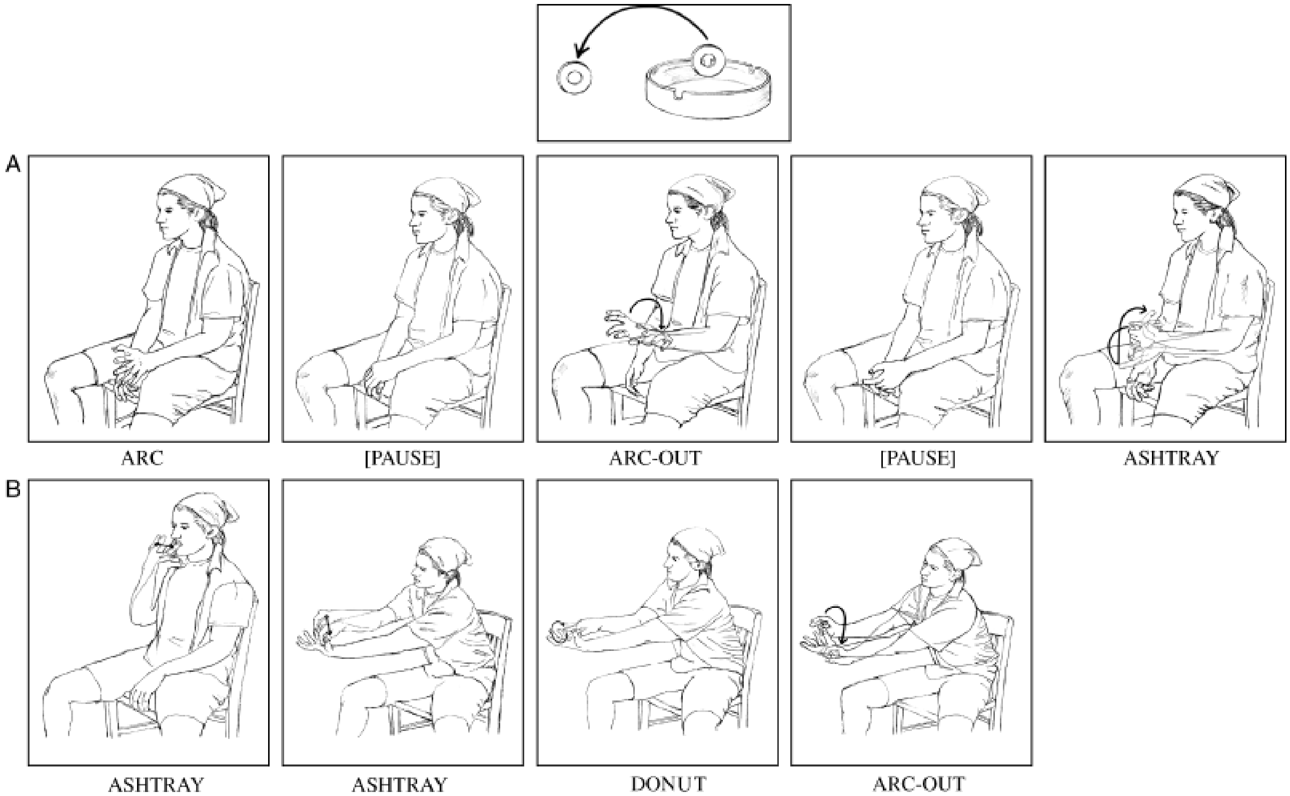

Fig. 1. Examples of the gestures adults produce with and without speech. The top picture displays the event the adult is describing—a donut-shaped object arcing out of an ashtray. The middle row of pictures displays the gestures the adult produces when asked to describe this event in speech. Note that, although he produces several gestures, those gestures are separated by pauses (he relaxes his hands in his lap) and thus do not form a single gesture string. In addition, the hand shapes he uses are loosely formed and sloppy. The bottom row of pictures displays the gestures the adult produces when asked to describe the event using only his hands and no words. He now produces a string of gestures without breaking his flow of movement, and his hand shapes become crisp and clearly articulated. In addition, his gestures adhere to a consistent order: stationary object (ashtray) → moving object (donut) → action (arc-out). Reprinted from *Hearing Gesture: How Our Hands Help Us Think*, by Susan Goldin-Meadow, 2003, Harvard University Press, pp. 234–235. Copyright 2003 by Harvard University Press. Reprinted with permission.

strings characterized by order and, interestingly, this order did not follow canonical English word order (Fig. 1B).

To summarize thus far: When gesture is called upon to fulfill all of the communicative functions of speech, it takes on the properties of segmentation and combination characteristic of speech. This transformation happens in deaf children not exposed to a linguistic model and also in hearing adults asked on the spot to communicate only with their hands. The appearance of these properties is particularly striking given that they are not found in the gestures that speakers routinely produce when they talk.

WHEN GESTURE ACCOMPANIES LANGUAGE

Gesture Can Tell Us What Is on a Speaker's Mind (Even If She Doesn't Say It)

Speech conveys meaning discretely, relying on codified words and grammatical devices. Gesture that accompanies speech conveys meaning holistically, relying on visual and mimetic imagery. Because gesture and speech employ such different forms of representation, the two modalities rarely contribute identical information to a message.

Nonetheless, the information conveyed in gesture and speech can overlap to a greater or lesser degree. For example, consider a hearing child asked first whether two identical rows of checkers have the same number, and then whether the number of checkers in one of the rows changes after the checkers are spread out. The child says that the number of checkers is the same at the beginning but different after the checkers are moved. When asked to explain this answer, the child mentions the movements the experimenter made when spreading the checkers apart in her speech and gesture: She says "It's different because you moved them" while producing a "spreading out" motion with her hands. The child thus conveys a justification in gesture that overlaps a great deal with the justification in speech; she has produced a gesture–speech match.

Now consider another child who gives the same explanation as the first child in speech, but conveys different information in gesture: He moves a pointing finger from the first checker in row 1 to the first checker in row 2 and then does the same with the

TABLE 2

Examples of Matching and Mismatching Gestures on Mathematical Equivalence Problems

Math problem	Speech	Matching gesture	Mismatching gesture
(a) $7 + 6 + 4 = \_\_ + 4$	"I added the 7, 6, and 4 and got 17" (add-to-equal-sign)	Point at 7, 6, left 4, and the blank (add-to-equal-sign)	Point at 7, 6, left 4, right 4, and the blank (add-all-numbers)
(b) $3 + 5 + 2 = 3 + \_\_$	"I added the 3, 5, 2, and 3 and got 13" (add-all-numbers)	Point at left 3, 5, 2, right 3, and the blank (add-all-numbers)	V-shaped hand placed under the 5 and 2, point at blank (group-and-add-two-numbers)
(c) $6 + 3 + 4 = \_\_ + 4$	"I made both sides of the problem equal" (equalize-two-sides)	Sweep under the left side of the equation; sweep under the right side of the equation (equalize-two-sides)	Point at 6, 3, left 4, flick-away movement near the right 4 (add-numbers-on-left-then-subtract-number-on-right)

Note. Both of the strategies illustrated in problem (a) lead to an incorrect solution; the mismatching response thus contains two incorrect strategies. In contrast, in problem (b), the strategy conveyed in the mismatching gesture leads to a correct solution, whereas the strategy conveyed in speech and the matching gesture leads to an incorrect solution; the mismatching response thus contains a correct strategy (in gesture) and an incorrect strategy (in speech). In problem (c), both strategies lead to correct solutions; the mismatching response thus contains two correct strategies.

second checkers in each row. This child focused on the experimenter's actions in speech, but on the one-to-one correspondence between the checkers in the two rows in his gestures; he has produced a gesture–speech mismatch. The child expressed an idea in his gestures that could not be found in his speech.

Children who produce gesture–speech mismatches on a task may have information relevant to solving the task literally at their fingertips and could, as a result, be on the cusp of learning how to solve that task. If so, they ought to be particularly receptive to instruction—and indeed they are. We asked children to solve a task and explain how they did it; none of the children solved the problem correctly. During their explanations, some of the children produced gestures conveying the same information as their speech (matchers). Other children produced gestures conveying different information from their speech (mismatchers). We then gave all of the children instruction in the task, and found that children who were mismatchers prior to instruction were more likely to profit from that instruction than children who were matchers (Goldin-Meadow, 2003b; see also Pine, Lufkin, & Messer, 2004). Interestingly, the mismatchers benefited from instruction even if both their gestures and their speech conveyed incorrect information (e.g., Table 2, problem a).

The gestures that children produce as they explain a task reflect their knowledge of the task (see Goldin-Meadow, 1997). But current work suggests that gesture does more: It can play a role in changing knowledge.

Our Gestures Can Change How Others React to Us

Gesture has the potential to function as a mechanism of change through its communicative effects: (a) Speakers reveal information about their cognitive status through their gestures; (b) listeners may pay attention to those gestures and alter their input accordingly; (c) speakers could then profit from this altered input. We have just reviewed evidence for the first step in this process. The evidence for the second and third steps comes from math tutorials involving teachers and individual children.

Teachers spontaneously give children who produce mismatches on a task different instruction on that task than they give children who produce only matches (Goldin-Meadow & Singer, 2003). For example, teachers use more mismatches of their own (see example in Table 2, problem c) when teaching mismatchers than they do when teaching matchers—and mismatchers learn faster than matchers do.

But do mismatchers learn faster because of the different instruction they receive or because they are ready to learn? To find out, we experimentally manipulated children's instruction. Following a script, an experimenter taught children a correct strategy for solving a math problem in speech and gave some children the same correct (matching) strategy in gesture, some a correct but different (mismatching) strategy in gesture, and some no gesture at all (see Table 2, problem c). Children who were taught with mismatching gestures were more successful after instruction than were children taught with matching gestures or no gestures (Singer & Goldin-Meadow, 2005).

A conversation in gesture thus appears to be taking place alongside the conversation in speech whenever speakers use their hands. Children's gestures reveal their cognitive state to their listeners who, in turn, provide instruction in gesture that promotes learning. Learners use their hands to change their learning environments.

Our Gestures Can Change How We Think

Gesture also has the potential to function as a mechanism of change through its internal cognitive effects. When faced with a difficult problem to solve, people find it helpful to externalize their thoughts—for example, writing a problem down, thereby freeing cognitive resources that can then be used to solve the problem. Can gesture, like writing, improve learning by influencing learners directly?

Children imitate the gestures that a teacher produces. Moreover, children who produce these gestures are more likely to succeed after instruction than are children who do not (Cook &

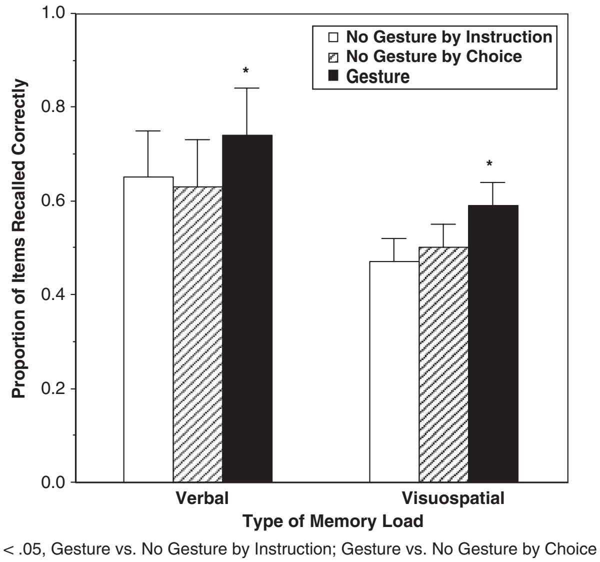

Fig. 2. Proportion of verbal and visuospatial items that adults recalled while explaining how they solved a math problem. Adults remembered more items of both types when they spontaneously gestured during their explanations than when they did not gesture—either when they were instructed not to gesture or when they spontaneously chose not to gesture. Gesturing thus frees up cognitive resources that can then be used on either a verbal or visuospatial task. Adapted from Wagner, Nusbaum, and Goldin-Meadow (2004, Fig. 3).

Goldin-Meadow, in press). Thus gesturing during instruction might be effective because it encourages children to produce gestures of their own, which, in turn, leads to learning. Learners use their hands to change their minds.

But how? It may be that gesturing lightens cognitive load. Adults and children were asked to explain how they solved a math problem while at the same time remembering a list of words or letters. Both groups remembered more items when they gestured during their math explanations than they did when they did not gesture (Goldin-Meadow, 2003b). Gesturing appears to save speakers cognitive resources on the explanation task, permitting them to allocate more resources elsewhere—in this case, to a memory task.

But gesture might not be lightening the speaker's load. It might be merely shifting the load from a verbal memory store to a visuospatial memory store. The idea here is that gesturing allows speakers to convey in gesture information that might otherwise have gone into a verbal store. Lightening the burden on the verbal store should make it easier to do a verbal task that is performed simultaneously. If, however, the burden has really been shifted to a visuospatial store, it should be harder to perform a spatial task (such as recalling the location of dots on a grid) when simultaneously gesturing than when not gesturing. But we have found that gesturing continues to lighten the speaker's load even if the second task is a spatial one (Fig. 2; Wagner, Nusbaum, & Goldin-Meadow, 2004).

Perhaps gesturing lightens a speaker's load because it is a motor activity that energizes the memory system (Butterworth & Hadar, 1989). If that were the case, the type of gesture produced should not matter; it should only matter *that* a speaker gestures, not *what* the speaker gestures. But the number of items that speakers remember does depend on the meaning conveyed by gesture. Speakers remember more items when their gestures convey the same information as their speech (i.e., one piece of information about the problem) than when their gestures convey different information (two pieces of information; Wagner et al., 2004). Gesture's content thus determines demands on working memory, suggesting that gesture confers its benefits, at least in part, through its representational properties.

WHERE TO NEXT?

Gesture is chameleon-like in form, and that form is tied to function. When gesture assumes the full burden of communication, acting on its own without speech, it takes on language-like form (as in the deaf children described earlier and the hearing adult in Fig. 1B). But when gesture shares with speech the burden of communication, it loses its language- structure and assumes instead a holistic form (as in all hearing speakers, including the deaf children's hearing mothers and the adult in Fig. 1A). Although not language-like in structure, gesture that accompanies speech is not just handwaving. It conveys information imagistically and, as such, accesses different information than speech does. Gesture thus lets speakers convey thoughts they do not have words for and may even play a role in changing those thoughts. But many questions remain.

First, the left hemisphere is specialized for processing linguistic information, be it spoken or signed. Do the gestures hearing speakers produce with speech show left-hemisphere dominance? We do not know the answer yet, but it is likely to be *no*, as these gestures do not exhibit the hierarchically segmented structures found in speech and sign. Do the language-like gestures deaf children of hearing parents use instead of speech show left-hemisphere dominance? Again we do not know, but the answer is likely to be *yes*, as these homemade gesture systems, if truly linguistic, ought to be processed like natural language.

Second, do adults and children differ in how they use gesture with speech and without it? Although adults can introduce many linguistic properties into gesture when asked to use it without speech, their gestures lack certain properties found in the deaf children's gestures (Singleton, Morford, & Goldin-Meadow, 1993). In contrast, adults and children seem to use gesture with speech in the same ways. But do these gestures serve the same functions for adults and children?

Finally, how does cultural variation affect gesture produced with speech and without it? American and Chinese deaf children invent gesture systems with many similarities despite differences in their hearing parents' gestures. What about deaf children in other cultures (e.g., in Nicaragua, where deaf children were brought together in a group for the first time in 1980, allowing gesture creation to take place within a social community; Senghas & Coppola, 2001)? And does gesture produced with speech play the same role in thinking for hearing speakers around the globe?

Gesture offers insight into the basic capacity we have for structured communication when produced without speech and into how we think when produced with speech. The time is ripe to take advantage of our hands.

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Acknowledgments—This research was supported by grants from the National Institute on Deafness and Other Communication Disorders (R01 DC00491) and the National Institute of Child Health and Human Development (R01 HD47450).

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