CHAPTER 12

GESTURE

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Human communicators move. Heads tilt, eyebrows raise, hands wave, fingers point, bodies lean, faces contort, and all synchronize with vibration of vocal chords and the opening and closing of the mouth. You might say that human communication is a triumphant study in multimodality. However, what is the point of all of this movement? Is it purposeful? Is it communicative? Is it part of language? The communicative utility of *extralinguistic* features of language (communicative elements not governed by the linguistic rules of the language) has been acknowledged for thousands of years (see Kendon, 2004), but researchers are finally coming to a better understanding of the ways in which the body is an integral part of both language and thought.

WHAT IS GESTURE?

In this chapter, we focus on manual gesture and its relationship to both spoken and signed languages. We aim to illustrate what gesture is, but also what it is not, addressing both the scope and limitations of gesture as a communicative medium. We begin by defining gesture and the ways in which it is different from signed languages. We discuss the range of meanings that gesture can communicate and the way in which gesture integrates with linguistic structures. We ask what happens when gesture becomes the dominant communicative medium, and we explore what is unique about gesture when it is compared to other nonverbal forms of human communication and to the manual communication of other species. We end by discussing gesture's relationship to cognition, and we raise the question of whether gesture is really for communicating at all.

Gesture Is Not Sign Language

Sign languages (like gesture) are produced in the manual modality, but (unlike gesture) sign languages display the same underlying structural features as spoken languages (Klima & Bellugi, 1979; Sandler & Lillo-Martin, 2006). Signed languages are fully structured languages with phonological (e.g., Stokoe, 1960), morphological (e.g., Klima & Bellugi, 1979), and syntactic (e.g., Liddell, 1980) rules. Some signs iconically represent things in the world (meaning that the form of the sign is related to the physical features of the gesture's referent). For example, the sign for "bird" in American Sign Language is made by pinching the thumb and forefinger together in front of the mouth like a bird's beak. However, many signs have no iconic elements whatsoever. Moreover, iconicity does not appear to play a central role in guiding young children's acquisition of sign language (Bonvillian, Orlansky, & Novack, 1983; but see R. L. Thompson, Vinson, Woll, & Vigliocco, 2012). When signs do have iconic elements, they are not holistic iconic representations of entire events, and there are linguistic rules that constrain the form of the signs; for example, rules that determine whether events that co-occur in the world can be expressed simultaneously within a single sign. Although it would be easy enough to indicate the manner of motion in a sign describing a skate boarder moving in a circle, to be grammatically correct, the American Sign Language signer

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must produce separate, serially linked signs, one for the manner (illustrating how the foot works the board) and one for the path (illustrating the circling movement; Supalla, 1990). Sign languages thus do not always take advantage of the iconic potential that the manual modality offers.

This separation of manner and path illustrates one aspect of the *compositionality* of sign language (i.e., it is structured and assembled on multiple levels). Each sign language has several layers of structure—rules governing the use of signs (morphological structure), the use of subsign elements (phonological structure), and the assembly of signs into sentences (syntactic structure). It is important to note that although these levels of structure are shared across all signed and spoken languages, each sign language follows its own particular rules about the signs, elements, and combinations that are permissible in that language.

Sign languages do not depend on the verbal languages spoken in their communities (e.g., British Sign Language and American Sign Language are different languages), but they do differ from country to country or from region to region in the same way spoken languages do. Many countries have standardized national sign languages, whereas others have regional languages shared by the deaf individuals in a local community. Just as with spoken languages, different sign languages are not mutually intelligible (Klima & Bellugi, 1979).

Gesture shares a *modality* with signed languages; they are both produced manually rather than vocally. However, gesture lacks the regular structures and rules that are central to language. Unlike sign language, gesture does not exhibit combinatorial properties and lacks syntactic rules. This lack of structure may restrict gesture's communicative potential, but it does provide greater freedom for individual variation.

Gesture Involves the Hands

Gesture is typically considered to be movement of the hands and arms, but other parts of the body may sometimes be used (e.g., shrugging the shoulders to express uncertainty or nodding the head in affirmation). Sometimes the whole body can be used to illustrate an action or event (e.g., when explaining an unusual walk or touchdown dance), but these whole-body gestures are not typical (see Chapter 15, this handbook). The head and shoulders are also often involved in gesture (e.g., head tilts can be used to mark perspective shift during narrative speech; McClave, 2000).

What Counts as Gesture?

In 1969, Ekman and Friesen attempted to identify and categorize the kinds of nonverbal behavior produced during spontaneous communication. They identified five categories (*affect displays*, *regulators*, *adaptors*, *emblems*, and *illustrators*) that are still used to frame the field of nonverbal communication today. These categories are differentiated by form, function, and communicative intent. They have been further refined by McNeill (1992) and are also described in Chapter 19 of this handbook.

According to Ekman and Friesen's (1969) classification, affect displays convey internal emotional states (e.g., frowning suddenly or walking with a bounce in your step). Regulators maintain the give-and-take between speakers during a spoken conversation (e.g., leaning in to indicate a desire to speak or raising the chin toward another person to cede the floor to him or her). Adaptors (also called *self-adaptors*) are routinized movements directed toward one's own body that have been maintained by habit and are not produced with intent to communicate (e.g., retucking hair behind one's ear even when it is already there). The last two categories—emblems and illustrators—are what people typically visualize when they think of gesture.

Emblems are gestures that have shared conventional meanings. They are frequently called *conventional* gestures (Cartmill, Demir, & Goldin-Meadow, 2012; McNeill, 1992, 2005). These gestures are culturally specific and come with expectations about how they should look and when they should be used. Variation from these learned forms and uses makes a gesture difficult to understand in much the same way that variation in the pronunciation or use of a word would lead to misunderstanding. It would be difficult, for example, to interpret an "OK" sign if only the pinky finger were extended, or a "thumbs up" if the other fingers were not curled into the palm or if the thumb pointed to the side rather than up.

Emblems, more than other types of gestures, are like words or sentences in that they have specific, shared meanings and, as just noted, can be produced incorrectly. Speakers use them consciously to communicate particular concepts, and they can be produced either with or without accompanying speech. For example, in the United States it would be perfectly acceptable for a speaker to respond to a yes/no question with a horizontal shake of the head instead of the word "no." However, emblems are mainly culturally distinct. For example, in Bulgaria, where the gesture for "no" is a vertical "head toss," shaking the head horizontally would not convey the desired meaning (Kita, 2009; McClave, Kim, Tamer, & Mileff, 2007). However, some emblematic forms are shared across cultures within particular regions of the world, and a few emblems appear to be similar across multiple regions (Matsumoto & Hwang, 2013). The standards of form that are applied to emblems make them comparable to words and signs. However, unlike words or signs, emblems are not assembled into sequences. Each emblem has a specific, learned meaning (e.g., "OK," "great," "bye-bye," "I don't know," "wait"), but emblems are not combined with one another according to structural rules.

Illustrators are movements that are produced alongside speech and often illustrate the concepts conveyed in speech. As such, they are referred to as *cospeech gestures* (this is the term we adopt here) or, sometimes, just gestures (McNeill, 1992). This broad category of gestures includes most of what is studied by gesture researchers and is the main focus of our chapter. From this point on, we use the general term *gesture* to refer to the category of "communicative" acts that includes both illustrators and emblems. We use the term cospeech gesture to refer to illustrators only.

Cospeech gestures differ from emblems in that (as their name suggests) they are produced along with speech, and their meanings depend on that speech. Emblems can convey their meanings in the absence of speech (at least to others who have learned the same gesture; e.g., holding up a finger to tell someone to wait for a moment while saying nothing). In contrast, the meaning of a cospeech gesture relies heavily on the spoken contexts in which it is produced. Someone might illustrate the phrase "all the beads hit the floor and scattered" by moving both hands slightly out to one side while wiggling their fingers as if playing the piano. If the same gesture were accompanied by the sentence "I need to respond to that e-mail," it would be interpreted as typing. In other contexts, the same movement might represent playing the piano or a rainstorm.

Because cospeech gestures are produced in the context of spoken communication, they are, in this sense, deliberate (unlike adaptors). However, people are not typically aware of the specific movements they make when producing cospeech gestures (i.e., illustrators), and thus these gestures are rarely under conscious control. This combination of being produced unconsciously but within a consciously produced communicative act sets cospeech gesture apart from other forms of nonverbal behavior and makes it a powerful tool with which to ask questions about the mind and intent of the gesturer. Gesture can add information to speech by illustrating features of objects (such as size or shape) or properties of events (such as speed or path) that are not explicitly conveyed in speech. Taking gesture into account when looking at language provides a more complete understanding of the reasoning and intent of the speaker. In this way, cospeech gesture can be said to provide a "window on the mind" (Goldin-Meadow, 2003a; McNeill, 1992).

Types of Cospeech Gesture

Cospeech gesture can be further categorized according to the presence of iconic, deictic, or emphatic elements (McNeill, 1992). These categories are defined by the ways they convey meaning: Some employ imagery to represent the world, either iconically or metaphorically; others convey meaning by directing attention to things in the environment or rhythmically highlighting parts of the accompanying speech.

Iconic gestures convey meaning by recreating an aspect of their referent's shape or movement. These gestures represent physical objects or events by mimicking an aspect of the shape, size, or movement of the object or event. The hand can represent a hand performing an action (e.g., a cupped hand pushing an imaginary toy train along a curved track), but it can also represent an object or entity directly (e.g., a flat hand moving in a curved line to represent the same train). The hand can also take on a neutral handshape and serve only as a "tracer" in space, tracing the outline of an object or the path of an action (e.g., an extended index finger drawing a curved line in the air to show the path of the train). Figures 12.1A–12.1D provide further examples of these different handshapes.

Metaphoric gestures represent abstract ideas or concepts, but by illustrating the concepts with a gesture, the concept is given physical characteristics (see Figure 12.1E). The speech accompanying these gestures may already contain a metaphor, or the gesture may add a metaphoric element to the speech. For example, a person might produce a lifting gesture with the sentence, "I need to *raise* my grade in that class," or with the sentence, "I need to *improve* my grade in that class." In the first case, the gesture is illustrating a metaphor present in speech; in the second case, the gesture is adding the metaphoric element by mapping the

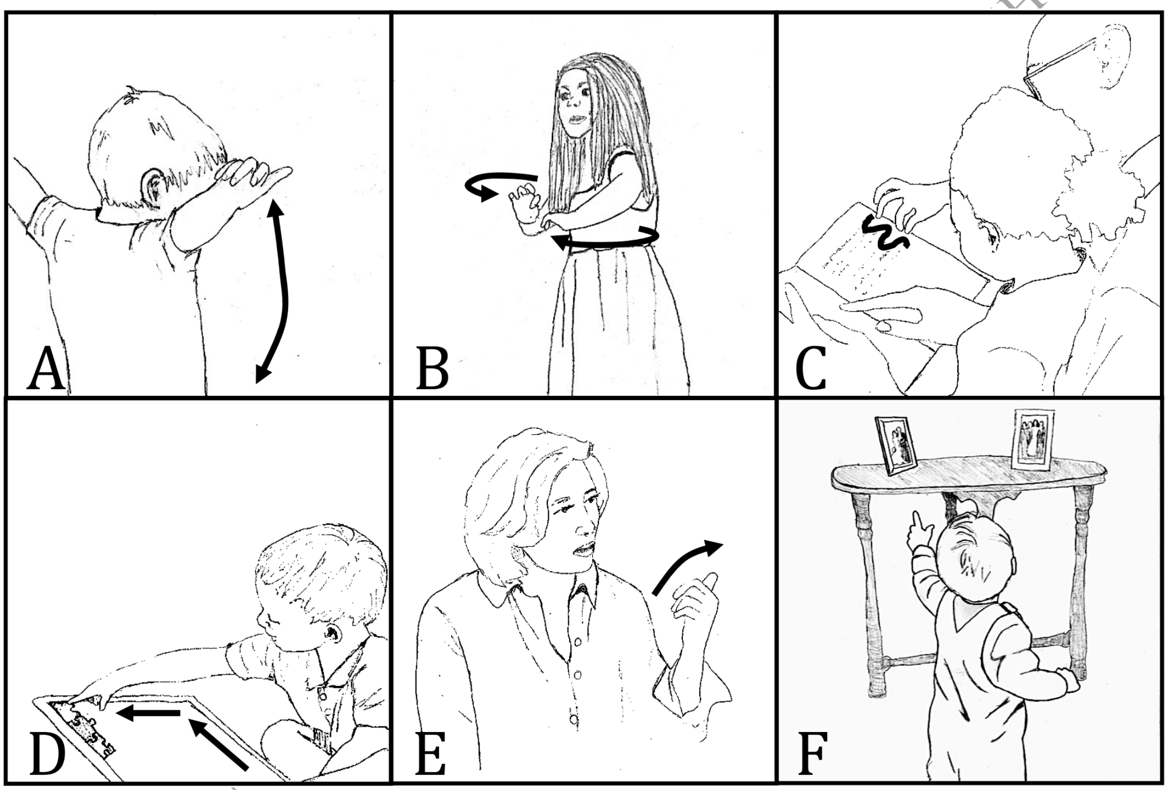

FIGURE 12.1. Examples of different types of cospeech gestures and different handshapes. Figure 12.1A shows a 38-month-old boy depicting a bat flying through an iconic gesture. His arms are outstretched, and he flaps them up and down as wings; his hand (and arm) represents a hand (and arm) acting in the world. Figure 12.1B shows a 50-month-old girl producing an iconic gesture to depict a towel by gesturing as if she were holding a towel and wrapping it around her body. Her hands represent hands acting on an invisible object (the towel). Figure 12.1C shows a 22-month-old girl producing an iconic gesture of a spider; she holds her fingers downward and wiggles them and, thus, uses her hand to represent another object (in this case, the spider). Figure 12.1D shows a 38-month-old boy gesturing to the uncompleted edges of a puzzle; he uses his finger to trace along the bottom and right edges of the puzzle frame, producing an iconic gesture in which his hand serves as a pointer or tracer, outlining the space that the puzzle will fill. Figure 12.1E shows an adult woman producing a metaphoric gesture while being interviewed about her acting career. She gestures outward with her thumb while describing a project that someone wrote "years ago." The gesture is metaphoric because it attributes physical spatial features to the concept of time, situating the past event to the left of her body. Figure 12.1F shows a 14-month-old boy producing a deictic gesture by pointing to a framed picture on top of a table.

more abstract word "improve" to the act of physically lifting.

Deictic or indexical gestures direct attention toward objects, people, events, or locations in the surrounding environment (see Figure 12.1F). Pointing with the index finger is the paradigmatic deictic gesture, but deictic gestures may be made with other handshapes (e.g., a flat hand with the palm up or to the side) or with other body parts (e.g., pointing with the chin by lifting it in the desired direction; Wilkins, 2003). Holding up or touching objects to draw attention to them may also be considered deictic gestures. The direction of the point gives some indication as to its meaning, but, without accompanying speech, it is often difficult to discern the precise meaning of the point. This phenomenon can be seen when observing young infants pointing. Sometimes parents can infer the meaning immediately, but other times it will take many attempts to guess the thing that the child has in mind.

Beat gestures are rhythmic movements of the hands or head that correspond to, and serve to highlight, the prosody of speech (Ekman & Friesen, 1969, referred to these gestures as rhythmic gestures). Beat gestures do not have imagistic or indexical meaning, but they can segment and emphasize elements in speech by moving during certain words. For example, a person listing off a number of items or events might "beat" the air rhythmically by bringing the hand sharply downward with each element in the list: "We need to get *bread* (beat), *apples* (beat), and *carrots* (beat), and then we should go get *cheese* (beat)." You see many of these gestures when people are giving speeches (try looking for them in politicians). They emphasize the speech they accompany, sort of like a gestural highlighter.

These categories are useful in conceptualizing the range of cospeech gestures, but they should not be thought of as mutually exclusive. A gesture may easily fall into more than one category. For example, a person giving directions might trace the shape of a bridge over a road (an iconic gesture) and also produce the gesture in the direction of the bridge's location (adding a deictic element). Gestures can be extremely complex, and understanding the meaning of a gesture requires more than simply observing the shape of its movement.

Understanding the meaning of a gesture can require shared knowledge of conventions (in the case of emblems) or the significance of objects in the environment (in the case of deictic gestures). However, most importantly, understanding a gesture's meaning requires understanding the speech that accompanies the gesture and identifying the relationship between gesture and speech.

Gesture Relates to Speech

Speech and gesture are intimately entwined. More than 90% of all gestures occur in the presence of speech (McNeill, 1992). This close relationship between gesture and speech emerges early in life and is strengthened as children learn language. In adults, the gesture–speech relationship is characterized by both *temporal* and *semantic* integration (further discussed in the How Does Gesture Fit Into a Linguistic System? section).

The temporal relationship between gesture and speech is highly synchronous, and the alignment of the two modalities can be seen by looking at the moments of greatest intensity in both speech and gesture. The movement phase of a speaker's gesture co-occurs with the point of peak prosodic emphasis in the accompanying clause in speech (Kendon, 1980; McClave, 1998). Importantly, it is not the case that people synchronize speech with any manual movement: Gestures show greater synchrony with accompanying speech than manual actions do (Church, Kelly, & Holcombe, 2014).

The semantic relationship between gesture and speech can be defined by the degree to which gesture conveys information that is not found in speech. On one end of the spectrum, gesture can *complement* the information in speech (essentially duplicating the information in speech). On the other end, gesture can *supplement* the information in speech, conveying information that is not found anywhere in that speech. Often, the relationship between speech and gesture falls somewhere in between, with gesture echoing the information found in speech but providing some additional details (e.g., about the size, shape, or location of an object). This dual function is particularly clear when gesture is used to *disambiguate* a referent in speech—for example, when a point is produced along with "that one" or "put it there." Without the gesture, both of these utterances would be underspecified, providing insufficient information in speech to be understood without some other clues to meaning. Figure 12.2 illustrates gestures that have a complementary, supplementary, or disambiguating relation to speech. The categories are more fully described next.

Gesture can complement information in speech by reinforcing size, shape, movement, path, or location information conveyed in speech. The degree of specificity in speech and overlap in meaning between speech and gesture can vary. For example, the utterance "there was a huge bird" could be accompanied by flapping hands like a bird's wings (reinforcing the meaning "bird"). However, the same flapping gesture could incorporate the meaning "huge" by making the flapping motion larger and using the whole arm (thus reinforcing the meaning of both "huge" and "bird").

Gesture can supplement information in speech by adding information about size, shape, movement, path, or location that is not expressed in speech. For example, a child might request help in opening a jar by pointing to it and saying "open." By taking into account both the spoken word (specifying the requested action, opening) and the gesture (indicating the item to be opened), a complete imperative can be seen, "open jar." Supplementary relationships between gesture and speech can indicate transitional periods in the acquisition of language or learning. This type of gesture–speech relationship is particularly revealing in the language of young children who are not yet combining words into sentences. A child is very likely to produce his or her first sentence-like meaning entirely in speech ("open jar") several months after he or she produces his or her first sentence-like meaning in gesture plus speech (point at jar + "open"; Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005). By observing children's gesture–speech combinations, it is possible to predict linguistic achievements before they emerge entirely in speech. We discuss this developmental phenomenon more extensively in the How Does Gesture Fit Into a Linguistic System? section.

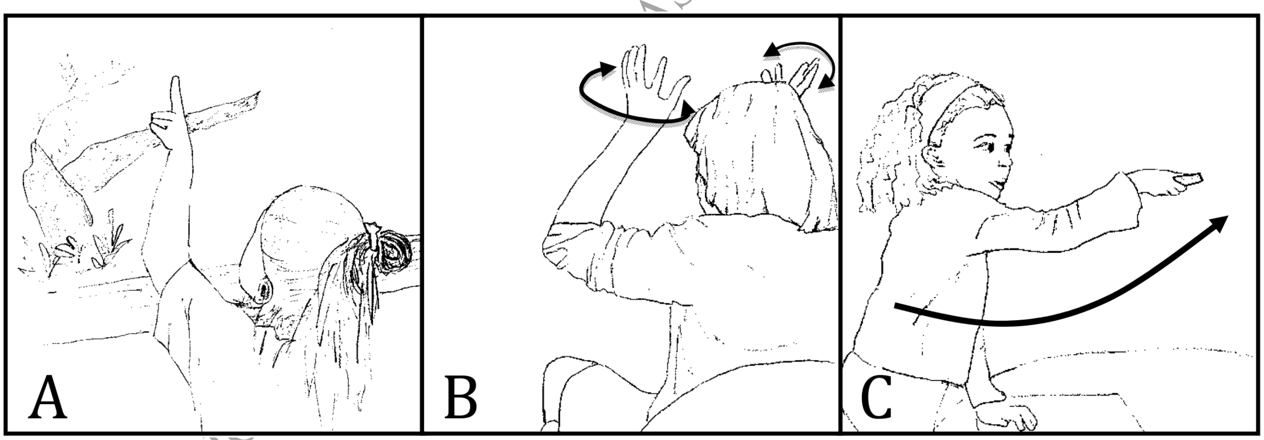

FIGURE 12.2. Examples of the three different types of gesture–speech relationships: complementary, supplementary, and disambiguating. Figure 12.2A shows a 50-month-old girl pointing to fish in a fish tank. She says "It's a guppy." Her gesture indicates the same thing (the fish) that she is naming in speech, and thus her gesture complements the speech it accompanies. Figure 12.2B shows a mother using an iconic gesture to describe the lights on a fire truck to her 14-month-old infant. She rotates her hands while saying "The fire truck goes woo woo woo woo." She identifies the noise that the fire truck makes in speech ("woo woo"), but the gesture provides information about the lights on top of the truck flashing. This information appears nowhere in speech, and thus her gesture supplements the speech it accompanies. Figure 12.2C shows a 46-month-old girl producing an iconic gesture in which she conveys the path traveled by an animal in a story. She is holding a marker, and although her handshape does not convey any information about the animal, the movement of her gesture represents the trajectory of the action she describes. She says "he went over there and over there" while sweeping her arm back and forth across her body. The terms "here" and "there" are ambiguous when conveyed in speech alone. Her gesture thus disambiguates her speech by clarifying which directions the character traveled.

Gesture can disambiguate information in speech by specifying the referent of an underspecified speech act. For example, the sentences, "I'll have two of those," "It was right there," and "It went like this," are ambiguous without an accompanying gesture. Adding a deictic or iconic gesture makes these sentences highly informative. Deictic words in speech (here, there, this, that) are, in fact, frequently accompanied by gesture. Even young children make use of gesture to disambiguate their speech, and children speaking a language that permits a great deal of ambiguity (e.g., Turkish, which allows more omission than English) use gesture to fully specify their utterances (Demir, So, Özyürek, & Goldin-Meadow, 2012). Gesture can thus give children learning structurally different languages a way to achieve comparable levels of specification while adhering to the referential expressions dictated by their language.

These categorical distinctions are useful in conceptualizing the range of relationships that gesture can hold to speech, but attributing a gesture–speech relationship to a particular communicative act can be problematic. This difficulty arises because a gesture can complement or disambiguate speech while at the same time adding information that is not expressed in speech. In the huge bird example, the gesture is adding information about the action of the bird. However, it is not clear from the sentence in isolation whether the bird was flying. The gesture could simply be referencing a bird by means of the stereotypical action associated with the animal. It gets even more complicated if we allow for the possibility that the movement indicates something about the flying style of the bird (say, fast shallow wing beats vs. long, slow ones). A speaker may not vary this information intentionally but might nevertheless gesture differently to depict a flamingo and a buzzard.

There are times when the information conveyed in gesture contradicts the information conveyed in speech, for example, pointing to the left while saying, "then you take a right." These are true errors, and they are rare. Errors of this sort should not be confused with what has come to be called *gesture–speech mismatches* (Church & Goldin-Meadow, 1986; Goldin-Meadow, 2003a). The gesture in a gesture–speech mismatch conveys different information from the information conveyed in speech, but that information can (in principle) be integrated with the information in speech, although the speaker may not yet have integrated the information. For example, consider a child learning about mathematical equivalence who is asked to solve the problem, $5 + 9 + 3 = \_\_ + 3$, and to explain her answer. After putting 17 in the blank (an incorrect answer), the child explains that to get the answer she "added the five, the nine, and the three" (an add-to-equal-sign strategy in speech); at the same time, she points to the 5, the 9, and the 3 on the left and to the 3 on the right of the blank (an add-all-numbers strategy in gesture). Note that to solve the problem correctly, the child must recognize that the equal sign breaks the equation into parts (reflected in her speech) and that there is an additional number on the right side of the equation (reflected in her gestures). The child in this example does not yet appear to have fully integrated these two pieces of information, but her gestures, taken in conjunction with her speech, suggest that she is aware of both pieces (Alibali & Goldin-Meadow, 1993). Producing gesture–speech mismatches of this sort indicates that the learner is in a transitional period with respect to a concept and, if given instruction in the concept, is likely to make significant progress (Goldin-Meadow & Alibali, 2013).

WHAT KINDS OF INFORMATION CAN BE COMMUNICATED THROUGH GESTURE?

Gesture can be used to communicate a wide range of meanings, but those meanings rely heavily on the surrounding linguistic, social, and physical contexts. The meaning of a gesture, particularly cospeech gesture, is often not transparent without speech. If you were to watch a video of person speaking and gesturing with the sound turned off, you are not likely to guess the person's message (Krauss, Morrel-Samuels, & Colasante, 1991; emblems are, of course, an exception because, by definition, they can be interpreted without speech). Even seemingly transparent gestures, such as pointing, require a close inspection of the accompanying speech to be correctly interpreted.

Indexing the Environment (Deictic Gestures)

Deictic gestures index the environment by directing the attention of others. However, this process is not always as straightforward as it seems. Deictic gesture may refer to whole objects in the immediate environment (e.g., “Can you hand me that?” used with a point to a glass). However, these gestures can also refer to parts, features, or properties of objects (e.g., pointing to the same glass while saying “It’s a little dirty,” or “I think we need a new washer”). In all these cases, the gesture is indexing an object present in the immediate environment, but the specific meaning of the gesture is made clear by the accompanying speech.

Surprisingly, deictic gestures can also be used to refer to objects that are not present, either by pointing out their absence or by referring to an object that has a salient relationship to a nonpresent object. For example, while pointing to the glass, a person can say, “Would you get me some more please?” In this case, the gesture does not refer to the glass itself, but to the absence of the liquid inside it. Similarly, at a party, someone might point to the glass of a friend who is out of the room and ask, “Does anyone know where she went?” In this case, the glass is serving as an anchor for a particular person because it is associated with that person; the point to the glass is referencing the absent individual. Points at a present object to refer to a nonpresent object can also be found in young children (Liszkowski, Schäfer, Carpenter, & Tomasello, 2009; see also Butcher, Mylander, & Goldin-Meadow, 1991). For example, a child can point to a chair and say “daddy.” If daddy is present, the gesture–speech combination could be a request for daddy to sit in the chair. If, however, daddy is not there, then the combination could be a statement that it is “daddy’s chair.”

Referencing Shared Meanings (Emblems)

In that same way that a word or idiomatic expression requires both speaker and listener to have preexisting knowledge of the expression, emblems rely on a shared understanding of the relationship between form and meaning. Because they require prior knowledge of meaning, emblems function like a code and can refer to an essentially unlimited range of concepts. For example, emblems can refer to concepts that correspond to single words (e.g., nodding to indicate “yes”) or to entire phrases (e.g., shrugging the shoulders to indicate “I don’t know”). Emblems can bear an iconic relationship to the things they symbolize (e.g., holding the palm against the cheek and tilting the head to refer to sleeping), but they more often have an *arbitrary* relationship (e.g., scraping one index finger against the other to scold someone).

Emblems vary between cultures in both form and meaning (e.g., Americans cross their index and middle finger as an emblem of good luck, whereas Germans make a fist and tuck their thumb under their index finger). Though emblems are typically shared broadly within a culture, emblems may be established in smaller groups (e.g., a baseball coach developing a code to signal plays to the pitcher). They may even emerge in particular families. Just as families may invent unique words shared only within the family (e.g., by adopting a young child’s mispronunciation of a word as a slang term), so may they develop local customs in their emblems.

Depicting Objects, Actions, and Events (Iconic Gestures)

Iconic gestures capture an aspect of the objects or actions they represent. For example, a speaker uses two flat hands, palms facing each other, to indicate the width of a container while saying, “It’s not very wide,” or moves his hand across a table wiggling his fingers while saying, “He crawled over.” Iconic gestures also reveal information about the perspective speakers take vis-à-vis the event they are describing and can be produced from two different perspectives: (a) In character viewpoint gestures, the gesture portrays an event from the character’s point of view (e.g., pumping the arms as though running to describe a character who is moving quickly; moving a closed-hand away from the torso to describe a character giving something away) and (b) in observer viewpoint gestures, the gesture portrays the event from the observer’s point of view (e.g., moving the two fingers of an upside-down V-hand back and forth representing the moving legs of a character in a running event; moving an index finger up to represent the ascent of the character in a climbing event).

Depicting Abstract Thoughts (Metaphoric Gestures)

Metaphoric gestures are defined by their relationship to speech. They can have exactly the same forms as iconic gestures, but they are considered metaphoric because they refer to things that do not have physical features. In principle, any abstract concept may be depicted in gesture; it just needs to activate a visuo-spatial schema (such as height, weight, containment, or forward movement). Even highly abstract concepts, such as "justice" or "truth," can be illustrated in gesture by tying them to images of balance or containment. However, without the accompanying speech, there would be no way to differentiate a metaphoric gesture from an iconic gesture.

HOW DOES GESTURE FIT INTO A LINGUISTIC SYSTEM?

In the sections that follow, we describe the ways in which gesture is an integral part of the human linguistic system by drawing on evidence from studies of gesture production, gesture comprehension, and gesture's role during language development. We also consider what happens when gesture is the dominant communicative medium (e.g., in profoundly deaf children who are not exposed to a sign language, or during communication games in which hearing participants are not allowed to speak).

Gesture Is an Integral Part of Language

Gesture is not a supplemental or secondary system applied on top of speech. Rather, gesture and speech together form an *integrated* linguistic system. Gesture is part of the planning process of language, and this deep integration reveals itself in the alignment of both semantic and temporal features between gesture and speech. Evidence from behavioral, neurological, and developmental studies provides support for the view that language is an integrated, multimodal system.

Integration of gesture and speech during language production. Gesture is linked to spoken language at every level of analysis. For example, at the phonological level, producing hand gestures influences the voice spectra of the accompanying speech for deictic gestures (Chieffi, Secchi, & Gentilucci, 2009), emblems (Barbieri, Buonocore, Volta, & Gentilucci, 2009; Bernardis & Gentilucci, 2006), and beat gestures (Krahmer & Swerts, 2007). When phonological production breaks down, as in stuttering or aphasia, gesture production stops as well (Mayberry & Jaques, 2000; McNeill, Levy, & Pedelty, 1990). The simultaneous disruption of gesture during an arrest of speech provides further evidence for the tight temporal synchrony between gesture and speech.

At the lexical level, gesture can both reflect and compensate for gaps in a speaker's verbal lexicon. For example, when speakers of English, Japanese, and Turkish are asked to describe a scene in which an animated figure swings on a rope, English speakers overwhelmingly use the verb "swing" along with an arced gesture (Kita & Özyürek, 2003). In contrast, Japanese and Turkish speakers, who speak languages that do not have single verbs that express an arced trajectory, use generic motion verbs along with the comparable gesture, that is, a straight gesture (Kita & Özyürek, 2003). However, gesture can also compensate for gaps in the speaker's lexicon by conveying information that is not encoded in the accompanying speech. For example, complex shapes that are difficult to describe in speech can be conveyed in gesture (Emmorey & Casey, 2001).

At the syntactic level, gestures are influenced by the structural properties of the accompanying speech. For example, English expresses manner and path within the same clause, whereas Turkish expresses the two in separate clauses. The gestures that accompany manner and path constructions in these two languages display a parallel structure—English speakers produce a single gesture combining manner and path (a rolling movement produced while moving the hand forward), whereas Turkish speakers produce two separate gestures (a rolling movement produced in place, followed by a moving forward movement; Kita & Özyürek, 2003; Kita et al., 2007).

Integration of gesture and speech during language comprehension. Listeners glean information from both gesture and speech and seamlessly integrate the two pieces of information. One strong piece of evidence that listeners are truly integrating information across modalities and not perceiving speech and gesture separately comes from experimental work showing that people will report in their speech information that was conveyed only in gesture (Cassell, McNeill, & McCullough, 1999). For example, a person is told a story in which the narrator says, “She whacks him one,” while producing a punching gesture. When retelling the story, the person says, “She punches Sylvester,” integrating information conveyed only in gesture into the spoken account (see also Goldin-Meadow, Kim, & Singer, 1999; Goldin-Meadow & Singer, 2003). Being able to integrate information across gesture and speech is a skill found early in development, even in one-word speakers (Morford & Goldin-Meadow, 1997).

Gesture can help listeners understand speech by providing information that complements or elaborates on that in speech. Listeners are more likely to correctly perceive and recall information conveyed in speech when it is accompanied by gesture that complements the meanings in speech than when it is accompanied by no gesture (Beattie & Shovelton, 1999, 2000; Graham & Argyle, 1975; McNeil, Alibali, & Evans, 2000; L. A. Thompson & Massaro, 1994). However, if the information conveyed in gesture conflicts with the information conveyed in speech, listeners may have greater difficulty processing the speech (Kelly, Özyürek, & Maris, 2010). When faced with information in gesture that differs from the information in speech, listeners are less likely to understand the information in speech than if there is no gesture at all (Goldin-Meadow & Sandhofer, 1999; Kelly & Church, 1998; McNeil et al., 2000). This decrement in the perception of speech when gesture provides different information provides further evidence that gesture and speech form an integrated system. It further suggests that this integration is automatic. If gesture–speech integration was under voluntary control, listeners could choose to ignore gesture and focus solely on speech. However, experimental evidence suggests that they cannot ignore gesture, even when explicitly instructed to do so (Kelly et al., 2010; Langton, O’Malley, & Bruce, 1996).

The semantic integration between gesture and speech can be seen on a neurological level. Gesture affects the neural processing of language in that speech receives a different response when it is perceived with or without gesture. This effect has been found using both event-related potentials (Kelly, Kravitz, & Hopkins, 2004) and functional magnetic resonance imaging designs (Dick, Goldin-Meadow, Hasson, Skipper, & Small, 2009). Importantly, these processing differences are not explained by the mere presence or absence of movement during speech comprehension. Noncommunicative actions (such as scratching one’s chin) do not elicit the same pattern of activation as semantically meaningful gestures (Dick et al., 2009). One study found that gestures and actions accompanying speech are processed differently in Broca’s area; gestures showed a pattern more consistent with semantic processing, and actions showed a pattern more consistent with mirror system activation (Skipper, Goldin-Meadow, Nusbaum, & Small, 2007).

Furthermore, the specific *relationship* between gesture and speech, rather than the presence of gesture itself, is visible in the neural processing of language. Using an event-related potential design, Kelly et al. (2004) found that video stimuli in which gestures and speech conveyed *contradictory* information (gesturing “short” while saying “tall”) produced a large negativity at 400 ms after stimulus presentation (the so-called N400 effect indicating semantic distance between linguistic items). Interestingly, gestures conveying information that is different from, but integratable with, information conveyed in speech (gesturing “thin” while saying “tall” to describe a tall, thin container; i.e., a gesture–speech mismatch) are processed no differently at this stage from gestures that convey the same information as speech (gesturing “tall” while saying “tall”; i.e., a gesture–speech match). Neither one produces a large negativity at 400 ms; that is, neither one is recognized as a semantic anomaly (Kelly et al., 2004). It is important to note, however, that at early stages of sensory/phonological processing (P1–N1 and P2), speech accompanied by a mismatching gesture (e.g., gesturing “thin” while saying “tall”) is processed differently from speech accompanied by a matching gesture (gesturing “tall” while saying “tall”).

Thus, information conveyed in gesture that is different from, but has the potential to be integrated with, information conveyed in speech is noted at early stages of processing but not at later higher level stages. Neurological studies of gesture are still in their infancy, but further work in this area holds great promise for untangling the precise relationship between gesture and speech in perceiving and interpreting meaning in language.

Integration Emerges During Typical Language Development

Gesture plays a particularly important role during early language development. Children begin to gesture before they can talk, and during the early years of language development, gesture provides children with a means of supplementing and modifying their spoken language. By using gestures when they cannot yet produce words, and by combining words and gestures when their spoken repertoires are limited, children increase their communicative potential and extend beyond the proficiency of their speech.

Onset of gesture–speech integration. Children typically begin to gesture between 8 and 12 months of age (Bates, 1976; Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). These early gestures are mainly deictic points and hold-ups (holding up an object to draw attention to it). Deictic gestures are grounded in the physical environment because they have meaning only by directing others' attention to objects, events, or locations. However, just like adults, young children can use deictic gestures to refer to absent objects (Butcher et al., 1991; Liszkowski et al., 2009). Along with points and hold-ups, very young children begin to use the conventional gestures (emblems) that are common to their culture (Guidetti, 2002). These include gestures such as side-to-side head shakes used to indicate "no," and hands at shoulder height with palms facing up used to indicate "I don't know." Iconic gestures are rare in 1-year-old children, but they do occur, and children differ in how frequently they produce them (Acredolo & Goodwyn, 1988). Beat and metaphoric gestures, however, do not appear until much later in development (McNeill, 1992).

Once children begin to communicate in gesture, they begin the process of integrating their visual and vocal channels. During the period when children are using gesture but have not yet acquired spoken words, children frequently combine their gestures with nonword vocalizations (Iverson & Thelen, 1999). However, once children acquire their first spoken words, they do not immediately combine those words with gesture. In the earliest stages of speech, children produce either gesture or speech alone—rarely combining the two (Butcher & Goldin-Meadow, 2000).

During the one-word period (where children are using single words but not yet combining those words into sentences), the relationship between gesture and speech changes (Goldin-Meadow, 2006). At the beginning of this period, children are using more gestures than words and are not habitually combining words with gestures. On the rare occasions when children of this age do combine a word—or more likely, a meaningless vocalization—with a gesture, the two are not temporally synchronized in an adult-like manner (i.e., the word or vocalization is not aligned with the *stroke* or peak of the gesture). However, there comes a critical point in this one-word period where children begin to combine words with gestures in earnest and to synchronize their production of gesture and speech in those combinations (Butcher & Goldin-Meadow, 2000). These features—semantic integration and temporal synchrony—characterize the relationship between gesture and speech in adults (McNeill, 1992).

The onset of gesture–speech combinations heralds a new phase in children's linguistic development and dramatically expands the scope of children's communicative systems. Children's early gesture–speech combinations are *complementary* in that they reference the same object or event in both modalities (e.g., point to shoe + "shoe"; Capirci, Iverson, Pizzuto, & Volterra, 1996; de Laguna, 1927; Greenfield & Smith, 1976; Leopold, 1949). Children's gestures can also add information by conveying an idea that is found nowhere in speech (e.g., point to shoe + "gimme"). These additive or *supplementary* combinations emerge only after (or at the same time as) complementary combinations

(Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005). Supplementary combinations thus do not appear until after gesture and speech have become temporally synchronized (Goldin-Meadow & Butcher, 2003). The fact that supplementary gesture–speech combinations (combinations in which gesture and speech convey different, but potentially integratable, information) do not appear until after gesture and speech achieve temporal and semantic integration provides further evidence that gesture and speech are part of a single, integrated system, rather than two separate communicative systems.

Gesture precedes and predicts structures in speech. Throughout early language development, linguistic phenomena tend to appear in gesture before they emerge in speech. The deictic gestures and emblems that children produce before they can speak are relatively simple, but they mark the onset of children's linguistic development. Points and hold-ups, in particular, indicate a growing desire to communicate about things and presage the acquisition of verbal labels for objects. At this early stage of language development (when children are learning their first words and building a vocabulary), the number of different meanings children communicate in their gestures predicts the total number of spoken words they will acquire in the next few years (Rowe & Goldin-Meadow, 2009a). Indeed, the gestures children produce in the early stages of language learning have reliably been found to foreshadow subsequent vocabulary development (Bavin et al., 2008; Goodwyn & Acredolo, 1993; Rowe & Goldin-Meadow, 2009a, 2009b; Rowe, Özçalişkan, & Goldin-Meadow, 2008). For example, a child's early deictic gestures reliably predict which nouns are likely to enter that child's spoken vocabulary in the next 3 months (Iverson & Goldin-Meadow, 2005).

New linguistic constructions are also foreshadowed in gesture. By combining a gesture with a word, children are able to convey two different ideas within a single communicative act (e.g., pointing at a cup while saying "gimme"). Importantly, the age when a child first produces these supplementary gesture–speech combinations predicts the age when that child will produce his or her first two-word utterance (e.g., "gimme cup"; Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005). Gesture continues to forecast children's verbal milestones beyond the transition from one-word to two-word speech. For example, children produce their first complex sentence containing two predicates in gesture and speech (e.g., "I like it," said while producing an "eat" gesture) several months before producing their first complex sentence entirely in speech ("I like eating it"; Özçalişkan & Goldin-Meadow, 2005).

What Happens When Gesture Becomes the Dominant Linguistic System?

We have seen that gesture assumes a holistic form when it is used along with speech. However, what happens when gesture is called upon to replace speech and thus fulfill all of the functions typically served by speech?

Homesign and emerging sign languages. We know that the manual modality can assume linguistic properties—as described earlier, sign languages of the deaf are segmented and combinatorial in form (Klima & Bellugi, 1979; Sandler & Lillo-Martin, 2006), as are spoken languages. However, what would happen if a child was not exposed to a conventional sign language and had only gesture with which to communicate?

Deaf children born to deaf parents learn their parents' sign language as naturally as hearing children learn spoken language from their hearing parents (Newport & Meier, 1985). However, most deaf children are born, not to deaf parents, but to hearing parents who do not know a sign language and want their child to learn to speak. Unfortunately, most children with profound hearing losses are unable to learn the spoken language that surrounds them, even with hearing aids and intensive instruction. In addition, they frequently do not have access to a sign language model. Despite their lack of an accessible model for language, deaf children under these circumstances communicate with the hearing people in their worlds and use gestures, called *homesign*, to do so.

Homesign is characterized by many, although not all, of the properties found in natural languages

(Goldin-Meadow, 2003b). For example, homesigners' gestures form a lexicon, and these lexical items are composed of parts, comparable in structure to a morphological system (Goldin-Meadow, Mylander, & Butcher, 1995; Goldin-Meadow, Mylander, & Franklin, 2007). Moreover, the lexical items combine to form structured sentences, comparable in structure to a syntactic system (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow & Mylander, 1984, 1998). In addition, homesigners use gestural lexical markers that modulate the meanings of their gesture sentences (negation and questions; Franklin, Giannakidou, & Goldin-Meadow, 2011) and grammatical categories (nouns, verbs, and adjectives; Goldin-Meadow, Butcher, Mylander, & Dodge, 1994). Homesigners display hierarchical structure in their sentences by building structure around the nominal constituent (Hunsicker & Goldin-Meadow, 2012) or by adding a second proposition to create a complex sentence (Goldin-Meadow, 1982). Finally, homesigners use their gestures not only to make requests of others but also to comment on the present and nonpresent (Butcher et al., 1991; Morford & Goldin-Meadow, 1997), to make generic statements about classes of objects (Goldin-Meadow, Gelman, & Mylander, 2005), to tell stories about real and imagined events (Morford & Goldin-Meadow, 1997; Van Deusen-Phillips, Goldin-Meadow, & Miller, 2001), to talk to themselves (Goldin-Meadow, 2003b), and to talk about language (Goldin-Meadow, 1993)—that is, to serve the typical functions that all languages serve, signed or spoken.

In countries such as the United States, child homesigners are likely to learn a conventional sign language at some later point in their lives, often around adolescence. However, in other countries (Nicaragua is a good example), many homesigners are never integrated into the deaf community and continue to use their gesture systems with the hearing people who surround them as their sole means of communication. Analyses of adult homesigners in Nicaragua have uncovered linguistic structures that may (or may not) turn out to go beyond the structures found in child homesigners: the grammatical category subject (Coppola & Newport, 2005), pointing devices representing locations versus nominals (Coppola & Senghas, 2010), morphophonological finger complexity patterns (Brentari, Coppola, Mazzoni, & Goldin-Meadow, 2012), and morphological devices that mark number (Coppola, Spaepen, & Goldin-Meadow, 2013). By contrasting the linguistic systems constructed by child and adult homesigners, the impact that cognitive and social maturity has on language can be seen.

We can also examine gesture as it continues on the path toward becoming a fully established language. In the late 1970s, deaf individuals in Nicaragua (who were likely to have been homesigners) came together for the first time and began to fashion a shared communication system, which has come to be called *Nicaraguan Sign Language* (NSL; Kegl, Senghas, & Coppola, 1999; Senghas & Coppola, 2001). By contrasting the linguistic systems constructed by adult homesigners in Nicaragua with the structures used by the first cohort of NSL signers, the impact that a community of users has on language can be seen.

However, NSL has not stopped growing. Every year, new students enter the school and learn to sign among their peers. This second cohort of signers has as its input the sign system developed by the first cohort and, interestingly, changes that input so that the product contains increasingly complex linguistic structure (e.g., Senghas, 2003). The members of the second cohort, in a sense, stand on the shoulders of the first cohort and can therefore take the transformation process one step further. By contrasting the linguistic systems developed by the first and second cohorts of NSL, the impact that passing a language through a new generation of learners has on language structure can be seen. Once learners are exposed to a system that contains linguistic structure (i.e., Cohort 2 and beyond), the processes of language change may be identical to the processes studied in historical linguistics. One interesting question is whether the changes seen in NSL in its earliest stages are of the same type and magnitude as the changes that occur in mature languages over historical time.

Cospeech gesture versus silent gesture. A defining feature of homesign is that it is not shared in the way that conventional communication systems are shared. Deaf homesigners produce gestures to communicate with the hearing individuals in their homes. However, the hearing individuals, particularly hearing parents who are committed to teaching their children to talk and thus to oral education, use speech back. As a result, when the children's parents gesture, those gestures are produced along with speech and, as we have shown, form an integrated system with that speech. The parents' cospeech gestures are thus not free to take on the properties of homesign, and, indeed, the structures found in children's homesigns cannot be traced back to the spontaneous gestures that the children's hearing parents produce while talking to them (Goldin-Meadow et al., 1994, 1995; Goldin-Meadow & Mylander, 1983, 1984). Homesigners see the global and unsegmented gestures that their parents produce. However, when gesturing themselves, they use gestures that are characterized by segmentation and linearization.

Cospeech gestures thus do not assume the linguistic properties found in homesign. However, what would happen if hearing speakers were asked to abandon speech and to create a manual communication system on the spot? Would that system contain the linguistic properties found in homesign? Examining the gestures that hearing speakers produce when requested to communicate without speech allows us to explore the robustness of linguistic constructions created online in the manual modality.

Hearing gesturers asked to gesture without speaking are able to construct some properties of language with their hands. For example, the order of the gestures they construct on the spot indicates who does what to whom (Gershkoff-Stowe & Goldin-Meadow, 2002; Goldin-Meadow, McNeill, & Singleton, 1996). However, hearing gesturers do not display other linguistic properties found in established sign languages and even in homesign (Goldin-Meadow, 2015). For example, they do not use consistent form-meaning pairings akin to morphemes (Singleton, Morford, & Goldin-Meadow, 1993), and they do not use the same finger complexity patterns that established sign languages and homesign display (Brentari et al., 2012).

Interestingly, the gestures that hearing speakers construct on the spot without speech do not appear to be derived from their spoken language. When hearing speakers of four different languages (English, Spanish, Chinese, Turkish) are asked to describe animated events using their hands and no speech, they abandon the order typical of their respective spoken languages and produce gestures that conform to the same order—agent, object, action (e.g., captain–pail–swings; Goldin-Meadow, So, Özyürek, & Mylander, 2008). This order is also found when hearing speakers of these four languages perform a noncommunicative, nongestural task (Goldin-Meadow et al., 2008). Recent work on English, Turkish, and Italian speakers has replicated this finding in hearing gesturers but has found that gesturers move away from the agent–object–action order when asked to describe reversible events involving two animates ("girl pulled man"; Meir, Lifshitz, Ilkbasaran, & Padden, 2010) and when asked to describe more complex events ("man tells child that girl catches fish"; Langus & Nespor, 2010). Studies of hearing gesturers give researchers the opportunity to manipulate conditions that have the potential to affect communication and to then observe the effect of those conditions on the structure of the emerging language.

WHAT IS UNIQUE ABOUT GESTURE AS A COMMUNICATIVE MEDIUM?

In the sections that follow, we compare gesture to different kinds of human communication and behavior (speech, sign language, vocal cues, and manual actions) and explore how it differs from these other ways of communicating and interacting. We also ask whether human gesture is unique in any ways from the gestures and communicative body movements of other animals.

Less Digital Than Speech (or Sign)

Gesture conveys meaning in a somewhat different way than speech (or sign language) does. Speech is discrete and combinatorial: Words are made up of meaningful subunits and are, in turn, combined into meaningful sequences according to predefined rules. Gesture is more holistic, and gestures can combine with speech or blend into other gestures in flexible ways (though gestures are rarely combined with other gestures). Because of this difference, gesture is a relatively *analog* form of communication, whereas speech is relatively *digital*. Gesture is not constrained by the rules and conventionally defined forms that govern speech and thus lacks the expressive power that comes with combinatoriality and syntax.

However, gesture is spatial and imagistic in a way that speech is not. This property means that gesture can be a powerful tool for mapping concepts onto spatial representations or for embodying mental representations. Even ideas that are not inherently spatial can be described in gesture. For example, when asked to reason about moral dilemmas, speakers of all ages use gestures that reveal whether they are reasoning from one person's perspective (e.g., the speaker holds both hands out and curls the fingers in as though grasping an object, indicating the acquisitiveness of a single character) or from multiple perspectives (e.g., the speaker lays out the viewpoint of one character in her right hand and the viewpoint of a second character in her left hand; she then moves the two viewpoints together and apart, indicating that the two views are incompatible). Interestingly, if children are told to gesture when explaining their moral reasoning immediately before receiving a lesson on moral dilemmas, they produce significantly more multiple-perspective responses in speech after the lesson than children told not to gesture, or than children given no instructions in how to use their hands (Beaudoin-Ryan & Goldin-Meadow, 2014). Because it is so tightly tied to space, gesture allows speakers to literally take one perspective on one hand and another perspective "on the other hand." Doing so may allow speakers to make use of spatial learning mechanisms (Newcombe, 2010) that they would not have used had they not gestured.

How Does Gesture Differ From Other Nonverbal Cues?

In the sections that follow, we compare gesture to other nonverbal behaviors like qualities of the voice and physical action. We describe the characteristics that gesture shares with these other behaviors and identify some of the differences that set gesture apart. We also compare human gesture to gestures produced by nonhuman primates and identify the ways in which human gesture stands out.

Voice. Like gesture, the voice can convey extralinguistic information that complements or adds to the semantic content of speech. Vocal features such as pitch, loudness, and formant frequency convey information about the speaker's physical characteristics and emotional state. Characteristics such as size, age, and individual identity are all marked in acoustic parameters of the voice (e.g., Harnsberger, Shrivastav, Brown, Rothman, & Hollien, 2008; Sell et al., 2010). These features are what allow listeners to identify speakers on the phone. Emotion is also conveyed in the voice, as is made clear by imagining the different emotions that can be conveyed by changing the way you might utter the phrase "I'm fine" (see also Chapter 11, this handbook).

Much of the extralinguistic information carried in the voice marks properties of the speaker rather than the language itself. However, in some cases, vocal features contribute information that is semantically related to the information conveyed in the words. In these cases, the vocal features display a nonarbitrary relationship to the semantic content of the speech. This kind of vocal modulation (deemed *acoustic analog expression* by Shintel, Nusbaum, & Okrent, 2006) resembles the way iconic gesture conveys meaning and might be thought of as a type of vocal gesture. Much like gesture, vocal features may have varying relationships to the content of speech. The voice may complement the idea conveyed in speech—for example, by lowering the pitch of the voice when saying "It's going down" (Perlman, 2010; Shintel et al., 2006). However, the voice may also add information to speech—for example, by slowing down the rate of speech while saying "It's going down" if the object is descending slowly (Shintel et al., 2006). Importantly, listeners are able to successfully integrate the information in these supplementary relationships—they correctly interpret the earlier sentence as involving a slowly descending object (Shintel & Nusbaum, 2007).

While the modulation of vocal features during speech has much in common with gesture–speech combinations, the use of a single modality for both linguistic and extralinguistic content may restrict the range of possible meanings conveyed uniquely in the features of the voice. The study of vocal gesture is still in its infancy, but hopefully the coming years will see increased research in this area. It would be particularly useful to compare the use of vocal gesture during speech to the use of manual gesture during sign language (see Goldin-Meadow, Shield, Lenzen, Herzig, & Padden, 2012). Comparisons of this sort have the potential to provide insight into how linguistic and gestural systems are shaped by the auditory versus visual modality and by constraining communication to a single modality.

Action. Gesture is similar to action in that it involves physical movement (see also Chapter 15, this handbook). Iconic or metaphoric gestures may closely resemble actions (e.g., turning an imaginary key while saying "lock it"). However, gesture differs from action in that it is *representational*—physically twisting a key locks the door; gesturing the twisting motion does not. As a result, unlike action, gesture is not tied to the affordances of the physical environment. A gesture representing an action can be performed in the location where the action would be performed, but it can also be displaced and performed in the absence of any physical objects. Take, for example, the act of turning the crank on a handmixer. A parent teaching a child to use the mixer might use an action to demonstrate to the child how to operate the device. In this case, the parent might perform the action slowly, turning the crank so that the child can see how the act is done. If however, the parent was to convey the same information using gesture, the range of possibilities is greatly increased. The parent could gesture a facsimile of the action with the hand held near the handle of the mixer. Or the parent could produce the same handle-turning gesture farther away from the mixer (perhaps while the child was holding it) or even in another room to refer to the mixer in its absence. The parent might also use a more abstract representation of the movement, drawing circles with a finger to highlight the path of the handle as it rotated. This flexibility in form and the ability to distance movement from the affordances of physical objects clearly differentiates even very action-like gestures from action itself.

Gesture and action also affect mental representation of events in different ways. Gesturing about performing an action encodes features of the action in greater detail than performing the action itself (Beilock & Goldin-Meadow, 2010). When using a gesture to represent an action on an object (say, turning a crank), the gesturer performs an action on an "invisible" object. To do this, the gesturer has to form a clear mental representation of the object. When performing the same action on an object, the actor does not need to retain a representation of the object in his or her memory because he or she can offload the features and affordances of the object onto the physical environment (Cartmill, Beilock, & Goldin-Meadow, 2012). Even when gesture closely resembles the movements of the action it represents, gesturing about an event has a stronger effect on the mental representation of the action involved than performing the action again (Goldin-Meadow & Beilock, 2010).

Because gesture does not depend on the affordances of the objects and events it represents, it has the potential to affect learning differently from the way action affects learning. Novack, Congdon, Hemani-Lopez, and Goldin-Meadow (2014) asked whether gesturing promotes learning because it is itself a physical action or because it uses physical action to represent abstract ideas. To address this question, they taught third-grade children a strategy for solving mathematical equivalence problems that was instantiated in one of three ways: (a) in the physical action children performed on objects, (b) in a concrete gesture miming that action, or (c) 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. The results suggest that gesture promotes transfer of knowledge better than action and that the beneficial effects gesture has on learning may reside in the features that differentiate it from action.

Is Gestural Communication Unique to Humans?

Humans are not unique in using manual gestures to communicate, but humans may be unique in their ability to exploit gesture's vast representational potential. Other primates use manual gestures, and their gestures share some properties with human gesture. However, their gestures do not exhibit the iconic, imagistic properties that make human gesture such a powerful representational medium.

Like humans, great apes (our closest living relatives) use gestures to communicate with one another in seemingly intentional ways, and their gestures appear to be meaningful (Call & Tomasello, 2007; Cartmill & Maestripieri, 2012). Great apes also take the gaze of their partner into account when gesturing; they use visual gestures more often when others are looking, but when a potential partner is looking away, apes will switch to audible gestures (like clapping) or move to a location where they can be seen (Call & Tomasello, 2007; Liebal, Call, Tomasello, & Pika, 2004; Poss, Kuhar, Stoinski, & Hopkins, 2006). Great apes are also able to use deictic gestures (such as pointing), but they primarily produce these gestures when communicating with humans in captive conditions and not when communicating with other apes in their natural environments (Leavens, 2004; Leavens, Hopkins, & Bard, 1996).

Ape gestures differ from human gestures in several notable ways. First, they are not temporally synchronized with vocalization in the way human gestures are synchronized with speech. Second, they are not richly iconic or representational. Some ape gestures have been described as iconic (e.g., one ape swung its arm in the direction it wished another to go; Savage-Rumbaugh, Wilkerson, & Bakeman, 1977; Tanner & Byrne, 1996), but the degree of iconicity in these gestures is debated (see Cartmill, Beilock, & Goldin-Meadow, 2012). Third, ape gestures seem to have only imperative meanings (e.g., move away, come here, gimme that), whereas human gesture can convey both imperative and declarative meanings (Tomasello & Camaioni, 1997). Early in development, human children start out producing primarily imperative communicative gestures. For example, a young infant reaches for or points to things that he or she wants. However, within the first 12 months of life, children begin to communicate *declaratively*—pointing out things because they want to share the experience with others, not because they want to obtain an item (Tomasello, Carpenter, & Liszkowski, 2007). This development can be easily observed if you are around a parent with a 1-year-old child. Typically, the child will point to something in the environment (such as a bird), and the parent will respond by saying something such as, "Yes, that's a bird. Isn't it pretty?" This exchange will likely satisfy both participants. To appreciate the difference between imperative and declarative pointing, imagine a different scene in which a child points to a favorite toy that has fallen out of his or her stroller. If the parent responds with "Yes, it fell down," it is doubtful that the child would be content with the response. The child in the second example is using a point to request a specific action from the parent; the child in the first example is using a point to initiate an affiliative social interaction with the parent.

Finally, human gesture is unique because it is part of human language. It displays greater flexibility and representational features than the communication systems of other animals. Although human gesture does not display the linguistic compositionality and syntactic structures of spoken language, it is semantically and temporally integrated with speech. Gesture is also flexible in how it conveys meaning. It can refer to something in the environment or use something in the environment to refer to something else (deictic gesture). It can rely on learned forms and culturally shared meanings (emblems). It can use rhythm to emphasize concepts in speech (beat gesture). Or, it can convey meaning imagistically, through iconic similarity to physical referents (iconic gesture) or by aligning abstract concepts with spatial schemas (metaphoric gesture).

IS GESTURE FOR COMMUNICATION AT ALL?

In this final section, we turn to the question of whether gesture exists primarily as a tool for communication or for thought. It is clear that speakers produce meaningful gestures that can complement and supplement the information conveyed in speech, and that listeners pick up on the information in gesture, integrating across modalities to gain a fuller understanding of the speaker's meaning.

It is unclear, however, the degree to which a speaker's gestures are intended to communicate versus produced during speech to aid in the organization of thought and the production of language. It is possible that gesture is able to fulfill both communicative and cognitive functions simultaneously.

There is evidence that speakers produce at least some of their gestures for the purpose of communicating with the listener, in other words, for the listener. If gestures were produced solely to help with speech planning and production, then gesture rates should decline when speakers repeat the same message to different listeners. However, speakers experience no such decrease in gesturing (Jacobs & Garnham, 2007). Similarly, if gesture is not produced for the listener, then gesturing should not change when the speaker and listener cannot see each other. However, if a screen is placed between speaker and listener, the rate of gesturing declines (Alibali, Heath, & Myers, 2001; Mol, Krahmer, Maes, & Swerts, 2011). In short, people gesture more when they can be seen. These findings suggest that gesture is used for the purpose of communicating with others. However, other studies demonstrate the ways that gesture can also benefit the speaker.

Gesturing for Thinking

People gesture in many situations where there is no obvious benefit to a listener (or perhaps no listener at all). One common example is the habitual use of gesture while talking on the phone. Even more convincing, congenitally blind speakers, who have never seen another person gesture, produce gestures when they speak, even when speaking to blind listeners (Iverson & Goldin-Meadow, 1998). The fact that congenitally blind speakers gesture to blind listeners suggests that gesture may be playing a role for speakers as well as listeners. In this section, we consider a number of ways in which gesturing has been shown to influence how speakers think.

Facilitating Lexical Access

Gesturing can support the planning and production of speech by facilitating lexical retrieval—by helping speakers "find" words (Rauscher, Krauss, & Chen, 1996). For example, if you were asking a friend for a corkscrew but could not remember the word, you might produce a gesture that represented the corkscrew while you were searching for the right word. Support for the lexical access theory comes from the observation that speakers are particularly likely to gesture during unrehearsed speech (Chawla & Krauss, 1994) or when they use words that are unpredictable given the surrounding context (Beattie & Shovelton, 2000). When lexical access is impaired (during experimental manipulation or in patients with aphasia), rates of gesturing increase. Finally, experimental studies manipulating gesture rate have demonstrated that both adults and children are more successful at finding correct words (as in the corkscrew example) when they are allowed to gesture than when they are not allowed to gesture (Frick-Horbury & Guttentag, 1998; Pine, Bird, & Kirk, 2007). These findings support the theory that gesturing can aid lexical access.

Reducing Demands on Conceptualization

Speakers gesture on problems that are conceptually difficult, even when there are no lexical demands (Alibali, Kita, & Young, 2000; Hostetter, Alibali, & Kita, 2007; Kita & Davies, 2009; Melinger & Kita, 2007), suggesting that gesture can do more than facilitate lexical access. For example, when adults are asked to describe dot patterns, they gesture more when talking about patterns that do not have lines connecting the dots (patterns that are more difficult to conceptualize) than patterns that do have lines (Hostetter et al., 2007). As a second example, children who are asked to solve Piagetian conservation problems (problems that require conceptualization) gesture more than when they are simply asked to describe the materials used in the conservation problems (Alibali et al., 2000).

However, we need to be cautious in interpreting these results. In all of these studies, conceptualization difficulty and gesturing go hand-in-hand (the more conceptually difficult a problem, the more gesture). However, to be certain that gesturing plays a causal role in reducing conceptualization demands (as opposed to merely reflecting those demands), researchers need to manipulate gesture and demonstrate that the manipulation has an impact on conceptualization demands. Studies of this type have not yet been done.

Reducing Demands on Working Memory

Studies have been done that experimentally manipulate gesture and explore the impact of that manipulation on working memory. Adults and children were asked to remember an unrelated list of items while explaining how they solved a math problem. One group was allowed to gesture freely during their explanations; the other group was prevented from gesturing. Speakers recalled more items (and thus maintained more items in verbal working memory) when they gestured during their explanation than when they did not gesture (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Wagner, Nusbaum, & Goldin-Meadow, 2004). This effect was found even when the gestures were directed at objects that were not present in the context (Ping & Goldin-Meadow, 2010), suggesting that gesturing confers its benefits not just by tying abstract speech to objects directly visible in the environment. Importantly, it was not being told not to gesture that increased demands on working memory—speakers remembered more words when they gestured than when they did not gesture, both when they were instructed not to gesture and also when they chose not to gesture (Goldin-Meadow et al., 2001).

Bringing in New Knowledge

Gesturing can also affect thinking by bringing new knowledge into a speaker's repertoire. To determine whether gesture can create new ideas, we again need to manipulate gesture, but this time we need to tell speakers to move their hands in particular ways. Speakers' ideas should change as a function of the particular hand movements they make. Goldin-Meadow, Cook, and Mitchell (2009) manipulated gesturing during a math lesson, asking some children to produce gestures that instantiated a correct procedure for solving the math problem, some to produce gestures that instantiated a partially correct procedure for solving the math problem, and some to produce no gestures at all. Children in all three groups were taught a different (but also correct) procedure in speech. 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. It was clear that children in the gesture conditions had added new information to their repertoires simply because, after the lesson, they produced in speech the procedure that had been instantiated only in their gestures during the lesson (and that the teacher had not conveyed at all). Researchers may be able to lay the foundations for new knowledge simply by telling learners how to move their hands.

APPLICATIONS OF GESTURE RESEARCH

Growing numbers of researchers are incorporating gesture into their work because of gesture's potential to reveal aspects of mental representation or reasoning that are not conveyed in speech. For example, studying gesture can reveal differences in the ways experts and novices conceptualize problems (Ping, Larson, Decatur, Zinchenko, & Goldin-Meadow, 2014), shed light on the use and impact of nonverbal input in instruction (Alibali & Nathan, 2012; Church, Ayman-Nolley, & Mahootian, 2004; Richland, Zur, & Holyoak, 2007), and help identify students who are on the cusp of learning a new concept (e.g., Alibali, Flevares, & Goldin-Meadow, 1997; Church & Goldin-Meadow, 1986; Perry, Church, & Goldin-Meadow, 1988; Pine, Lufkin, & Messer, 2004). Chapter 19 of this handbook looks in greater detail at the coding of gesture and how the study of gesture can be applied to the study of the mind. Gesture can be particularly insightful in the study of language production and language acquisition. The gestures young children produce often predict the upcoming developments in speech. Conversely, a lack of gesture can be an early marker of language delay.

Children begin gesturing before they can speak, and gesture plays a large part in children's early communicative repertoire. As described earlier, linguistic developments often manifest in gesture before they become apparent in speech, and this early window onto language development can be used to identify atypical developmental trajectories before they become visible in speech. Low gesture rates early in development may be a signal that a child is likely to experience delays in language learning (Sauer, Levine, & Goldin-Meadow, 2010), providing an opportunity for early interventions.

Conversely, robust gesturing in children who have low language skills relative to their peers signals that they are ready to learn and are "late bloomers" who will catch up without the need for intervention. One study of low verbal children (whose vocabularies were in the lowest 10% of their age group) found that the children in this group who were the most competent in gesture caught up with their peers within the following year, whereas the children who had fared poorly on gesture at the initial evaluation remained delayed a year later (Thal, Tobias, & Morrison, 1991). Similarly, a study of children with early brain injury found that children whose gesture rates were within the typical range were the most likely to catch up with their typically developing peers, whereas children whose gesture rates were below the typical range were likely to display persistent language delay (Sauer et al., 2010).

Gesture's potential for early identification of delay has become increasingly important in autism research. One study of gesturing in 12-month-old infants found that infants who were later diagnosed with autism had gestured less overall and produced very little pointing when compared to typically developing infants (Osterling & Dawson, 1994; see also Bernabei, Camaigni, & Levi, 1998). This reduced gesturing has also been found in studies of younger siblings of children with autism—children who displayed smaller communicative repertoires in gesture had increased likelihood of receiving an autism diagnosis later in development (Mitchell et al., 2006). Although further work is needed to understand the development of gesture and speech in atypically developing populations, gesture's potential to reveal communicative delays before they manifest in speech makes gesture a powerful tool in the early identification (and possible treatment) of linguistic disorders.

Gesture can also play an important role in the legal world. The accuracy of information obtained in forensic interviews is critically important to credibility in the legal system. It is well-known that the way interviewers frame questions influences the accuracy of witnesses' reports. Broaders and Goldin-Meadow (2010) studied children interviewed about an event that they had witnessed. They found that the interviewer's gestures served as a source of information and, at times, misinformation that led the child witnesses to report incorrect details. Conversely, they also found that the gestures that the child witnesses spontaneously produced during the interviews conveyed substantive information that was not always conveyed in their speech and, thus, would not appear in written transcripts of the proceedings. The findings underscore the need to attend to and document gestures produced in investigative interviews, particularly interviews conducted with children.

Finally, gesture can play a role in the classroom. Because children's gestures often display information about their thinking that they do not express in speech, gesture can provide teachers with important information about their pupils' knowledge. Not only do teachers pay attention to the information that children express in gesture (e.g., Alibali et al., 1997) but they also alter their input to children as a function of those gestures (Goldin-Meadow & Singer, 2003). In addition, the gestures that teachers themselves produce during their lessons have been found to matter for student learning. Lessons that contain gestures promote deeper learning (i.e., new forms of reasoning, generalization to new problem types, retention of knowledge) better than lessons that do not contain gestures (Church et al., 2004; Valenzeno, Alibali, & Klatzky, 2003). Moreover, because it is known that the act of gesturing can itself promote learning (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007), teachers can consider encouraging their students to gesture, which has the potential to activate implicit knowledge and make the students particularly receptive to instruction.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Gesture is a powerful representational tool and an integral part of human language. It can convey meaning through deixis, rhythm, convention, iconicity, and even metaphor. Gesture and speech are tightly integrated both temporally and semantically. Gesture can have a complementary or supplementary relationship with speech, and the combination of gesture and speech often conveys a richer meaning than either modality does on its own. Gesturing can reveal thoughts that are not expressed in speech, and professionals involved in learning and assessment (e.g., teachers and clinicians) would benefit from taking gestures into account when performing evaluations. Gesture emerges early in language development and has great potential as an early indicator of linguistic delay or other atypical development. Further research into the clinical and educational applications of gesture will help clarify when and how gesture may be used as a diagnostic tool.

Gesture also plays a role in cognition: reducing demands on memory and conceptualization and integrating new knowledge during learning. It is known that gesture can play a role in cognition and learning—it not only reflects knowledge but it can also play a causal role in changing that knowledge (e.g., Goldin-Meadow et al., 2009). However, researchers do not yet know the extent to which gesturing changes the way a person represents an idea or reasons through a problem. Researchers also do not know whether gesture's role in cognition stems from its embodied nature (i.e., the fact that it resembles action) or its visiospatial properties. These questions are particularly salient in the realm of language development—children's gestures presage upcoming linguistic developments and have the potential to play a causal role in that development (see, e.g., LeBarton, Goldin-Meadow, & Raudenbush, 2013). Understanding when and how gesture can affect language and thought is a rich area for future inquiry.

The movements we make with our hands when we talk are important to both communication and thought. Understanding the specific ways in which gesture reflects and affects language and learning is an important challenge for future research. Integrating gesture into clinical and scientific approaches to language and thought will ultimately lead to a deeper understanding of the nature of the human mind.

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