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Putting Language Back in the Body: Speech and Gesture on Three Time Frames

Spencer D. Kelly
Department of Psychology—Neuroscience Program
Colgate University

Jana M. Iverson
Department of Psychological Sciences
University of Missouri-Columbia

Joseph Terranova, Julia Niego,
Michael Hopkins, and Leslie Goldsmith
Department of Psychology—Neuroscience Program
Colgate University

This article investigates the role that nonverbal actions play in language processing over 3 different time frames. First, we speculate that nonverbal actions played a role in how formal language systems emerged from our primate ancestors over evolutionary time. Next, we hypothesize that if nonverbal behaviors played a foundational role in the emergence of language over evolution, these actions should influence how children learn language in the present. Finally, we argue that nonverbal actions continue to play a role for adults in the moment-to-moment processing of language. Throughout, we take an embodied view of language and argue that the neural, cognitive, and social components of language processing are firmly grounded in bodily action.

Human language is special because it is at the pinnacle of the mind's capabilities and is most notably what separates our minds from the minds of other thinking animals. Language is so special, in fact, that many people have argued that there is a designated language device built into the human brain at birth. These views, made

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Requests for reprints should be sent to Spencer D. Kelly, Colgate University, Department of Psychology/Neuroscience Program, 13 Oak Drive, Hamilton, NY 13346. E-mail: skelly@mail.colgate.edu

popular by such scholars as Chomsky, Pinker, and Fodor (Chomsky, 1965; Fodor, 1983; Pinker, 1995), generally also claim that language has become encapsulated—that is, it has developed as a neurocognitive ability separate from other abilities. This view has been very influential and has often led to scientific treatment of language as a disembodied entity, as something that has a life of its own.

To be sure, such approaches have been very useful in understanding many aspects of language. However, there may be drawbacks to studying language as an entity unto itself. For example, just as there are limitations to zoologists studying animals in isolation, it is likely that psychologists might develop an incomplete or, worse, incorrect understanding of language by studying it in isolation.

This article attempts to take language out of isolation and bring it back to its original habitat, the body. This approach is guided by the more general notion of embodiment, which argues that all of human cognition is deeply affected by the physical make-up and functioning of the body (Barsalou, 1999; Johnson, 1987; Thompson & Varela, 2001). Our article takes the specific position that language emerged from the body over evolutionary time and that bodily action continues to influence language use and development in the present.

We provide three lines of evidence to support this position. In the first part of the article, we consider the evolutionary roots of language. We argue that the original functions of communication and language systems were perfectly suited for the body, and that the body continued to shape language over evolutionary time. The second part of the article narrows the time frame and considers the effects of the body on language acquisition over a lifetime. We hypothesize that if the body did indeed play a defining role in the emergence of language over evolution, those effects should be manifest in the emergence of language over development. Finally, the third part of the article examines language on an even smaller time frame, the moment-to-moment time frame. This time frame is truly the front line of developmental change. If the body plays a role in how adults produce and comprehend language from one moment to the next, this influence would provide insights into how the brain has developed to handle language over developmental and evolutionary time.

EVOLUTIONARY TIME FRAME

This article takes a decidedly ethological approach to studying human language. It is largely guided by Tinbergen's (1968) analysis of animal behavior. In particular, it draws on Tinbergen's notions of *function* and *mechanism* in exploring the evolution of human language. Function refers to what purpose a behavior serves for an organism—the question of why—and mechanism refers to the machinery that allows that behavior to work—the question of how. In the following section, we adopt this perspective and explore the functions for, and mechanisms of, the evolution of human language by considering its natural habitat: the body.

Function

It is always difficult to make arguments about the evolution of mental functions. For example, no geologist to date has ever found a fossil for language (Povinelli, 1993). However, accounts of the evolution of mental functions, such as language, can rely on basic knowledge of evolutionary principles to piece together realistic and plausible accounts of how language came to be.

One of the fundamental tenets of evolution is that outcomes that are the most functional at a particular time in a particular situation win out over outcomes that are not as functional (Darwin, 1867). One way to think about the evolutionary emergence of language is to consider the basic functions of language or, more generally, communication in the present day; that is, which functions of human communication have "won out" and are still with us today?

Clark (1996) argued that there are three basic functions of communication—*describing, indicating,* and *demonstrating*. Traditionally, language researchers have focused on the describing function of communication. Indeed, all of the world's current language systems are exquisitely suited for describing. All languages have abstract, conventionalized symbols that can be combined in structured ways to describe almost anything—objects, actions, feelings, thoughts, events, and so on.

However, descriptions are not the only form of communication. Indication and demonstration are also powerful ways to communicate. Communicators indicate things using their eyes, hands, or demonstrative terms like *this* or *that* (as in saying, "Don't touch that plant," while looking at and pointing to some poison ivy). They also demonstrate actions to addressees (e.g., saying, "This is how you tie a slip knot," while physically demonstrating the action). These forms of communication rely on nonverbal behaviors to large degree (Clark, 1996).

Although these three modes of communication are utilized in present-day communication, they may not have emerged at the same time in the evolution of language systems. Description is abstract and relies on a formal and conventional system of rules. It is unlikely that this system sprung from the brain of our Australopithecus ancestors, like Athena from the forehead of Zeus. Rather, abstract and conventionalized description was most likely late in coming and a slowly developing aspect of communication.

On the other hand, the methods of indication and demonstration probably developed much earlier and more quickly. For example, indication was probably one of the first functions of communication. Indexes function to direct attention, to such external things as objects, events, and locations, or to such internal things as emotions and thoughts. It is not difficult to imagine situations in which our ancestors used indication to communicate. For example, the actions of holding up and looking at an object or pointing to a location or event may have been some of the earliest ways in which our ancestors communicated. From there, nonverbal actions may have progressed to index things that were not directly observable, such as where events have occurred or will occur (through gaze or gesture) or how someone was feeling (through stressed vocalizations or facial expressions). In this way, language could have evolved from this more primitive form of indexing to a way of more flexibly "pointing to" things that were no longer perceptually salient (a key component of all languages). In fact, some theorists have even argued that all formal language systems are elaborate forms of indicating (Barsalou, 1999; Hanks, 1996). For example, Barsalou (1999) argued that language has meaning because it indexes the initial multimodal encoding of experiences (auditory, visual, haptic, etc.). At the very least, it is difficult to imagine the emergence of a formal language system without some sort of indexical starting point.

Demonstration may have also been a very important early method of communication. This method is concrete and by definition grounded in physical action. Given humans' propensity for imitation (Meltzoff, 1990; Piaget, 1952; Tomasello, 2001), it is highly likely that our ancestors used demonstration to impart information to one another. For example, demonstration may have been used to communicate information about how to hunt game, gather food, build shelters, start fires, make tools, and so on. From these examples, it is also easy to imagine such communicative interactions laying the groundwork for other more abstract types of communication, such as description. For example, vocal utterances probably conveyed meaning by initially overlaying onto physical demonstrations.

Though the question of how humans ever developed the abilities to indicate and demonstrate intentionally in the first place is beyond the scope of this article (see Tomasello, 2001), it seems clear that indicating and demonstrating were important functions in the evolution of early attempts at communication. Indeed, some have even argued that these actions served as a matrix within which more advanced forms of communication, such as formal language systems, could have evolved (Barsalou, 1999; Corballis, 1998; Hauser, 1996; Hewes, 1973). For example, vocalizations that accompanied the physical actions of indicating and demonstrating could have become more conventional and codified with repetition, and could have eventually evolved into words and sentences. If this were the case, language can be seen as being born from the body and growing up from there. In the next section, we explore a possible mechanism—evolutionary conservation—to support such a claim.

Mechanism

Evolutionary conservation is the idea that the incredible phenotypic diversity seen across organisms on Earth can be explained by a relatively small number of shared biological and developmental mechanisms operating across evolution (Gerhart & Kirshner, 1997). So instead of viewing differences in language abilities between humans and nonhumans as evidence that language must have evolved as a special and separate ability from our primate ancestors, an evolutionary conservation view would explain differences among species as a gradual emergence of a new skill built out of preexisting and shared parts (Bates, 1999; Bonin, 1944). As support for this position, this section reviews research arguing that the traditional language areas in the human brain are not so different from the neural areas of some of our closest nonhuman ancestors and, further, that the shared areas reveal links between bodily action control in nonhuman primates and language abilities in humans.

Wernicke's area. In humans, Wernicke's area is located in the posterior part of the superior temporal gyrus, just behind the primary auditory cortex in the left hemisphere. Traditionally, this area is considered to be involved in language comprehension. However, this area is not unique to humans. In fact, cross-species research suggests that there may be homologues to Wernicke's area in nonhuman primates (Galaburda & Pandya, 1982; Preuss, 2000). For example, Galaburda and Pandya (1982) found that the auditory region in the temporal lobe of rhesus macaques was organized in a manner similar to humans and, specifically, they found that the architectonic area Tpt (the location of Wernicke's area in humans) was present for monkeys.

This area appears to serve similar functions for macaques as it does for humans. Japanese macaques show left-hemisphere specialization, like human lateralization for language, for the perception of species-specific vocalizations (Heffner & Heffner, 1984). Further, unilateral ablation of the left superior temporal gyrus, including the auditory cortex, resulted in impairment in the ability of the macaques to discriminate coo calls. This result parallels the classic description of damage to Wernicke's area in humans (Dronkers, Redfern, & Knight, 2000).

The most important piece of evidence for this argument comes from research demonstrating a link between language comprehension in humans and control of nonverbal actions in nonhuman primates. Brodmann's area (BA) 40 is dorsal to area Tpt in humans. Located within the left supramarginal gyrus, this area is implicated in language comprehension (Preuss, 2000; Preuss & Goldman-Rakic, 1989). Functional imaging studies have shown a homology between BA 40 in humans and the left inferior parietal lobule in nonhuman primates, the area now known as area 7b (Colebatch, Deiber, Passingham, Friston, & Frackowiak, 1991; Preuss, 2000). Specifically, this research has shown that BA 40 is active during forearm movements in humans, and the monkey homologue (area 7b) is active during facial and forelimb movements. These findings are even more interesting given that BA 40 in humans is also active during linguistic tasks (Paulescu, Frith, & Frackowiak, 1993). This suggests that the continuity in structure across humans and monkeys is marked by an interesting difference in function. BA 40 and area 7b are both involved in facial and forearm movements in humans and monkeys, but BA 40 is also responsible for language in humans. This provides support for the argument that language comprehension may have evolved out of body systems employed in nonverbal communication in our primate ancestors.

Broca's area. In humans, Broca's area is located in the posterior part of the third frontal gyrus in the left hemisphere (BAs 44 and 45). Traditionally, this area has been associated with language production. However, as with Wernicke's area, Broca's area does not appear to be unique to humans (Preuss, 2000). This fact is extremely important to the theory of evolutionary conservatism and language emergence, given that language represents the major difference between humans and some of our closest primate relatives. Despite this difference, recent research suggests that neural representation in BAs 44 and 45 in humans is homologous to area F5 in nonhuman primates, which is located in the left ventral premotor cortex in macaques (Arbib & Rizzolatti, 1996; Deacon, 1992; Preuss, 2000).

Functionally, these two areas appear linked. In humans, BAs 44 and 45 are active not only during language tasks, but also during simple movements of the hand and mouth. Similarly, in nonhuman primates, movements of the hand and mouth activate neurons in the homologous area F5 (Arbib & Rizzolatti, 1996; Colebatch et al., 1991). Additional research has shown that F5 neurons in macaques have connections with supplementary motor cortex and primary motor cortex, allowing F5 neurons to mediate control of orofacial and mouth–tongue movements (Deacon, 1992). Thus, there are structural similarities between action areas in nonhuman primates and traditional human language areas, suggesting that evolution conserves basic neural structures that connect bodily action and communication in primates.

This claim receives further support from the discovery of "mirror neurons" in nonhuman primates (Arbib & Rizzolatti, 1996; Rizzolatti & Arbib, 1998). Mirror neurons are cells in area F5 that become active not only when a monkey produces an action, but also when that monkey views another monkey (or human) produce that same action. In this way, mirror neurons provide a very simple pathway to understanding other's actions. It is interesting that neuroimaging techniques have revealed that a very similar mirror neuron system may be in place for humans as well (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). The link between monkeys and humans suggests that the mirror neuron system may have laid the groundwork for the development of a full-blown gesture communication system in our evolutionary past.

Finally, the transition from a gesture system to a verbal language system is not hard to imagine. Both spoken languages and gestured languages (e.g., American Sign Language) are excellent at segmenting and combining discrete units into a structured form of communication (Goldin-Meadow, McNeill, & Singleton, 1996). Thus, the fact that area F5 in nonhuman primates controls hand movements in addition to orofacial and laryngeal movements suggests that F5 could have been co-opted into performing more sophisticated vocalization functions (Arbib & Rizzolatti, 1996; Colebatch et al., 1991; Rizzolati & Arbib, 1998). Moreover, with subsequent evolutionary changes in the location and orientation of the larynx and pharynx as a result of bipedal walking, our ancestors could more easily produce what we now call speech (Lieberman, 1984). This evolutionary development would leave hand gestures with their original job at which they truly excelled: iconically representing thought (demonstrating) and indexing relations among things (indicating). Thus, speech currently handles one function of language and nonverbal gestures handle another, but through an inbred evolutionary past, these two systems are now tightly coupled and both codetermine meaning in communication (Goldin-Meadow et al., 1996).

Naturally, it is extremely difficult to validate a mechanistic link between human and primate brain areas with regard to language. We cannot simply subject nonhuman primates to our evolutionary circumstances and see if they develop language. However, at the very least, we can be fairly certain that primates have brain areas that are well suited to represent language—spoken or otherwise. We posit that modern human language represents the gradual progression of the capabilities of brain areas that were already present in our primate ancestors. Moreover, we argue that this gradual progression was tightly constrained by bodily action and nonverbal communication (see also Corballis, 1999). In this way, we can view language as an emergent ability that has come a long way but has not forgotten its home, the body.

We began this section by conceding that it would be difficult to determine the impact of the body on the evolution of human language systems. After all, there are no fossils indicating how bodily action influenced the brain's ability to develop language over evolution. Or are there? Perhaps looking at the role that the body plays in language use in the present may provide clues into how the brain became equipped to develop language over evolutionary time. In the next two sections, we explore this question by asking how bodily action influences language production and comprehension over the developmental and moment-to-moment time frames.

DEVELOPMENTAL TIME FRAME

In this section, we hypothesize that if the body did indeed play a foundational role in the emergence of language over evolution, those effects may have a lasting impact on how people use language over a lifetime. Specifically, we focus on the role that certain nonverbal bodily actions, such as eye gaze and hand movements and gestures, play in how children learn language. In this way, we concur with recent revivals in the developmental literature of the view that ontogeny loosely recapitulates phylogeny (Nelson, 1996). If nonverbal actions functioned to support the emergence of language systems in our evolutionary past, this functional relationship has probably been phenotypically encoded and carried into the present.

We begin by reviewing literature that suggests that humans (and nonhumans) are not wired early in development to process information in a strictly modular fashion. Then we discuss research that argues that nonverbal bodily action lays the groundwork for speech production. Along those lines, we then review research suggesting that specific hand movement—hand gestures—help children produce one- and two-word speech. Finally, we review research that suggests that nonverbal behaviors in the social environment play a crucial role in early and later language comprehension. Throughout the section, we approach each of our topics from multiple levels of analysis, from social to cognitive to neurological.

Early Multimodal Integration

There is an established body of research in the area of perceptual and cognitive development arguing that human infants are quite capable of integrating information across multiple modalities early in development (Kuhl & Meltzoff, 1984; Lawson, 1980; Meltzoff & Borton 1979; Ruff & Kohler, 1978). These studies have demonstrated that very young infants process information in a multimodal fashion. That is, information conveyed through one modality influences how infants process information conveyed through a different modality. For example, when an infant touches an object, that infant is more likely to look at an object that is similarly—not differently—shaped (Meltzoff & Borton, 1979); when an infant sees a face making a sound, that infant will show a preference for sounds that match versus mismatch that face (Kuhl & Meltzoff, 1984). From this work, researchers have hypothesized that these types of multimodal skills lay the groundwork for sophisticated cognitive abilities later in development, for example, in perspective taking and language abilities.

Though there is solid evidence for multimodal integration on the behavioral level of analysis, relatively little research has focused on underlying brain mechanisms that make this integration of modalities possible. In one study, Neville (1995) explored this issue using event-related potentials. She recorded auditory event-related potentials (AERs) from 6-month-old children and found that AERs were equally large over auditory (temporal) and visual (occipital) brain regions. Though this effect diminishes with age, it provides strong neural evidence that young children process simple language stimuli in multiple areas of the brain.

There are several animal models of this type of early neural integration of multimodal information (Wallace & Stein, 1997; Wallace, Wilkinson, & Stein, 1996). In a study looking at multimodal integration in cats, Wallace and Stein (1997) demonstrated that multiple modalities become increasingly integrated in the cortex with development. Specifically, they showed that multimodal neurons in the midbrain superior colliculus (SC), an area specialized for visually shifting attention, became increasingly sensitive to information conveyed through multiple modalities. Using a single-cell recordings technique, they found that simultaneously presenting visual and auditory stimuli to 30-day-old cats produced a very powerful response in SC neurons, whereas presenting stimuli in one or the other modality produced very small effects. It is interesting that this synergistic effect did not occur for younger cats (20 days old). However, once the SC neurons become synergistically tuned to visual and auditory stimuli, they appear to remain so throughout adulthood (Ramachandran, Wallace, & Clemo, 1993).

Thus, it appears as if the developing brain is specially tuned to process information in a multimodal fashion. This suggests that humans and nonhumans alike do not process information conveyed through one modality in a strictly modular fashion early in development. In the remainder of this section, we explore language development research that appears consistent with these neural mechanisms.

Bodily Action and Speech Sound Production

In this section, we review evidence indicating that the relationship between motor action and language is in place from the first year (for a theoretical model of this relationship, see Iverson & Thelen, 1999). We focus on studies of rhythmic motor and vocal behaviors in young preverbal infants.

The occurrence of rhythmically organized activity is characteristic of systems under immature control. During the first year, infants frequently produce rhythmic movements of the limbs, torso, and head, and rhythmic organization is also evident in vocalizations. Thelen (1979, 1981a, 1981b) has documented the developmental time course of infant rhythmic behaviors. Her observations indicate that infants frequently produce rhythmic limb movements, and that the age of onset of rhythmic movements in specific body segments is strongly and positively related to the emergence of new motor skills involving those same body segments. Thus, for example, infants rock back and forth on all fours before they crawl, and the appearance of rocking is a good indicator that crawling onset is imminent. Based on these findings, Thelen has concluded that rhythmic movements appear at a time when infants have some degree of intentional control of limbs or body postures but do not yet have the skill required to produce fully goal-directed movements.

This view, recently adopted with reference to infant babbling, has led MacNeilage and Davis (1993) to suggest a reinterpretation of the traditional perspective on the role of babbling in language development. At around 27 weeks of age, infants begin to produce canonical babble, or vocalizations consisting of repetitions of the same consonant–vowel sequence (e.g., /bababa/ or /dididi/; Oller & Eilers, 1988). Because production of canonical babble is predictive of later language development and a reliable early indicator of future language disorders

(Oller, Eilers, Neal, & Schwartz, 1999; Stoel-Gammon, 1992), some investigators have claimed that babbling production reflects the operation of language-specific processes (e.g., Petitto, Holowka, Sergio, & Ostry, 2001; Petitto & Marentette, 1991).

Important for our argument that language has its roots in bodily action, MacNeilage and Davis (1993) pointed out that the properties of canonical babbling are similar to those of the rhythmic motor behaviors just described. They suggested that canonical babble is the unique behavioral result of three factors operating in concert: mandibular oscillation, phonation, and limited tongue control. When infants begin to babble, they repeatedly lower and raise the mandible while phonating; and due to poor tongue control, the tongue's position remains relatively constant during these cycles. The overall result is a perceived contrast between consonants produced when the vocal tract is closed and vowels produced when the vocal tract is open. As infants gradually gain control of the tongue and vary its position during mandibular cycles, they widen the repertoire of syllabic patterns appearing in their vocalizations (MacNeilage & Davis, 2000; MacNeilage, Davis, Kinney, & Matyear, 1999). According to this view, then, babbling is simply another example of the rhythmic activity characteristic of infant motor behavior in the first year.

Support for this view comes from the finding that infants regularly produce silent mandibular oscillations, or "jaw wags," during the early stages of babbling (Meier, McGarvin, Zakia, & Willerman, 1997). This suggests that oscillation of the mandible and phonation in early babbling are under separate control, an interpretation strengthened by observations of phonated and nonphonated babbling alternating without pause within a single utterance. In addition, there are striking cross-linguistic similarities in the organizational patterns of infants' babble and first words. Despite wide variability in sound co-occurrence patterns in their native languages, infants from different linguistic backgrounds show a strong preference for the same three consonant–vowel patterns in early productions (MacNeilage & Davis, 2000).

Thus, rhythmically organized activity is a hallmark of both the infant motor and vocal systems during the first year. Based on these developmental similarities, it is tempting to speculate that common mechanisms may link the two systems. Evidence for this view comes from the existence of a temporal relationship between canonical babbling onset and changes in frequency of rhythmic motor activity, specifically, movements of the arms and hands.

The basic finding is that around the time of canonical babbling onset, production of rhythmic movements of the arms and hands (e.g., waving, swinging, and banging) increases sharply (e.g., Thelen, 1979). At first glance, this temporal co-occurrence might seem to be just an interesting coincidence. However, three findings suggest that it is not.

First, in typically developing infants, there is a strong, positive relationship between the ages at which hand banging and canonical babbling emerge (e.g., Cobo-Lewis, Oller, Lynch, & Levine, 1996; Eilers, Oller, Levine, Basinger, Lynch, & Urbano, 1993). That this relationship may suggest a developmental link between banging and babbling is underscored by the fact that it appears to be preserved in populations characterized by delayed or atypical patterns of development, including Down syndrome (Cobo-Lewis et al., 1996), Williams syndrome (Masataka, 2001), and preterm infants (Eilers et al., 1993).

Second, the rate of rhythmic arm activity in an experimental session (elicited by giving infants a rattle to shake) has been shown to relate to babbling experience; it is relatively low among prebabblers, increases substantially among infants who have just begun to babble, and then declines somewhat among infants who have been babbling for longer periods of time (but remains above that for prebabblers). It was important that the observed increase among new babblers was not uniform across the two hands, suggesting that it cannot simply be attributed to heightened arousal levels (Locke, Bekken, McMinn-Larson, & Wein, 1995).

Third, infants frequently coordinate rhythmic motor and vocal behavior (Iverson, 2002), and characteristics of these behaviors may be modified as a result of co-production. In a recent longitudinal study of Japanese infants, Ejiri and Masataka (2001) examined the acoustic characteristics of infant vocalizations that co-occurred with a bout of rhythmic motor activity and compared them to vocalizations produced without accompanying rhythmic movement. Relative to vocalizations produced alone, vocalizations co-occurring with rhythmic movement had significantly shorter syllable lengths and formant-frequency transitions. These are precisely the dimensions that distinguish the syllabic structure of canonical babble (and mature syllables in general) from precanonical vocalizations.

Thus, before children even begin to utter their first word, bodily action is coupled with the production of speech sounds. In the next section, we explore this relationship a step further and argue that the production of more directed types of bodily action—hand gestures—begins to shape language in children's one- and two-word speech.

Gesture and Early Language Production

By the end of the first year, the rhythmic repetition frequently observed in the motor and vocal activity of young infants begins to give way to more articulated control and more directed communication. In addition, between the ages of 9 and 12 months, most infants begin to produce communicative gestures (e.g., pointing, showing, requesting, and waving bye-bye). During this time, the close relationship between motor activity (now in the form of gestures) and language production continues to be apparent. Gestures and words begin to develop at roughly the same time, usually around the first birthday (e.g., Acredolo & Goodwyn, 1988). For many children, the production of first words is preceded by the appearance of first gestures (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Caselli, 1990). The emergence of pointing is a particularly good predictor of first-word onset, and gesture production is positively related to gains in language development between 9 and 13 months (Bates et al., 1979).

In the early stages of vocabulary development, word learning proceeds in a relatively slow and piecemeal process (e.g., Fenson, Dale, Reznick, Bates, Thal, & Pethick, 1994). During this time, many children also rely heavily on gestures to expand their communicative potential. Gestures that carry a fixed meaning (e.g., waving bye-bye, and smacking the lips for “fishie”) form an integral part of children’s communicative repertoires at this stage, and several observations suggest that development in the gestural and vocal systems is closely linked. First, children use words and gestures for the same communicative functions: referring, requesting, replying, and commenting (e.g., Acredolo & Goodwyn, 1988). Second, words and gestures are used in similar contexts to refer to the same general semantic domains, such as eating, drinking, and the appearance and disappearance of objects and people (e.g., Bates et al., 1979). Finally, there is usually little semantic overlap between individual verbal and gestural items. Thus, if a child produces a lip-smacking gesture to refer to instances of fish, it is unlikely that the word fish will also be produced, and if a child can say fish, then a corresponding gesture is unlikely to be in the child’s repertoire (Acredolo & Goodwyn, 1988; Caselli & Volterra, 1990; Iverson, Capirci, & Caselli, 1994).

After a period of relatively slow-paced word learning, most children begin to acquire words at a more rapid rate. At this point, children begin to make greater use of speech relative to gesture when communicating, and the acquisition of new gestures slows substantially (Iverson et al., 1994). Despite this greater focus on speech and word learning, however, gestures continue to be produced, and current evidence suggests that gesture plays an important role at the next major transition in language development: the emergence of two-word combinations. Several months before the transition to two-word speech, children begin to combine single gestures with single words. This is an important developmental achievement: The child who was previously limited to one word or one gesture at a time can now coordinate production of two elements within a single utterance frame.

Children’s first gesture–word combinations are often called complementary because the gestured and spoken elements convey similar or redundant information (e.g., pointing to a cup while saying “cup” or shaking the head no while saying “no”). A second type of gesture–word combination, supplementary combinations, emerges somewhat later and only after children have begun to produce some complementary combinations. In supplementary combinations, the gestured and spoken elements each convey a different (but related) piece of information about the referent (e.g., pointing to a cup while saying “mommy,” indicating that this is mommy’s coffee cup; waving bye-bye while saying “car” to convey that a car is driving away; Capirci, Iverson, Pizzuto, & Volterra, 1996; Goldin-Meadow & Butcher, in press).

Supplementary combinations are thus comparable to two-word combinations in that both convey similar amounts of information. When children produce a supplementary combination, they demonstrate the ability to coordinate production of two communicative elements and convey two different pieces of information in a single, integrated message. Both of these skills are required for the production of two-word utterances. This has led to the hypothesis that the emergence of supplementary gesture–word combinations may be an especially good indicator of the imminence of the transition to two-word speech. This prediction was confirmed in a recent longitudinal study carried out by Goldin-Meadow & Butcher (in press). These investigators followed 6 children longitudinally through the second year, with biweekly observations continuing until they began to produce two-word utterances. They reported a very strong and significant correlation ($r = .90$) between age of onset of supplementary combinations and the age at which two-word combinations first appeared. It is interesting, however, the predictive relationship between gesture–word and two-word combinations was specific to supplementary combinations: The corresponding correlation for complementary combinations, although positive ($r = .46$), was weaker and not statistically reliable. These results suggest that a child's status with respect to a major milestone in early language development—the onset of two-word speech—is foreshadowed by changes in gesture production, specifically production of gestures that add information to a co-occurring spoken element.

In sum, vocal–motor linkages are evident in the emergence and development of communicative gestures and words. Onset of first gestures predicts the appearance of first words. Gestures and words initially develop in tandem, and changes in gesture production are predictive of the emergence of two-word speech. In short, early language development appears to be firmly rooted in the body and bodily activity.

Language Comprehension

The previous two sections reviewed research that argued that a child's own nonverbal actions influence language production. The following section addresses the flip side to that question: How do nonverbal actions of other people in the social environment influence how a child learns language?

Children do not learn language in a social vacuum. On the contrary, language learning is only possible during face-to-face social interactions with others. During these interactions, parents do a lot more than just speak to their child. They glance. They point. They smile. Speech is inextricably embedded in a rich context of nonverbal action (Baldwin, 1993; Bates, 1976; Bruner, 1984; Moore, Angelopoulos, & Bennett, 1999; Morford & Goldin-Meadow, 1992; Tomasello, 1992). What effect do these nonverbal actions have on children's ability to comprehend language?

Developmental psychologists have known for many years that eye gaze is an important nonverbal action in establishing joint attention between an infant and adult (Bruner, 1984; Scaife & Bruner, 1975). Recent research suggests that even children as young as 6-months-old can follow an adult's gaze under certain circumstances (Morales, Mundy, & Rojas, 1998). This suggests that joint attention may lay the groundwork for later language learning (Baldwin, 1993; Moore et al., 1999). Indeed, Baldwin (1993) argued that 18-month-olds use an adult's eye gaze to infer the adult's intentions. For example, children learned names for novel objects more often when an experimenter looked at the objects while labeling them versus when the experimenter did not look.

In addition, nonverbal behaviors such as hand gestures may facilitate early language comprehension. To be sure, young language learners are very good at interpreting gestures, especially pointing gestures (Lempers, Flavell, & Flavell, 1976; Murphy & Messer, 1977). Subsequent research has argued that these and other types of gestures actually play a key role in early language comprehension (Allen & Shatz, 1983; Macnamara, 1977; Morford & Goldin-Meadow, 1992). For example, Morford and Goldin-Meadow (1992) demonstrated that children at the one-word stage were able to go beyond their verbal limitations and comprehend multiple pieces of information when they were communicated through both speech and hand gestures. In this way, young children appear to benefit from having communication distributed across multiple modalities during early language development.

These studies suggest that children may need the combination of speech and nonverbal behaviors to "get them off the ground" in learning language. In addition to the effects of nonverbal action on early language development, nonverbal actions continue to play a role later in development. For example, Povinelli, Reaux, Bierschwale, Allain, and Simon (1997) demonstrated that as children get older, they begin to interpret pointing gestures (gaze and gesture) in more sophisticated ways. Moreover, their understanding becomes different from the understanding of their primate relatives, chimpanzees, who on the surface appear to understand pointing gestures as well as human children. Povinelli et al. showed that human toddlers (2- and 3-year-olds) were able to understand the referential meaning of pointing gestures quite easily under a variety of conditions. However, adolescent chimpanzees (6- and 7-years-old) exhibited breakdowns in understanding the gestures when gesture-referent relationships became more complex (e.g., when the experimenters manipulated the distance between the gesture and referent). One may speculate from these results that perhaps young language learners (2 years and younger) are not so different from chimps in their superficial understanding of nonverbal gestures, but as human children get older they begin to differentiate themselves from chimpanzees and show a "special" understanding of nonverbal behaviors.

Indeed, nonverbal pointing behaviors appear to play a special role in very complex language processes later in development (Kelly, 2001; Thompson & Massaro, 1986, 1994). For example, Kelly (2001) studied the role that eye gaze and gesture played in 3- to 5-year-old's understanding of complex pragmatic utterances (e.g., uttering indirect requests, such as "I need to write something down" while pointing to and looking at a pen). Kelly discovered that the youngest children could not understand the indirect requests when speech was presented alone (just saying the words) or when the nonverbal behaviors were presented alone (just pointing and looking at the pen). However, when the two pieces of information were presented together, 3-year-olds showed excellent understanding of the requests. It is interesting that in addition to older children (4–5-year-olds) showing an excellent understanding when speech and nonverbal behaviors were presented together, they also showed a better understanding of speech or nonverbal behaviors when these were presented alone. Kelly argued that these results suggest that the synergistic combination of speech and nonverbal gestures may help very young children "break into" an understanding of complex forms of language, but as children get older, they become better at understanding the individual contributions of speech and nonverbal behaviors.

Other evidence that nonverbal actions help later language development come from blind children. Although research suggests that blind children develop certain aspects of language (syntax, phonology) as easily as sighted children (Landau & Gleitman, 1985), other research observes that blind children exhibit breakdowns in higher level language processes (semantics and pragmatics; Dunlea, 1989). For example, blind individuals have difficulty establishing reference and appealing to mutually known information among communicators. These deficits may be due to the fact that reference and mutual knowledge are accessed largely through nonverbal visual information, such as gestures and eye gaze.

Nonverbal pointing behaviors are not the only type of gestures that affect later language comprehension. Representational gestures also play a powerful role. A representational gesture imagstically depicts attributes, movements, or spatial relationships of objects and events. These gestures greatly complement the linear and segmented aspects of language (we will return to this distinction at the end of the article). Several studies have demonstrated that children are sensitive to these types of gestures during social and educational interactions (Church, Kelly, & Lynch, 2000; Kelly & Church, 1998). For example, Church et al. (2000) found that 7- and 10-year-olds integrated information conveyed through representational gestures that conveyed additional information to speech in tasks that required children to make knowledge assessments of other children. For example, when children were presented with speech that described one attribute of an object ("a tall glass") and a representational gesture that described a different aspect ("a thin glass"), these child observers often integrated the two pieces of information into both a tall and thin representation of the glass.

Researchers have explored the implications of this type of research in clinical and educational settings. For example, Brown and Thal (1997) noted that interventions that incorporated symbolic gestures facilitated language progress in toddlers with early specific expressive language delay. These findings generalize to normally developing children in educational contexts. Church, Ayman-Nolley, and Alibali (2001) found that 10-year-old children showed a better understanding of mathematical concepts when nonverbal gestures accompanied verbal instruction on the concepts. In this way, multimodal communication appears to facilitate learning and language development in typical and atypical populations

In sum, children not only appear to be neurally and cognitively suited to produce and comprehend language in a multimodal fashion, but multimodal communication may be an optimal way for children to tackle the tasks of learning language and other cognitive skills. In the next section, we extend this line of reasoning and explore how this multimodal processing continues into adulthood.

MOMENT TO MOMENT TIME FRAME

Traditionally, developmental psychologists and neuroscientists have focused on development that occurs either over phylogenic or ontogenetic time frames. However, development can be studied on a still smaller time frame: the moment-to-moment time frame. The moment-to-moment time frame is truly the front line of development. This section focuses on the moment-to-moment processing of language and gesture in adults. The way in which adults process language from one moment to the next will give researchers clues into how the adult neurocognitive system is designed to optimally process language. If adults process language in a multimodal fashion, this will provide insights into the continuity of the nonverbal influence on language processing over the entire developmental process.

Nontraditional Brain Areas and Language Processing

Traditional theories of language are based on evidence from lesion studies conducted by Broca and Wernicke over a century ago (Banich, 1997). However, recent research has revealed that language is not constrained to classic left-hemisphere language areas (Dronkers et al., 2000). Damage to many areas of the brain outside Broca's and Wernicke's areas result in language deficits, suggesting a new model of language not as an instinct residing in discrete cortical language areas, but an emergent skill based on a functional language system distributed over interacting modalities. Thus, new models of language include not only traditional brain areas, but also areas involved in different types of cognitive skills, such as sensori–motor and visuo–spatial abilities.

Subneocortical areas. The cerebellum is traditionally believed to be involved in the preparation and execution of sequential movements (Cui, Li, Zang, Weng, Ivry,

& Wang, 2000). This function, of course, has obvious relevance to language abilities. For example, researchers have implicated the cerebellum in the planning and execution of the articulatory movements involved in speaking (Dogil et al., 2002). Lesions of the cerebellum result in "ataxic dysarthria," a syndrome characterized by slowed speaking rate, distorted consonant and vowel productions, and impaired prosodic modulation of sentence utterances. The cerebellum supports acceleration of orofacial gestures and the timing of complex articulatory sequences in cooperation with the anterior perisylvian language zone and brain stem reflexes monitoring respiratory and laryngeal muscle activity (Ackermann & Hertrich, 2000).

However, recent research suggests that the cerebellum may also be involved in higher level cognitive functions. For example, the cerebellum is activated when humans perform cognitive and language tasks even in the absence of motor activity (Leiner, Leiner, & Dow, 1993). This activation is particularly strong when people engage in language tasks that involve visuo–spatial and sensori–motor skills (Fabbro, 2000). Moreover, children who have undergone surgery for the removal of vermal tumors have revealed that patients with right cerebellar tumors had disturbance of auditory sequential memory and language processing, whereas those with left cerebellar tumors showed deficits on tests of spatial and visual sequential memory (Grandcolas, 2000; Riva & Giorgi, 2000).

The structures of the thalamus and basal ganglia are associated with the organization and control of voluntary motor movements (Raeva, 1986). For example, the thalamus has recently been shown to play a role in the motoric aspects of speech production (Johnson & Ojemann, 2000). Moreover, researchers have shown that thalamic lesions cause aphasia characterized by fluent but paraphasic output, sometimes deteriorating to jargon (Crosson, 1986). Recent evidence suggests that the thalamic nuclei—especially ventro-lateral and pulvinar—in the language dominant hemisphere may be involved in language functioning, further validating the role of the thalamus in the production of speech and language (Stratton, 1980). Electrostimulation studies have discovered that stimulation of the left pulvinar disrupts verbal memory processing, whereas stimulation of the right pulvinar disrupts nonverbal memory processing (Johnson & Ojemann, 2000). Finally, the globus pallidus has also been shown to play a role in language. Troster et al. (1997) demonstrated that chronic stimulation of the globus pallidus resulted in disrupted semantic verbal fluency, as well as a decline in visuoconstructional ability.

Neocortical areas. The temporo-parieto-occipital junction in the left hemisphere is associated with the perception of spatial relationships. Studies of patients with infarctions to this region demonstrate an auditory comprehension deficit characterized by preserved understanding of single words but impaired understanding of grammatically complex constructions (Hier, Mogil, Rubin, & Komros, 1981). These researchers proposed that this deficit reflects an inability to fully grasp the meaning of words and grammatical constructions imbued with spatial information.

The occipital lobe is traditionally thought to be responsible for visual processing. Indeed, research suggests that the inferior visual association cortex is critical for gesture comprehension, whereas superior portions of this structure are critical for imitating or performing pantomime to an object presented visually (Rothi, Mack, & Heilman, 1986). However, the occipital lobe is also involved in certain language skills. In one case study, a woman recovering from aphasia had an additional hemorrhage in the right occipital lobe that caused deficits in comprehension, repetition, and writing and verbal expression (Nelles, Sullivan, Kaplan, Klein, & Calvanio, 1998). Another case study describes a participant with an injury involving the medial portion of the occipital lobe in the left hemisphere. This patient lost the ability to name and pantomime the use objects presented visually or tactually, although his recognition abilities were fully intact (Endo, Makishita, Yanagisawaa, & Sugishita, 1996).

Though traditional language research has not given much attention to the right hemisphere, recent work suggests that this "lesser" hemisphere may be crucial for language skills. Patients with right-hemisphere brain damage (RBD) have disrupted communication abilities, including problems with affect and visuo-spatial processing (Brownell, Gardner, Prather, & Martino, 1998). In one study investigating patients with a developmental language disorder, functional magnetic resonance imaging (fMRI) data showed that low performance on facial affect detection and spatial rotation tasks correlated with smaller gray matter volume within the right supramarginal gyrus (Plante, Boliek, Mahendra, Story, & Glaspey, 2001). In addition, destruction of the basal ganglia, insula, and the anterior temporal lobe in the right hemisphere results in patients' inability to comprehend emotional significance from language, specifically due to problems understanding others' intonation and facial expressions (Cancelliere & Kertesz, 1990).

Another relevant characteristic of patients with right hemisphere damage is their inability to understand spatial relationships in speech. A study by Gardner and Denes (1973) demonstrated that patients with various types of RBD had trouble matching linguistic concepts such as wealth or poverty with nonrepresentational line drawings, such as an up or down arrow. RBD patients also have trouble with idioms that involve physical metaphors, such as "He has a heavy heart" (Brownell, Gardner, Prather, & Martino, 1995).

Speech, action, and brain. Recent research has shown that traditional motor areas in the cortex are involved in language processing. For example, Etard, Mellet, Papathanassiou, Benali, and Houde (2000) performed positron emission tomography (PET) scans of people performing a lexical retrieval task and found that semantic processing of action words activated sensory and motor areas—supplementary motor area and precentral gyrus—in the brain. In a similar vein, Pulvermueller, Hearle, and Hummel (2001) used source analyses from a high-density electroencephalogram (EEG) and discovered that during the semantic processing of action verbs, the areas most active on the motor strip were those associated with the body part used to perform or carry out the action being processed. For example, saying or thinking about the verb grasp activated hand and forearm areas on the motor cortex. This research indicates that thinking about actions shares cortical activation with actually performing them (Pulvermueller et al., 2001). Moreover, damage to the sensory and motor cortex disrupts linguistic processing. Neininger and Pulvermueller (2001) studied a patient with a minor lesion on the motor, premotor, and somatosensory areas associated with the hand in the right hemisphere. They discovered that the patient had slower and less accurate responses to action verbs compared with the other word categories. These studies suggest that words are not entirely abstract and as removed from the body as some would argue.

In fact, researchers have found that the production of actions can facilitate language processing. For example, Hanlon, Brown, and Gerstman (1990) found that activation of the archaic proximal motor system (shoulder muscle) during the execution of communicative gestures facilitated performance in a word naming task. This facilitation effect was demonstrated in a nonfluent aphasia subgroup (Broca's and global aphasics) but not in a fluent group (Wernicke's aphasics), providing evidence that the production of nonverbal communicative gesture is intrinsically tied to language production (Hanlon et al., 1990). These results support their theory that nonverbal actions and language share common roots, and the functional activation of relevant muscles might tap into the core of language processing in the brain during word retrieval (see Hanlon & Brown, 1988).

In summary, language appears to rely on many nontraditional brain areas that are implicated in many different types of functions: high-level action control, sensory-motor integration, and visuo-spatial processing. It is important to note that these functions are also perfectly suited for gestural communication. This reveals not only a neuroanatomical, but also a psychological, link between verbal and nonverbal gestural communication. In the next section, we explore this relationship by reviewing research that demonstrates that hand gestures are tightly connected to speech at the psychological level of analysis.

Gesture and Speech at the Psychological Level

Speech and gesture convey information in two very different ways. McNeill (1992) explained that speech is linear, segmented, and arbitrary, whereas gesture is global, synthetic, and imagistic. Consider an example. A friend who recently had a car accident might tell you, "I didn't see it coming," while simultaneously making two flat-handed gestures coming together in a *T* shape. The speech describes the state of affairs at the time of the accident, but the gesture describes the spatial orientation of the vehicles, demonstrates the path of the vehicles, and indicates why your friend did not see it coming—she was blindsided by the oncoming car. Thus, speech is particularly good at doing some things (e.g., concrete and abstract description), and gesture is particularly good at other things (e.g., concrete description, demonstration, and indication). Together, speech and gesture reflect multiple pathways into what someone is thinking during communication. Later, we review research that suggests that gestures do a play an important cognitive role when people produce and comprehend language.

Some researchers have argued that gestures are used to help communicators access lexical entries when speaking (Hadar, Wenkert-Olenik, Krauss & Soroker 1998; Morrel-Samuels & Krauss 1992; Rauscher, Krauss, & Chen 1996). Indeed, gesture—because it exploits a different representational format than speech—is well suited for such a task. If someone has a word in mind and cannot find the matching lexical entry, a gesture may imagistically prime access to that word. However, there is no reason to believe that this is the only relationship gestures have with speech. In fact, McNeill (1992) argued that gestures and speech have a much deeper relationship. In his view, gesture and speech make up an integrated system of communication and are tightly linked at a deep conceptual level. The strength of this link has been demonstrated in observations of natural communication. For example, McNeill (1997) analyzed many hours of natural language production across many languages and found that speech and gesture interact at lexical, syntactic, and discourse levels to mutually capture and express thought. In fact, gesture appears so fundamentally linked to speech that it has been observed in congenitally blind speakers (Iverson, 1999; Iverson & Goldin-Meadow, 1997) even when they interact with another blind speaker (Iverson & Goldin-Meadow, 1998).

This view of an integrated relationship of speech and gesture receives empirical support from a recent study. Goldin-Meadow, Nusbaum, Kelly, and Wagner (2001) demonstrated that hand gestures—particularly deictic gestures—play a role in how people think during communication. In that study, 10-year-olds and adults were asked to explain their understanding of difficult mathematical problems. The main finding was that when participants gestured while they explained the problems, they performed better on a secondary cognitive load task (remembering words) than when they did not gesture. One interpretation of these results is that the act of gesturing while speaking distributed cognitive effort in parallel across different representational formats (visuo–spatial and linguistic), thus freeing linguistic processing space to think through one's explanation. Findings such as these suggest that gestures and speech may be related at a deep, conceptual level during language production.

There is also ample evidence that speech and gesture are linked during comprehension for adult communicators (Alibali, Flevares, & Goldin-Meadow, 1997; Goldin-Meadow & Sandhofer, 1999; Goldin-Meadow, Wein, & Chang, 1992;

Kelly, Barr, Church, & Lynch, 1999; Kelly & Church, 1998; McNeill, Cassell, & McCullough, 1994). Adults often integrate what they see in gesture into what they think they hear in speech. For example, Goldin-Meadow and Sandhofer (1999) observed natural adult–child interactions and discovered that adults often incorporated children's deictic and representational gestures into what they thought that children had verbally explained (about Piagetian conservation problems) in their speech. This has obvious educational implications. In fact, Alibali et al. (1997) demonstrated that teachers often incorporate gestured information into their assessments of children's mathematical knowledge.

These findings generalize to other types of interactions. For example, Kelly et al. (1999) showed videotapes of people producing pragmatically ambiguous speech to one another. They demonstrated that pointing gestures greatly influenced adult's interpretation of the speech, for example, saying, "Are you going out the back door," while pointing to an overflowing garbage container. Moreover, they argued that speech and gesture mutually disambiguated the pragmatic meaning. Specifically, they compared this video segment to the same segment with the volume muted and found that people were much better at identifying the referent of the pointing gesture (the garbage bag) when speech accompanied gesture versus when gestures appeared alone. The researchers interpreted these results as evidence that speech and gesture are tightly linked at comprehension, such that gestures not only disambiguate the meaning of speech (the traditional view), but that speech also disambiguates gesture.

In sum, gestures appear to be linked to adult speech on multiple levels of analysis, from neural to cognitive to social. The fact that this link is in place well into adulthood suggests that gestures are not merely a vestige of our evolutionary and developmental past, but are something that is fundamental to how fully formed humans continue to communicate in the present.

CONCLUSION

Language has come a long way. However, just as it is good to return home after a long journey, we have argued in this article that there is much to be gained by bringing language back to its original habitat—the body. The body most likely had a powerful role in shaping language over evolutionary time. Indeed, there appear to be functional and mechanistic links between present-day language and communication systems in our past. Moreover, this influence is still with us today. We have argued that nonverbal actions continue to shape language in children's development. Also, the fact that nonverbal actions play a role in adult language suggests that the human mind may be optimally designed to process language and nonverbal gestures. It is our hope that this return of language to its home will influence researchers to see language in a new, but familiar, way.

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