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Gesture, sign, and language: The coming of age of sign language and gesture studies

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Abstract: How does sign language compare with gesture, on the one hand, and spoken language on the other? Sign was once viewed as nothing more than a system of pictorial gestures without linguistic structure. More recently, researchers have argued that sign is no different from spoken language, with all of the same linguistic structures. The pendulum is currently swinging back toward the view that sign is gestural, or at least has gestural components. The goal of this review is to elucidate the relationships among sign language, gesture, and spoken language. We do so by taking a close look not only at how sign has been studied over the past 50 years, but also at how the spontaneous gestures that accompany speech have been studied. We conclude that signers gesture just as speakers do. Both produce imagistic gestures along with more categorical signs or words. Because at present it is difficult to tell where sign stops and gesture begins, we suggest that sign should not be compared with speech alone but should be compared with speech-plus-gesture. Although it might be easier (and, in some cases, preferable) to blur the distinction between sign and gesture, we argue that distinguishing between sign (or speech) and gesture is essential to predict certain types of learning and allows us to understand the conditions under which gesture takes on properties of sign, and speech takes on properties of gesture. We end by calling for new technology that may help us better calibrate the borders between sign and gesture.

Keywords: categorical; gesture-speech mismatch; gradient; homesign; imagistic; learning; morphology; phonology; syntax

One of the most striking aspects of language is that it can be processed and learned as easily by eye-and-hand as by ear-and-mouth – in other words, language can be constructed out of manual signs or out of spoken words. Nowadays this is not a controversial statement, but 50 years ago there was little agreement about whether a language of signs could be a "real" language: that is, identical or even analogous to speech in its structure and function. But this acceptance has opened up a series of fundamental questions. Welcoming sign language into the fold of human languages could force us to rethink our view of what a human language is.

Our first goal in this article is to chart the three stages that research on sign language has gone through since the early 1960s. (1) Initially, sign was considered nothing more than pantomime or a language of gestures. (2) The pendulum then swung in the opposite direction – sign was shown to be like speech on many dimensions, a surprising result because it underscores the lack of impact that modality has on linguistic structure. During this period, sign was considered a language just like any other language. (3) The pendulum is currently taking another turn. Researchers are discovering that modality does influence the structure of language, and some have revived the claim that sign is (at least in part) gestural.

But in the meantime, gesture – the manual movements that speakers produce when they talk – has become a popular topic of study in its own right. Our second goal is to review this history. Researchers have discovered that gesture is an integral part of language – it forms a unified system with speech and, as such, plays a role in processing and learning language and other cognitive skills. So what, then, might it mean to claim that sign is gestural? Perhaps it is more accurate to say that signers gesture just as speakers do – that is, that the manual movements speakers produce when they talk are also found when signers sign.

Kendon (2008) has written an excellent review of the history of sign and gesture research, focusing on the intellectual forces that led the two to be considered distinct categories. He has come to the conclusion that the word "gesture" is no longer an effective term, in part because it is often taken to refer to *nonverbal* communication, paralinguistic behaviors that are considered to be outside of language. He has consequently replaced the word with a superordinate term that encompasses both gesture and sign – visible action as utterance (Kendon 2004). By using a superordinate term, Kendon succeeds in unifying all phenomena that involve using the body for communication, but he also runs the risk of blurring distinctions among different uses of the body, or treating all distinctions as equally important.

We agree with Kendon's (2008) characterization of the history and current state of the field, but we come to a different conclusion about the relationships among sign, gesture, and language or, at the least, to a different focus on what we take to be the best way to approach this question. Our third goal is to articulate why. We argue that there are strong empirical reasons to distinguish between linguistic forms (both signed and spoken) and gestural forms – that doing so allows us to make predictions about learning that we would not otherwise be able to make. We agree with Kendon that gesture is central to language and is not merely an add-on. This insight leads us (and Kendon) to suggest that we should not be comparing all of the movements signers make to speech, simply because some of these movements have the potential to be gestures. We should, instead, be comparing signers' productions to speech-plus-gesture. However, unlike Kendon, whose focus is on the diversity of forms used by signers versus speakers, our focus is on the commonalities that can be found in signers' and speakers' gestural forms. The gestural elements that have recently been identified in sign may be just that – co-sign gestures that resemble co-speech gestures – making the natural alignment sign-plus-gesture versus speech-plus-gesture. Sign may be no more (and no less) gestural than speech is when speech is taken in its most natural form: that is, when it is produced along with gesture. We conclude that a full treatment of language needs to include both the more categorical (sign or speech) and the more imagistic (gestural) components regardless of modality (see also Kendon 2014) and that, in order to make predictions about learning, we need to recognize (and figure out how to make) a critical divide between the two.

Our target article is thus organized as follows. We first review the pendulum swings in sign language research (sects. 2, 3, 4), ending where the field currently is – considering the hypothesis that sign language is heavily gestural. We then review the contemporaneous research on gesture (sects. 5, 6); in so doing, we provide evidence for the claim that signers gesture, and that those gestures play some of the same roles played by speakers' gestures. We end by considering the implications of the findings we review for the study of gesture, sign, and language (sect. 7). Before beginning our tour through research on sign and gesture, we consider two issues that are central to the study of both – modality and iconicity (sect. 1).

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1. Modality and iconicity

Sign language is produced in the manual modality, and it is commonly claimed that the manual modality offers greater potential for iconicity than the oral modality (see Fay et al. 2014 for experimental evidence for this claim). For example, although it is possible to iconically represent a cat using either the hand (tracing the cat's whiskers at the nose) or the mouth (saying "meow," the sound a cat makes), it is difficult to imagine how one would iconically represent more complex relations involving the cat in speech – for example, that the cat is sitting under a table. In contrast, a relation of this sort is relatively easy to convey in gesture – one could position the right hand, which has been identified as representing the cat, under the left hand, representing the table. Some form-to-world mappings may be relatively easy to represent iconically in the oral modality (e.g., representing events that vary in speed, rhythm, repetitiveness, duration; representing events that vary in arousal or tension; representing objects that vary in size; but see Fay et al. 2014). However, there seems to be a greater range of linguistically relevant meanings (e.g., representing the spatial relations between objects; the actions performed on objects) that can be captured iconically in the manual modality than in the oral modality.

Many researchers have rightly pointed out that iconicity runs throughout sign languages (Cuxac & Sallandre 2007; Fusellier-Souza 2006; Taub 2001) and that this iconicity can play a role in processing (Thompson et al. 2009; 2010), acquisition (Casey 2003; Slobin et al. 2003), and metaphoric extension (Meir 2010). But it is worth noting that there is also iconicity in the oral modality (Perniss et al. 2010; see also Haiman 1980; Nygaard et al. 2009a; 2009b; Shintel et al. 2006 – more on this point in sect. 7.2), and that having iconicity in a system does not preclude arbitrariness, which is often taken as a criterion for language (Hockett 1960; de Saussure 1916, who highlighted the importance of the arbitrary mapping between the signifier and the signified). Indeed, Waugh (2000) argues that it is time to "slay the dragon of arbitrariness" (p. 45) and embrace the link between form and meaning in spoken language. According to Waugh, linguistic structure at many levels (lexicon, grammar, texts) is shaped by the balance between two dynamical forces centered on the relation between form and meaning – one force pushing structures toward iconicity, and the other pushing them toward non-iconicity. Under this view, iconicity is a natural part of all languages (spoken or signed). We therefore do not take the presence of iconicity in a system as an indicator that the system is not a language.

2. Sign language is not a language

In 1880, the International Congress of the Educators of the Deaf, which met in Milan, passed a resolution condemning the use of manualist methods to teach language to deaf children (Facchini 1983). This resolution reflected the widespread belief that sign was not an adequate language, an attitude that educators of the deaf continued to hold for many years (see Baynton 2002 for a description of the cultural attitudes that prevailed during this period). As an example, in his book, *The Psychology of Deafness*, Myklebust (1960, p. 241) described sign language as "more pictorial, less symbolic" than spoken language, a language that "falls mainly at the level of imagery." In comparison with verbal symbol systems, sign languages "lack precision, subtlety, and flexibility." At the time, calling a language pictorial was tantamount to saying it was not adequate for abstract thinking.

At the same time as Myklebust was writing, discoveries in linguistics were leading to a view that speech is a special vehicle for language. For example, listeners do not accurately perceive sounds that vary continuously along a continuum like voice-onset-time (VOT). Rather, they perceive these sounds in categories – they can easily distinguish between two sounds on the VOT continuum that are on different sides of a categorical boundary, but they cannot easily distinguish between two sounds that are the same distance apart on the VOT continuum but fall within a single category. Importantly, these perceptual categories match the phonetic categories of the language the listeners speak (Liberman et al. 1967). This phenomenon, called categorical perception (see Harnad 1987 for a thorough treatment), was at first believed to be restricted to speech, and indeed, early attempts to find categorical perception in sign were not successful (Newport 1982; but see Baker et al. 2005, 2006; Emmorey et al. 2003). Subsequent work has shown that categorical perception is not unique to humans (Kuhl & Miller 1975) nor to speech sounds (Cutting & Rosner 1974). But, at the time, it seemed important to show that sign had the characteristics of speech that appeared to make it a good vehicle for language.[1]

Even more damaging to the view that sign is a language was the list of 13 design features that Hockett (1960) hypothesized could be found in all human languages. Hockett considered some of the features on the list to be so obvious that they almost went without saying. The first of these obvious features was the vocal-auditory channel, which, of course, rules out sign language. Along the same lines, Landar (1961, p. 271) maintained that "a signalling system that does not involve a vocal-auditory channel directly connecting addresser and addressee lacks a crucial design-feature of human language." Interestingly, however, by 1978, Hockett had revised his list of design features so that it no longer contained the vocal-auditory channel, a reflection of his having been convinced by this time that sign language does indeed have linguistic structure.

One of the important steps on the way to recognizing sign as a language was Stokoe's linguistic analysis of American Sign Language (ASL) published in 1960. He argued that sign had the equivalent of a phonology, a morphology, and a syntax, although he did point out differences between sign and speech (e.g., that sub-morphemic components are more likely to be produced simultaneously in sign than in speech). Despite this impressive effort to apply the tools of linguistics to sign language, there remained great skepticism about whether these tools were appropriate for the job. For example, DeMatteo (1977) attempted to describe syntactic relationships, morphological processes, and sign semantics in ASL and concluded that the patterns cannot be characterized without calling upon visual imagery. The bottom-line – that "sign is a language of pictures" (DeMatteo 1977, p. 111) – made sign language seem qualitatively different from spoken language, even though DeMatteo did not deny that sign language had linguistic structure (in fact, many of his analyses were predicated on that structure). Looking back on DeMatteo's work now, it is striking that many of the issues he raised are again coming to the fore, but with a new focus (see sect. 4). However, at the time, DeMatteo's concerns were seen by the field as evidence that sign language was different from spoken language and, as a result, not a "real" language.

3. Sign language is just like spoken language and therefore a language

One of the best ways to determine whether sign language is similar to, or different from, spoken language is to attempt to characterize sign language using the linguistic tools developed to characterize spoken language. Building on the fundamental work done by Stokoe (1960), Klima and Bellugi and their team of researchers (1979) did just that, and fundamentally changed the way sign language was viewed in linguistics, psychology, and deaf education.[2]

For example, Lane et al. (1976) conducted a study, modeled after Miller and Nicely's (1955) classic study of English consonants, which was designed to identify features in ASL handshapes. Miller and Nicely began with theoretically driven ideas in linguistics about the phonetic and phonological structure of English consonants, and used their experiment to determine the perceptual reality of these units. The basic aim of the study was to examine the confusions listeners made when perceiving syllables in noise. Consonants hypothesized to share several features were, in fact, confused more often than consonants hypothesized to share few or no features, providing evidence for the perceptual reality of the features. Lane et al. (1976) conducted a comparable study on features of ASL handshapes based on Stokoe's (1960) list of hand configurations. They presented hand configurations under visual masking to generate confusions and used the confusability patterns to formulate a set of features in ASL hand configurations. They then validated their findings by demonstrating that they were consistent with psycholinguistic studies of memory errors in ASL. Along similar lines, Frishberg

(1975) showed that processes found in spoken language (e.g., processes that neutralize contrasts across forms, or that assimilate one form to another) can account for changes seen in ASL signs over historical time; and Battison (1978) showed that assimilation processes in spoken language can account for the changes seen in fingerspelled forms (words spelled out as handshape sequences representing English letters) as they are "borrowed" into ASL. Studies of this sort provided evidence for phonological structure in at least one sign language, ASL.

Other studies of ASL followed at different levels of analysis. For example, Supalla (1982) proposed a morphological model of verbs of motion and location in which verb stems contain morphemes for the motion's path, manner, and orientation, as well as classifier morphemes marking the semantic category or size and shape of the moving object (although see discussions in Emmorey 2003); he then validated this linguistic analysis using acquisition data on deaf children acquiring ASL from their deaf parents. Fischer (1973) showed that typical verbs in ASL are marked morphologically for agreement in person and number with both subject and object (see also Padden 1988), as well as for temporal aspect (Klima & Bellugi 1979); in other words, ASL has inflectional morphology. Supalla and Newport (1978) showed that ASL has noun–verb pairs that differ systematically in form, suggesting that ASL also has derivational morphology. In a syntactic analysis of ASL, Liddell (1980) showed that word order is SVO in unmarked situations, and, when altered (e.g., in topicalization), the moved constituent is marked by grammatical facial expressions; ASL thus has syntactic structure.

These early studies of ASL make it clear that sign language can be described using tools developed to describe spoken languages. In subsequent years, the number of scholars studying the structure of sign language has grown, as has the number and variety of sign languages that have been analyzed. We now know quite a lot about the phonological, morphological, and syntactic structure of sign languages. In the following sections, we present examples of structures that are similar in sign and speech at each of these levels.

3.1. Phonology

Sign languages have features and segmental structure (Brentari 1998; Liddell & Johnson 1989; Sandler 1989), as well as syllabic and prosodic structure (Brentari 1990a; 1990b; 1990c; Perlmutter 1992; Sandler 2010; 2012b), akin to those found in spoken languages. A clear example of a feature that applies in a parallel way in spoken and signed language phonology is *aperture*. Spoken language segments can be placed on a scale from fully closed (i.e., stops /p, t, k, b, d, g/, which have a point of full closure), to fully open (i.e., vowels /a, i, u/), with fricatives /s, z/, approximates /l, r/, and glides /w, j/ falling in between. Handshapes in sign languages can be placed along a similar scale, from fully closed (the closed fist handshape) to fully open (the open palm handshape), with flat, bent, and curved handshapes in between. In spoken languages, there are phonotactics (phonological rules) that regulate the sequence of open and closed sounds; similarly, in ASL, phonotactics regulate the alternations between open and closed handshapes (Brentari 1998; Friedman 1977; Sandler 1989).

Sub-lexical phonological features are used in both spoken and signed languages to identify minimal pairs or minimal triples – sets of words that differ in only one feature (***p****at* vs. ***b****at* vs. ***f****at* in English; APPLE vs. CANDY vs. NERVE in ASL, see Fig. 1). The three sounds in bold are all bilabial and all obstruent, but /b/ differs from /p/ in that it is [+voice] and /f/ differs from /p/ in that it is [+continuant]; [voice] and [continuant] can vary independently. The three signs differ in handshape features (the number of fingers that are "selected," and whether the fingers are straight or bent): The handshape in CANDY differs from the handshape in APPLE in that the index finger is straight instead of bent (a feature of joint configuration, in this case aperture, as just described), and the handshape in NERVE differs from the handshape in APPLE in that there are two fingers bent instead of one (a feature of selected finger group). These features, like their spoken language counterparts, can also vary independently.

Liddell (1984) pointed out the functional similarities between vowels in spoken languages and movements in sign. Syllables in sign languages are based on number of movements (Brentari 1998), just as syllables in spoken language are based on number of vowels.

3.2. Morphology

We also see similarities between spoken and signed languages at the morphological level (Meir 2012). Reduplication

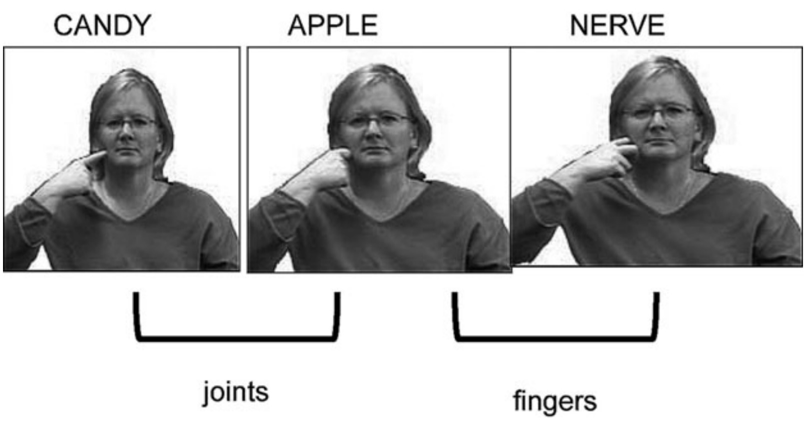

Figure 1. A set of three signs in ASL that differ from each other in only one handshape feature and thus form minimal pairs (Brentari 1998, reprinted with permission of MIT Press).

is a morpho-phonological process that both signed and spoken languages undergo, and recent work has shown that native users of both types of languages treat reduplication as a rule in their grammars. Reduplication takes many forms in spoken languages, but one common form is consonant reduplication at the right edge of a word in Semitic languages. For example, the Hebrew word *simem* (English: to drug, to poison) is formed from a diconsonantal root (*sm*, or AB), which has undergone reduplication (*smm,* or ABB) (Bat-El 2006; McCarthy 1981); words with reduplication at the left edge (*ssm*, or AAB) are unattested in Hebrew. Berent et al. (2001) showed that Hebrew speakers take longer to decide whether a non-word is an actual word if the non-word has the ABB pattern (i.e., if it behaves like a real word) than if it has the AAB pattern, suggesting that speakers have a rule that interferes with their judgments about novel non-words.

The same process takes place in reduplication in ASL (Supalla & Newport 1978). For example, one-movement stems can surface as single movements when used as a verb but as reduplicated restrained movements when used as a noun; CLOSE-WINDOW vs. WINDOW (Fig. 2, top). Berent et al. (2014) hypothesized that if reduplication is a core word-formational rule for ASL signers as it is for Hebrew speakers, then signers should have slower reaction times when deciding whether a disyllabic, reduplicated non-sign is an actual sign than if the non-sign is disyllabic but not reduplicated. Disyllabic signs in which the movement was reduplicated according to a derivational process in ASL (see Fig. 2, bottom left) were, in fact, more difficult for signers to reject (i.e., had longer reaction times) than disyllabic signs in which the movement was not reduplicated (Fig. 2, bottom right). Reduplication appears to be a core word-formational strategy for signers as well as speakers.

Figure 2. The top pictures display a noun-verb pair in ASL (Brentari 1998, reprinted with permission of MIT Press); the movement is reduplicated (two identical syllables) in the noun, WINDOW (top left), but not in the verb, CLOSE-WINDOW (top right). The bottom pictures display nonsense signs, both of which are disyllabic (i.e., they both contain two movements). The movement is reduplicated in the sign on the left, following a derivational process in ASL, but not in the sign on the right. Signers had more difficulty rejecting nonsense forms that followed the reduplication process characteristic of actual ASL signs (the left sign) than signs that violated the process (the right sign) (Berent et al. 2014).

3.3. *Syntax*

In syntax, many of the constituent structures found in spoken languages are the same as those found in sign languages. Consider, for example, relative clauses in Italian, English, Italian Sign Language (LIS), and ASL (see example 1). All four languages have complex sentences containing relative clauses, although each language has a different way of marking that clause. Italian (1a) and English (1b) both use complementizers to introduce the relative clause. Both LIS (1c) and ASL (1d) also use complementizers, along with raised eyebrows over the relative clause. LIS puts the complementizer, the sign PE, at the right edge of the relative clause, whereas ASL puts the complementizer, the sign WHO, at the left edge.

(1) Relative clause structures in Italian, English, Italian Sign Language (LIS), and ASL.

a. l'uomo [***che*** *lavora di sotto*] è un amico. [Italian]

b. The man [**who** works downstairs] is my friend. [English]

brow raise
c. UOMO [*LAVORA DI SOTTO* ***PE***] AMICO MIO. [LIS]

brow raise
d. MAN **[*WHO*** *WORKS DOWNSTAIRS*] MY FRIEND. [ASL]

As another example, *pro-drop* is a common phenomenon found in both spoken languages (e.g., Spanish and Italian) and sign languages (e.g., ASL, Brazilian Sign Language, and German Sign Language, Glück & Pfau 1999; Lillo-Martin 1986; Quadros 1999). *Pro-drop* occurs when a verb contains morphology that refers to its arguments, permitting those arguments to be dropped in speech (e.g., Italian, see example 2a) and sign (e.g., ASL, see example 2b). The subscript a's and b's in the ASL example indicate that the sign for Mary was placed in location b, the sign for John was placed in location a, and the verb sign ASK was moved from a to b, thereby indicating that John asked Mary. Because the argument signs had been set up in space in the initial question (i), the response (ii) could contain only the verb ASK, which incorporated markers for its arguments, that is, ${}_{a}ASK_{b}$. In the Italian example, note that the initial question contains nouns for both the subject *Maria* and the indirect object *Gianni*; the subject (she) is also marked on the auxiliary verb *ha,* as is the direct object clitic *l'* (*it*, standing in for *the question*). The response (ii) contains no nouns at all, and the subject (she), indirect object (to-him), and direct object (it) are all marked on the auxiliary verb *gliel'ha.* The argument information is therefore indicated in the verb in Italian, just as it is in ASL.[3]

(2) Null arguments in Italian (a) and ASL (b).

a. i. Maria l'ha domandata a Gianni? [Italian]
Maria it-has-she asked to Gianni
"Has Maria asked it [the question] to Gianni?"

ii. Sí, gliel'ha domandata.
Yes, to-him-it-has-she asked
"Yes, she has asked him it."

b. i. MARY_b JOHN_a $_a\text{ASK}_b$? [ASL]
Mary John he-asked-her
"Did John ask Mary?"

ii. YES, $_a\text{ASK}_b$.
Yes, he-asked-her
"Yes, he asked her."

4. Sign language is not like spoken language in all respects – could the differences be gestural?

Despite evidence that many of the same formal mechanisms used for spoken languages also apply to sign languages, there are striking grammatical differences between the two kinds of languages. Some of these differences are differences in degree. In other words, the difference between sign and speech can be accounted for by the same mechanisms that account for differences between two spoken languages. Other differences are more qualitative and do not fit neatly into a grammatical framework. We provide examples of each type of difference in the next two sections.

4.1. Differences between sign language and spoken language that can be explained within a grammatical framework

We return to the minimal pairs displayed in Figure 1 to illustrate a difference between sign and speech that can be explained using linguistic tools. The English word *pat* contains three timing slots (segments) corresponding to /p/, /a/, and /t/. Note that the feature difference creating the minimal pairs is on the first slot only. In contrast, the feature difference creating the minimal pairs in the three signs, CANDY, APPLE, and NERVE, is found throughout the sign.

At one time, this difference in minimal pairs was attributed to the fact that English is a spoken language and ASL is a sign language. However, advances in phonological theory brought about by autosegmental phonology (Goldsmith 1976) uncovered the fact that some spoken languages (languages with vowel harmony, e.g., Turkish, Finnish, and languages with lexical tones, e.g., the Chadic language Margi, the Bantu language Shona) have "ASL type" minimal pairs. When the plural suffix *–lar* is added to the Turkish word *dal* (English "branch"), the [-high] vowel in the suffix is [+back], matching the [+back] vowel [a] in the stem. But when the same plural suffix is added to the word *yel* (English "wind"), the [-high] vowel in the suffix is [-back], matching the [-back] vowel [e] in the stem. The important point is that the vowel feature [±back] has one value that spreads throughout the entire word, just as the features of the selected fingers in ASL have one value that spreads throughout the entire sign (Sandler 1986). Minimal pairs in sign and speech can thus be described using the same devices, although the distribution of these devices appears to differ across the two types of languages – vowel harmony and lexical tone patterns are not as widespread in spoken languages as the selected finger patterns of handshape are in sign languages.

As a second example, we see differences between signed and spoken languages in the typical number of morphemes and the number of syllables that are contained within a word (Brentari 1995; 1998; 2011; 2012). *Morphemes* are the meaningful, discrete, and productive parts of words – stems (morphemes that can stand alone as words) and affixes (prefixes and suffixes that attach to existing words and change either the part of speech or the meaning of the word). In English, *character–istic–ally* has three morphemes: the noun stem *character*, defined as "the distinctive nature of something" (Oxford English Dictionary, originally from Greek *kharakter*), followed by two suffixes that change it into first an adjective (*-istic*) and then an adverb (*-ally*). Morphemic units in sign languages meet the same criteria used for spoken language (meaningful, discrete, productive), and can assume any one of the five parameters of a sign – for example, a non-manual movement – pressing the lips together with a squint – can be added to many activity verbs (e.g., FISH, COOK, PLAN, READ, WRITE, LOOK-FOR) and is produced across the entire sign; the resulting meaning is *to-x-carefully*. In contrast, *syllables* are meaningless parts of words, based on vowels in speech – for example, the stem *character* [kæ.ɹək.tɝ] has three syllables, each marked here by a period. Recall that syllables in sign languages are determined by the number of movements – for example, CLOSE-WINDOW in Figure 2 has one movement and is therefore one syllable; WINDOW has two movements and is therefore disyllabic (Brentari 1998).

Importantly, morphemes and syllables are independent levels of structure. Figure 3 presents examples of each of the four types of languages that result from crossing these two dimensions (number of syllables, number of morphemes) – a 2 × 2 typological grid. Surveying the languages of the world, we know that some have an abundance of words that contain only one morpheme (e.g., Hmong, English), whereas others have an abundance of words that are polymorphemic (e.g., ASL, Hopi). Some languages have many words that contain only one syllable (e.g., Hmong, ASL); others have many words that are polysyllabic (e.g., English, Hopi).

English (Fig. 3, top right) tends to have words composed of several syllables (polysyllabic) and one morpheme (monomorphemic); *character* [kæ.ɹək.tɝ] with three syllables and one morpheme is such a word. Hmong (top left) tends to have words composed of a single syllable and a single morpheme (Ratliff 1992; Golston & Yang 2001). Each of the meaningful units in the Hmong sentence *Kuv. noj. mov. lawm.* (English: "I ate rice") is a separate monomorphemic word, even the perfective marker *lawm*, and each word contains a single syllable (each marked here by a period). Hopi (bottom right) tends to have words composed of many morphemes, each composed of more than one syllable; the verb phrase *pa.kiw.–maq.to.–ni.* (English: "will go fish-hunting") is a single word with three morphemes, and the first two of these morphemes each contains two syllables (Mithun 1984). Finally, ASL (bottom left) has many words/signs composed of several morphemes packaged into a single syllable (i.e., one movement). Here we see a classifier form that means *people–goforward–carefully*, which is composed of three single-syllable morphemes: (i) the index finger handshapes (☝ = *person*); (ii) the path movement (linear path =

goforward); and (iii) the non-manual expression (pressed together lips and squinted eyes = *carefully*).

Spoken languages have been identified that fall into three of the four cells in this typology. No spoken language has been found that falls into the fourth cell; that is, no spoken language has been found that is polymorphemic and monosyllabic. Interestingly, however, most of the signed languages analyzed to date have been found to be both polymorphemic and monosyllabic, and thus fall into the fourth cell. Although sign languages are different in kind from spoken languages, they fit neatly into the grid displayed in Figure 3 and, in this sense, can be characterized by the linguistic tools developed to describe spoken languages.

Note that the ASL sign in Figure 3 (bottom) contains three additional meaningful elements: (1) the two hands indicating that two people go forward; (2) the bent knuckle indicating that the people are hunched-over; and (3) the orientation of the hands with respect to one another indicating that the two people are side by side. Each of these aspects of the sign is likely to have been analyzed as a morpheme in the 1990s (see Brentari 1995; 2002). However, more recent analyses consider non-productive, potentially non-discrete, forms of this sort to be gestural (not a listable or finite set) rather than linguistic. This is precisely the issue that is raised by the examples described in the next section, to which we now turn.

4.2. Differences between sign language and spoken language that cannot be explained within a grammatical framework

We turn to syntax to explore differences between sign and speech that are not easily handled using traditional linguistic tools. Like spoken languages, sign languages realize person and number features of the arguments of a verb through agreement. For example, the ASL verb ASK (a crooked index finger), when moved in a straight path away from the signer (with the palm facing out), means *I ask you*; when the same verb is moved toward the signer (with the palm facing in), it means *you ask me* (see Fig. 4). This phenomenon is found in many sign languages (see Mathur & Rathmann 2010a; 2010b; Rathmann & Mathur 2012, p. 137) and is comparable to verb agreement in spoken language in that the difference between the two sign forms corresponds to a difference in meaning marked in spoken language by person agreement with the subject and/or object.

But these agreeing verbs in sign differ from their counterparts in speech in that the number of locations toward which the verbs can be directed is not a discrete (finite or listable) set, as agreement morphemes are in spoken languages. Liddell (2003) prefers to call verbs of this sort "indicating" verbs (rather than "agreeing" verbs), because they indicate, or point to, referents just as a speaker might gesture toward a person when saying *I asked him*. In addition to the fact that it is not possible to list all of the loci that could serve as possible morphemes for these verb signs, the signs differ from words in another respect – their forms vary as a function of the referents they identify or with which they agree (Liddell 2003; Liddell & Metzger 1998). For example, if the signer is directing his question to a tall person, the ASK verb will be moved higher in the signing space than it would be if the signer were directing his question to a child (as first noted by Fischer & Gough 1978).

These characteristics have raised doubts about whether agreement in sign should be analyzed entirely using the same linguistic tools as agreement in spoken language.

	Monosyllabic	**Polysyllabic**
Monomorphemic	*Hmong*	*English*
number of morphemes	1 #noj#	1 #character#
number of syllables	1 .noj.	3 .kæ.ɹək.tɚ.
translation	"eat"	"character"
Polymorphemic	*ASL*	*Hopi*
number of morphemes	3 #people–goforward–carefully#	3 #pakiw–maqto–ni#
number of syllables	1 .goforward.	5 .pa.kiw.maq.to.ni.
translation	"people go forward carefully"	"will go fish-hunting"

Figure 3. The top of the figure presents examples of word structure in the four types of languages that result from crossing the number of syllables with the number of morphemes. A period indicates a syllable boundary; a dash indicates a morpheme boundary; and a hash mark (#) indicates a word boundary. The bottom of the figure presents a depiction of the polymorphemic, monosyllabic ASL form "*people-goforward-carefully*" (Brentari 1998, reprinted with permission of MIT Press).

The alternative is that some of these phenomena could be analyzed using tools developed to code the co-speech gestures that hearing speakers produce. Liddell (2003, see also Dudis 2004; Liddell & Metzger 1998) argues that the analog and gradient components of these signs makes them more gestural than linguistic. This debate hints at the underlying problem inherent in deciding whether a particular form that a signer produces is a gesture or a sign. The same form can be generated by either a categorical (sign) or a gradient (gestural) system, and, indeed, a single form can contain both categorical and gradient components (see examples in Duncan 2005, described in sect. 6); it is only by understanding how a particular form relates to other forms within a signer's repertoire that we can get a handle on this question (see Goldin-Meadow et al. 1996 for discussion).

If a form is part of a categorical linguistic system, that is, if it is a sign, it must adhere to standards of form. Signers who use the same sign language should all produce a particular form in the same way if that form is a sign (i.e., there should be some invariance across signers). But we might not necessarily expect the same consistency across signers if the form is a gesture (see Sandler 2009, who uses this criterion to good effect to divide mouth movements that are grammatical from mouth movements that are gestural in signers of Israeli Sign Language). Since standards of form operate within a linguistic system, signers of *different* sign languages might be expected to use different forms to convey the same meaning – but there should be consistency across signers who all use the same sign language.

Schembri et al. (2005) examined adherence to standards of form in event descriptions by studying signers of three historically unrelated sign languages (Australian Sign Language, Taiwan Sign Language, and ASL). They looked, in particular, at the three linguistic dimensions Stokoe (1960) had established in sign languages – handshape, motion, and location (place of articulation) – and found that signers of the same sign language used the same handshape forms to describe the events (e.g., the ASL signers used a 3-handshape [thumb, index and middle fingers extended] to represent vehicles), but did not necessarily use the same handshape forms as signers of the other sign languages (the Australian Sign Language signers used a B handshape [a flat palm] to represent vehicles).

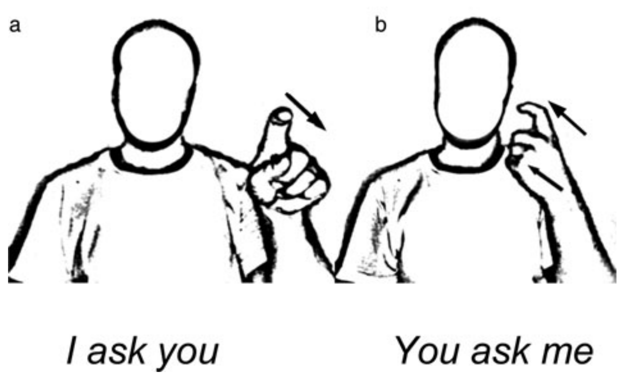

Figure 4. Examples of verb agreement in an ASL verb, ASK. When the verb is moved away from the signer (a), it means *I ask you*; when it is moved toward the signer (b), it means *you ask me* (Mathur & Rathmann 2010b, reprinted with permission of Cambridge University Press).

In contrast, signers of all three languages used the same motion forms and the same location forms to describe the events (e.g., signers of all three languages used a linear path to represent motion forward along a path). In other words, there was variability across signers of different languages in handshape, but not in motion and location. The findings suggest that handshape functions like a linguistic category in sign language, but leave open the possibility that motion and location may not.

Schembri & colleagues (2005) also entertained the hypothesis that motion and location (but not handshape) reflect influences from gesture, and tested the hypothesis by asking English-speakers who knew no sign language to use their hands rather than their voices to describe the same events. To the extent that the forms generated by signers share properties with gesture, there should be measurable similarities between the forms used by signers of unrelated languages and the forms generated by the "silent gesturers" (as these hearing participants have come to be known, Goldin-Meadow 2015). Schembri & colleagues (2005) found, in fact, that the handshape forms used by the silent gesturers differed from those used by the signers, but that their motion and location forms did not. Singleton et al. (1993) similarly found that English-speakers, asked to use only their hands to describe a series of events, produced different handshape forms from ASL signers who described the same events, but produced the same motion and location forms. In other words, hearing non-signers, when asked to use only their hands to communicate information, invent gestures that resemble signs with respect to motion and location, but not with respect to handshape.

Consistent with these findings, Emmorey et al. (2003) explored categorical perception (the finding that speech stimuli are perceived categorically rather than continuously despite the fact that they vary continuously in form) for two parameters – hand configuration and place of articulation – in ASL signers and in hearing non-signers. In a discrimination task, they found that the ASL signers displayed categorical perception for hand configuration, but *not* for place of articulation. The hearing non-signers perceived neither parameter categorically.

A recent neuroimaging study by Emmorey et al. (2013) also bears on whether handshape, motion, and location function as linguistic categories in signers. Deaf native ASL signers were asked to perform a picture description task in which they produced lexical signs for different objects, or classifier constructions for events that varied in type of object, location, or movement. Production of both lexical signs and classifier constructions that required different handshapes (e.g., descriptions of a bottle, lamp, or hammer, all in the same location) engaged left-hemisphere language regions; production of classifier constructions that required different locations (e.g., descriptions of a clock in different places relative to a table) or different motions (e.g., descriptions of a ball rolling off a table along different trajectories) did not.

Taken together, the findings from signers and silent gesturers suggest that handshape has many of the attributes found in linguistic categories in spoken language, but motion and location may not. It is important to note, however, that the silent gestures studied by Schembri et al. (2005) and Singleton et al. (1993) are not the spontaneous gestures that hearing speakers produce when they talk – they are gestures created on the spot to replace speech rather than to work with speech to communicate. But it is the spontaneous co-speech gestures that we need to compare the gradient aspects of sign to, not silent gestures. Before turning to developments in the literature on co-speech gesture that took place during the time these debates about sign languages were surfacing, we assess what we can learn about the relation between sign and gesture from silent gestures produced by hearing individuals.

4.3. Silent gesture in hearing speakers is really spontaneous sign

We begin by noting that the term "silent gesture" is, in some sense, a contradiction in terms given that we have defined gesture as co-occurring with talk. Consistent with this contradiction, Singleton et al. (1995; see also Goldin-Meadow et al. 1996) found that silent gestures not only fail to meet the "produced-with-speech" criterion for a gesture, but they also fail to take on the other characteristics associated with co-speech gesture. Singleton et al. asked hearing speakers who knew no sign language to describe a set of scenes using speech, and analyzed the gestures that the participants spontaneously produced along with that speech. They then asked the participants to describe the scenes again, this time using only their hands and not their mouths. They found a dramatic change in gesture form when it was produced with speech (i.e., when it was real gesture), compared with when it was produced without speech. The gestures without speech immediately took on sign-like properties – they were discrete in form, with gestures forming segmented word-like units that were concatenated into strings characterized by consistent (non-English) order.

These findings have two implications: (1) There is a qualitative difference between hand movements when they are produced along with speech (i.e., when they are gestures) and when they are required to carry the full burden of communication without speech (when they begin to take on linguistic properties and thus resemble signs); and (2) this change can take place instantly in a hearing individual. Taken together, the findings provide support for a categorical divide between these two forms of manual communication (i.e., between gesture and sign), and suggest that when gesture is silent, it crosses the divide (see also Kendon 1988a). In this sense, silent gesture might be more appropriately called "spontaneous sign."

Importantly, silent gestures crop up not only in experimental situations, but also in naturalistic circumstances where speech is not permitted but communication is required (see Pfau 2013 for an excellent review of these "secondary sign languages," as they are called). For example, in sawmills where noise prevents the use of speech, workers create silent gestures that they use not only to talk about the task at hand, but also to converse about personal matters (Meissner & Philpott 1975). Similarly, Christian monastic orders impose a law of silence on their members, but when communication is essential, silent gestures are permitted and used (Barakat 1975). As a final example, Aboriginal sign languages have evolved in Australia in response to a taboo on speaking during mourning; since mourning is done primarily by women in this culture, Walpiri Sign Language tends to be confined to middle-aged and older women (Kendon 1984; 1988b; 1988c). In all of these situations, the manual systems that develop look more like silent gestures than like the gestures that co-occur with speech. Although the gesture forms initially are transparent depictions of their referents, over time they become less motivated, and as a result, more conventionalized, just as signs do in sign languages evolving in deaf communities (Burling 1999; Frishberg 1975). In many cases, the structure underlying the silent gestures is borrowed from the user's spoken language (e.g., compound signs are generated on the basis of compound words in Walpiri Sign Language; the order in which signs are produced follows the word order in the monks' spoken language). Interestingly, however, the gesture strings used by the silent gesturers in the experimental studies (Goldin-Meadow et al. 1996; Singleton et al. 1995) did not adhere to English word order (although the strings did follow a consistent order; see also Goldin-Meadow et al. 2008). At the moment, we do not know which conditions are likely to encourage silent gesturers to model their gestures after their own spoken language, and which are likely to encourage them to develop new structures. But this would be an interesting area of research for the future. And now, on to co-speech gesture.

5. Gesture forms an integrated system with speech

In 1969, Ekman and Friesen proposed a scheme for classifying nonverbal behavior and identified five types. (1) *Affect displays,* whose primary site is the face, convey the speaker's emotions, or at least those emotions that the speaker does not wish to mask (Ekman et al. 1972). (2) *Regulators,* which typically involve head movements or slight changes in body position, maintain the give-and-take between speaker and listener and help pace the exchange. (3) *Adaptors* are fragments or reductions of previously learned adaptive hand movements that are maintained by habit – for example, smoothing the hair, pushing glasses up the nose even when they are perfectly positioned, holding or rubbing the chin. Adaptors are performed with little awareness and no intent to communicate. (4) *Emblems* are hand movements that have conventional forms and meanings – for example, the *thumbs up,* the *okay,* the *shush.* Speakers are typically aware of having produced an emblem and produce them, with speech or without it, to communicate with others, often to control their behavior. (5) *Illustrators* are hand movements that are part of an intentional speech act, although speakers are typically unaware of these movements. The movements are, for the most part, produced along with speech and often illustrate that speech – for example, a speaker says that the way to get to the study is to go upstairs and, at the same time, bounces his hand upward. Our focus is on illustrators – called *gesticulation* by Kendon (1980b) and plain old *gesture* by McNeill (1992), the term we use here.

Communication has traditionally been divided into content-filled verbal and affect-filled nonverbal components. Under this view, nonverbal behavior expresses emotion, conveys interpersonal attitudes, presents one's personality, and helps manage turn-taking, feedback, and attention (Argyle 1975; see also Wundt 1900) – it conveys the speaker's attitude toward the message and/or the listener, but not the message itself. Kendon (1980b) was among the first to challenge this traditional view, arguing that at least one form of nonverbal behavior – gesture – cannot be separated from the content of the conversation. As McNeill (1992) has shown in his groundbreaking studies of co-speech gesture, speech and gesture work together to convey meaning.

But speech and gesture convey meaning differently – whereas speech uses primarily categorical devices, gesture relies on devices that are primarily imagistic and analog. Unlike spoken sentences in which lower constituents combine into higher constituents, each gesture is a complete holistic expression of meaning unto itself (McNeill 1992). For example, in describing an individual running, a speaker might move his hand forward while wiggling his index and middle fingers. The parts of the gesture gain meaning because of the meaning of the whole. The wiggling fingers mean "running" only because we know that the gesture, as a whole, depicts someone running and not because this speaker *consistently* uses wiggling fingers to mean running. Indeed, in other gestures produced by this same speaker, wiggling fingers may well have a very different meaning (e.g., offering someone two options). To argue that the wiggling-fingers gesture is composed of separately meaningful parts, one would have to show that the three components that comprise the gesture – the V handshape, the wiggling motion, and the forward motion –are each used for a stable meaning across the speaker's gestural repertoire. The data (e.g., Goldin-Meadow et al. 1995; 2007b; McNeill 1992) provide no evidence for this type of stability in the gestures that accompany speech. Moreover, since the speaker does not consistently use the forms that comprise the wiggling-fingers gesture for stable meanings, the gesture cannot easily stand on its own without speech – which is consistent with the principle that speech and gesture form an integrated system.

Several types of evidence lend support to the view that gesture and speech form a single, unified system. First, gestures and speech are semantically and pragmatically co-expressive. When people speak, they produce a variety of spontaneous gesture types in conjunction with speech (e.g., deictic gestures, iconic gestures, metaphoric gestures; McNeill 1992), and each type of spontaneous gesture has a characteristic type of speech with which it occurs. For example, iconic gestures accompany utterances that depict concrete objects and events, and fulfill a narrative function – they accompany the speech that "tells the story." A social worker describes the father of a patient and says, "… and he just sits in his chair at night smokin' a big cigar …" while moving her hand back and forth in front of her mouth as though holding a long fat object and taking it in and out of her mouth (Kendon 1988a; 1988b, pp. 131–2). The cigar-smoking gesture is a concrete depiction of an event in the story and is a good example of an iconic gesture co-occurring with the narrative part of the discourse.[4] In contrast, other types of gestures (called metaphoric by McNeill [1992]) accompany utterances that refer to the structure of the discourse rather than to a particular event in the narrative.[5] For example, a speaker is describing a person who suffers from the neuropathological problem known as "neglect" and produces three open-hand palm-up gestures (with the hand shaped as though presenting something to the listener) at three different points in her speech (the placement of each gesture is indicated by brackets): "So there's [this woman], she's in the [doctor's office] and she can't, she doesn't recognize half of her body. She's neglecting half of her body and the doctor walks over an' picks up her arm and says 'whose arm is this?' and she goes, 'Well that's your arm' and he's an [Indian doctor]." The speaker used her first two open-palm gestures to set up conditions for the narrative, and then used the third when she explained that the doctor was Indian (which was notable because the woman was unable to recognize her own arm even when the skin color of the doctor who picked up her arm was distinctly different from her own; Kendon 2004, p. 267). Gesture works together with speech to convey meaning.

Second, gesture and speech are temporally organized as a single system. The prosodic organization of speech and the phrasal structure of the co-occurring gestures are coordinated so that they appear to both be produced under the guidance of a unified plan or program of action (Kendon 1972; 1980b; 2004, Ch. 7; McNeill 1992). For example, the gesture and the linguistic segment representing the same information as that gesture are aligned temporally. More specifically, the gesture movement – the "stroke" – lines up in time with the tonic syllable of the word with which it is semantically linked (if there is one in the sentence).[6] For example, a speaker in one of McNeill's (1992, p. 12) studies said "and he bends it way back" while his hand appears to grip something and pull it from a space high in front of him back and down to his shoulder (an iconic gesture representing bending a tree back to the ground); the speaker produced the stroke of the gesture just as he said, "bends it way back" (see Kita 1993, for more subtle examples of how speech and gesture adjust to each other in timing, and Nobe 2000). Typically, the stroke of a gesture tends to precede or coincide with (but rarely follow) the tonic syllable of its related word, and the amount of time between the onset of the gesture stroke and the onset of the tonic syllable of the word is quite systematic – the timing gap between gesture and word is larger for unfamiliar words than for familiar words (Morrell-Samuels & Krauss 1992). The systematicity of the relation suggests that gesture and speech are part of a single production process. Gesture and speech are systematically related in time even when the speech production process goes awry. For example, gesture production is halted during bouts of stuttering (Mayberry & Jaques 2000; Mayberry et al. 1998). Synchrony of this sort underscores that gesture and speech form a single system.

Third, the view that gesture and speech form a unified system gains further support from the hand (right or left) with which gesture is produced. Gestures are more often produced with the right hand, whereas self-touching adaptors (e.g., scratching, pushing back the hair) are produced with both hands. This pattern suggests a link to the left-hemisphere-speech system for gesture, but not for self-touching adaptors (Kimura 1973).

Fourth, gestures have an effect on how speech is perceived and thus suggest that the two form a unified system. Listeners perceive prominent syllables as more prominent when they are accompanied by a gesture than when they are not (Krahmer & Swerts 2007). In addition, gesture can clarify the speaker's intended meaning in an ambiguous sentence and, in incongruent cases where gesture and prosody are at odds (e.g., a facial expression for incredulity paired with a neutral prosodic contour), gesture can make it more difficult to perceive the speaker's intended meaning (Sendra et al. 2013).

Finally, the information conveyed in gesture, when considered in relation to the information conveyed in speech, argues for an integrated gesture–speech system. Often, a speaker intends the information conveyed in her gestures to be part of the message; for example, when she says, "Can you please give me that one," while pointing at the desired object. In this case, the message received by the listener, and intended by the speaker, crucially depends on integrating information across the two modalities. But speakers can also convey information in gesture that they may not be aware of having expressed. For example, a speaker says, "I ran up the stairs," while producing a spiral gesture – the listener can guess from this gesture that the speaker mounted a spiral staircase, but the speaker may not have intended to reveal this information. Under these circumstances, can we still assume that gesture forms an integrated system with speech for the speaker? The answer is "yes," and the evidence comes from studies of learning (Goldin-Meadow 2003a).

Consider, for example, a child participating in a Piagetian conservation task in which water from a tall glass is poured into a flat dish; young children are convinced that the pouring transformation has changed the amount of water. When asked why, one child said that the amount of water changed "'cause this one's lower than this one" and thus focused on the height of the containers in speech. However, at the same time, she indicated the widths of the containers in her gestures, thus introducing completely new information in gesture that could not be found in her speech. The child produced what has been called a *gesture–speech mismatch* (Church & Goldin-Meadow 1986) – a response in which the information conveyed in gesture is different from, but relevant to, the information conveyed in speech. Although there is no evidence that this child was aware of having conveyed different information in gesture and speech, the fact that she did so had cognitive significance – she was more likely to profit from instruction in conservation than a child who conveyed the same information in gesture and speech, that is, a *gesture–speech match*; in this case, saying "'cause that's down lower than that one," while pointing at the water levels in the two containers and thus conveying height information in both modalities.

In general, learners who produce gesture–speech mismatches on the conservation task are more likely to profit from instruction in that task than learners whose gestures convey the same information as speech (Church & Goldin-Meadow 1986; Ping & Goldin-Meadow 2008). The relation between a child's gestures and speech when explaining conservation thus indexes that child's readiness-to-learn conservation, suggesting that the information conveyed in speech and the information conveyed in gesture are part of the same system – if gesture and speech were two independent systems, the match or mismatch between the information conveyed in these systems should have no bearing on the child's cognitive state. The fact that gesture–speech mismatch *does* predict learning therefore suggests that the two modalities are not independent. Importantly, it is not merely the amount of information conveyed in a mismatch that gives it its power to predict learning – conveying the information across gesture and speech appears to be key. Church (1999) found that the number of responses in which a child expressed two different ideas in gesture and speech (i.e., mismatch) on a conservation task was a better predictor of that child's ability to learn the task than the number of responses in which the child expressed two different ideas all in speech. In other words, it was not just expressing different pieces of information that mattered, but rather the fact that those pieces of information were conveyed in gesture and speech.[7]

This phenomenon – that learners who convey information in gesture that is different from the information they convey in the accompanying speech are on the verge of learning – is not unique to 5- to 8-year old children participating in conservation tasks, but has also been found in 9- to 10-year-old children solving mathematical equivalence problems. For example, a child asked to solve the problem, 6+3+4=__+4, says that she "added the 6, the 3, and the 4 to get 13 and then put 13 in the blank" (an add-to-equal-sign strategy). At the same time, the child points at all four numbers in the problem, the 6, the 3, the 4 on the left side of the equal sign, and the 4 on the right side of the equal sign (an add-all-numbers strategy). The child has thus produced a gesture–speech mismatch. Here again, children who produce gesture–speech mismatches, this time on the mathematical equivalence task, are more likely to profit from instruction in the task than children whose gestures always match their speech – a child who, for example, produces the add-to-equal-sign strategy in both speech and gesture, that is, he gives the same response as the first child in speech but points at the 6, the 3, and the 4 on the left side of the equal sign (Alibali & Goldin-Meadow 1993; Perry et al. 1988; 1992).

The relation between gesture and speech has been found to predict progress in a variety of tasks at many ages: toddlers on the verge of producing their first sentences (Capirci et al. 1996; Goldin-Meadow & Butcher 2003; Iverson & Goldin-Meadow 2005) and a number of different sentence constructions (Cartmill et al. 2014; Özçalişkan & Goldin-Meadow 2005); 5-year-olds learning to produce narratives (Demir et al. 2015); 5- to 6-year-olds learning to mentally rotate objects (Ehrlich et al. 2006); 5- to 9-year-olds learning to balance blocks on a beam (Pine et al. 2004); and adults learning how gears work (Perry & Elder 1997) or how to identify a stereoisomer in chemistry (Ping et al., under review). When gesture and speech are taken together, they predict what a learner's next step will be, providing further evidence that gesture and speech are intimately connected and form an integrated cognitive system. It is important to note that this insight would be lost if gesture and speech were not analyzed as separate components of a single, integrated system; in other words, if they are not seen as contributing different types of information to a single, communicative act.

Further evidence that mismatch is generated by a single gesture–speech system comes from Alibali and Goldin-Meadow (1993), who contrasted two models designed to predict the number of gesture–speech matches and mismatches children might be expected to produce when explaining their answers to mathematical equivalence problems. They then tested these models against the actual numbers of gesture–speech matches and mismatches that the children produced. The first model assumed that gesture and speech are sampled from a single set of representations, some of which are accessible to both gesture and speech (and thus result in gesture–speech matches) and some of which are accessible to gesture but not speech (and thus result in gesture–speech mismatches). The second model assumed that gesture and speech are sampled from two distinct sets of representations; when producing a gesture–speech combination, the speaker samples from one set of representations for speech, and *independently* samples from a second set of representations for gesture. Model 1 was found to fit the data significantly better than model 2. Gesture and speech can thus be said to form an integrated system in the sense that they do not draw upon two distinct sets of representations, but rather draw on a single set of representations, some of which are accessible only to gesture. Interestingly, the model implies that when new representations are acquired, they are first accessible only to gesture, which turns out to be true for the acquisition of mathematical equivalence (Perry et al. 1988).

In summary, communicative acts are often critically dependent on combining information that is expressed uniquely in one modality or the other. Gesture and speech together can achieve speakers' communicative goals in ways that would otherwise not be accomplished by either channel alone.

6. Does gesture form an integrated system with sign?

McNeill (1992) has hypothesized that human communication contains both categorical and imagistic forms; categorical forms are typically found in speech, imagistic forms in gesture (see also Goldin-Meadow & McNeill 1999). If this view is correct, then sign, which for the most part is categorical in form, should also be accompanied by imagistic forms – in other words, signers should gesture just as speakers do.

Emmorey (1999) was among the first to acknowledge that signers gesture, but she argued that signers do not gesture in the same way that speakers do. According to Emmorey, signers do not produce idiosyncratic hand gestures concurrently with their signs. But they do produce gestures with their face or other parts of the body that co-occur with their signs – for example, holding the tongue out with a fearful expression while signing DOG RUNS; or swaying as if to music while signing, DECIDE DANCE (Emmorey 1999). The gestures that signers produce as separate units with their hands tend to be conventional (i.e., they are emblems, such as *shh, come-on, stop*), and they tend to alternate with signs rather than being produced concurrently with them. Note that an emblem can be produced in a correct or an incorrect way (i.e., emblems have standards of form), and they can also occur without speech; they thus do not fit the definition of gesture that we are working with here.

Sandler (2009), too, has found that signers can use their mouths to gesture. She asked four native signers of Israeli Sign Language to describe a Tweety Bird cartoon, and found that all four used mouth gestures to embellish the linguistic descriptions they gave with their hands. For example, while using his hands to convey a cat's journey up a drainpipe (a small-animal classifier moved upward), one signer produced the following mouth movements (Sandler 2009, p. 257, Fig. 8): a tightened mouth to convey the narrowness and tight fit of the cat's climb; and a zigzag mouth to convey a bend in the drainpipe. The signers' mouth movements had all of the features identified by McNeill (1992) for hand gestures in hearing speakers – they are global (i.e., not composed of discrete meaningless parts as words or signs are); they are context-sensitive (e.g., the mouth gesture used to mean "narrow" was identical to a mouth gesture used to indicate the "whoosh" generated by flying through the air); and they are idiosyncratic (i.e., different signers produced different mouth gestures for the same event). Signers can use their mouths to convey imagistic information typically conveyed by the hands in speakers.

Duncan (2005) agrees that signers gesture, but believes that they can use their hands (as well as their mouths) to gesture just like speakers do. Her approach was to ask signers to describe the events of a cartoon that has been described by speakers of many different languages (again, Tweety Bird). Since Duncan knows a great deal about the gestures that speakers produce when describing this cartoon, she could assess the productions of her signers with this knowledge as a backdrop. Duncan studied nine adult signers of Taiwan Sign Language and found that all nine gestured with their hands. They produced hand gestures interleaved with signs (as found by Emmorey 1999), but the gestures were iconic rather than codified emblems. As an example, one signer enacted the cat's climb up the outside of the drainpipe (looking just like a hearing gesturer), and interspersed this gesture with the sign for *climb-up* (a thumb-and-pinky classifier, used for animals in Taiwanese Sign Language, moved upward; see Fig. 5 in Duncan 2005, p. 301).

The signers also produced idiosyncratic hand gestures *concurrently* with their signs – they modified some features of the handshapes of their signs, reflecting the spatial–imagistic properties of the cartoon. For example, Duncan (2005) described how the signers modified another classifier for animals in Taiwan Sign Language, a three-fingered handshape, to capture the fact that the animal under discussion, a cat, was climbing up the *inside* of a drainpipe. One signer held the three fingers straight while contracting them to represent the fact that the cat squeezed inside the drainpipe; another signer curved two fingers in while leaving the third finger straight; a third signer bent all three fingers slightly inward. Duncan argues that the variability in how the three signers captured the cat's squeeze during his ascent is evidence that the modifications of these hand configurations are gestural – if all three signers had modified the handshape in the same way, the commonality among them would have argued for describing the modification as morphemic rather than gestural. The imagistic properties of the scene provide a source for gesture's meaning but do not *dictate* its form. Importantly, the variations across the three signers are reminiscent of the variations we find when we look at the gestures speakers produce as they describe this event; the difference is that hearing speakers can use whatever basic handshape they want (their linguistic categories are coming out of their mouths) – the signers all used the same three-fingered animal classifier.

What the signers are doing is idiosyncratically modifying their categorical linguistic morphemes to create a depictive representation of the event. We can see the same process in speakers who modify their spoken words to achieve a comparable effect. For example, Okrent (2002) notes that

English speakers can extend the vowel of a word to convey duration or length, *It took s-o-o-o l-o-o-o-ng*. Both Okrent (2002) and Emmorey and Herzig (2003) argue that all language users (speakers and signers) instinctively know which part of their words can be manipulated to convey analog information. Speakers know to say *l-o-o-o-ng*, and not **l-l-l-ong or *lo-ng-ng-ng*, and signers know which parts of the classifier handshape can be manipulated to convey the iconic properties of the scene while retaining the essential characteristics of the classifier handshape.

Signers can thus manipulate handshape in gesture-like ways. What about the other parameters that constitute signs – for example, location? As mentioned earlier, some verb signs can be directed toward one or more locations in signing space that have been previously linked with the verb's arguments. Although there is controversy over how this phenomenon is best described (e.g., Lillo-Martin & Meier 2011, and the commentaries that follow), at this moment, there is little disagreement that these verbs have a linguistic and a gestural component – that they either "agree" with arguments associated with different locations pointed out in the signing space (Lillo-Martin 2002; Rathmann & Mathur 2002), or that they "indicate" present referents or locations associated with absent referents pointed out in the signing space (Liddell 2000). The signs tell us what grammatical role the referent is playing; gesture tells us who the referent is.

As Kendon (2004) points out, speakers also use gesture to establish spatial locations that stand in for persons or objects being talked about. For example, in a conversation among psychiatrists discussing a case (Kendon 2004, p. 314), one speaker gesturally established two locations, one for the patient and one for the patient's mother. He said, "She [the patient] feels that this is not the case at times," while thrusting his hand forward as he said "she," and then said, "It's mother that has told her that she's been this way," while thrusting his hand to his left as he said "mother." Rathmann & Mathur (2002) suggest that gestures of this sort are more obligatory with (agreeing) verbs in sign languages than they are in spoken languages. This is an empirical question, but it is possible that this difference between sign and speech may be no different from the variations in gesture that we see across different spoken languages – co-speech gestures vary as a function of the structure of the particular language that they accompany (Gullberg 2011; Kita & Özyürek 2003). There are, in fact, circumstances in which gesture is obligatory for speakers (e.g., "the fish was this big," produced along with a gesture indicating the length of the fish). Perhaps this is a difference of degree, rather than a qualitative difference between signed and spoken languages (a difference comparable to the fact that sign is found in only 1 of the 4 cells generated by the 2 × 2 typology illustrated in Fig. 3).

Thus far, we have seen that gesture forms an integrated system with sign in that gestures co-occur with signs and are semantically co-expressive with those signs. The detailed timing analyses that Kita (1993) and Nobe (2000) have conducted on gesture and speech have not yet been done on gesture and sign. However, the fifth and, in some ways, most compelling argument for integration has been examined in gesture and sign. We have evidence that the information conveyed in gesture, when considered in relation to the information conveyed in sign, predicts learning (Goldin-Meadow et al. 2012).

Following the approach that Duncan (2005) took in her analyses of gesture in adult signers, Goldin-Meadow et al. (2012) studied the manual gestures that deaf children produce when explaining their answers to math problems, and compared them to gestures produced by hearing children on the same task (Perry et al. 1988). They asked whether these gestures, when taken in relation to the sign or speech they accompany, predict which children will profit from instruction in those problems. Forty ASL-signing deaf children explained their solutions to math problems on a pre-test; they were then given instruction in those problems; finally, they were given a post-test to evaluate how much they had learned from the instruction.

The first question was whether deaf children gesture on the task – they did, and about as often as hearing children (80% of the deaf children's explanations contained gestures, as did 73% of the hearing children's explanations). The next question was whether deaf children produce gesture-sign mismatches – and again they did, and as often as the hearing children (42% of the deaf children produced 3 or more mismatches across six explanations, as did 35% of the hearing children). The final and crucially important question was whether mismatch predicts learning in deaf children as it does in hearing children – again it did, and at comparable rates (65% of the deaf children who produced 3 or more mismatches before instruction succeeded on the math task after instruction, compared with 22% who produced 0, 1, or 2 mismatches; comparable numbers for the hearing children were 62% vs. 25%). In fact, the number of pre-test mismatches that the children produced prior to instruction continuously predicted their success after instruction – each additional mismatch that a child produced before instruction was associated with greater success after instruction (see Fig. 2 in Goldin-Meadow et al. 2012; footnote 5 in Perry et al. 1988).

Examples of the gesture-sign mismatches that the children produced are instructive, because they underscore how intertwined gesture and sign are. In the first problem, 2 + 5 + 9 = 2 + __, a child puts 16 in the blank and explains how he got this answer by producing the (incorrect) *add-to-equal sign* strategy in sign (he signs FOURTEEN, ADD, TWO, ANSWER, SIXTEEN); before beginning his signs, he produces a gesture highlighting the two unique numbers on the left side of the equation (5+9), thus conveying a different strategy with his gestures, the (correct) *grouping* strategy (i.e., group and add 5 and 9). In the second problem, 7 + 4 + 2 = 7 + __, a child puts 13 in the blank and explains how she got this answer by producing the (incorrect) *add-to-equal-sign* strategy in sign (ADD_{7+4+2}, PUT_{13}), and producing gestures conveying the (correct) *add-subtract* strategy – she covers the 7 on the right side of the problem while signing ADD over the 7, 4, and 2. Because the ADD sign is produced on the board over three numbers, we consider the sign to have gestural elements that point out the three numbers on the left side of the problem. In other words, the gesture string conveys adding 7 + 4 + 2 (via the placement of the ADD sign) and subtracting 7 (via the cover gesture). Gesture is thus incorporated into sign (the indexical components of the ADD sign) and is also produced as a separate unit that occurs simultaneously with sign (the covering gesture produced at the same time as the ADD sign).

The findings from this study have several implications. First, we now know that signers can produce gestures along with their signs that convey different information from those signs – that is, mismatches can occur within a single modality (the manual modality) and not just across two modalities (the manual and oral modality).

Second, the fact that gesture-sign mismatch (which involves one modality only) predicts learning as well as gesture–speech mismatch (which involves two modalities) implies that mismatch's ability to predict learning comes not from the juxtaposition of different information conveyed in distinct modalities (manual vs. oral), but rather from the juxtaposition of different information conveyed in distinct representational formats – a mimetic, imagistic format underlying gesture versus a discrete, categorical format underlying language, be it sign or speech. Thus, mismatch can predict learning whether the categorical information is conveyed in the manual (sign) or oral (speech) modality. However, the data leave open the possibility that the imagistic information in a mismatch needs to be conveyed in the manual modality. The manual modality may be privileged when it comes to expressing emergent or mimetic ideas, perhaps because our hands are an important vehicle for discovering properties of the world (Goldin-Meadow & Beilock 2010; Sommerville et al. 2005; Streeck 2009, Ch. 9).

Finally, the findings provide further evidence that gesture and sign form an integrated system, just as gesture and speech do – taking a learner's gesture and sign, or a learner's gesture and speech, together allows us to predict the next steps that the learner will take.

7. Implications for the study of gesture, sign, and language

7.1. Sign should be compared with speech-plus-gesture, not speech alone

The bottom line of our tour through the history of the sign and gesture literatures is that sign should not be compared with speech – it should be compared with speech-plus-gesture. If it were possible to easily separate sign into sign and its gestural components, it might then be reasonable to compare sign on its own to speech on its own. But there are problems with this strategy.

First, looking at speech or sign on its own means that we will miss generalizations that involve imagistic forms. We would not be able to see how sign and gesture collaborate to accomplish communicative goals – which may turn out to be the same type of collaboration that takes place between speech and gesture. Indeed, some (Kendon 2004; 2008; McNeill 1992) would argue that we miss the important generalizations about language if we ignore gesture. However, there is reason to want to take a look at the categorical components of language, be it sign or speech (knowing, of course, that we are setting aside its imagistic components).

Second, even if our goal is to examine the categorical components of sign on their own, it is currently difficult to separate them from sign's gestural components. Articulating criteria for gesture in sign is difficult, and we are still, for the most part, using hearing speakers' gestures as a guide – which means that sign transcribers must be well-trained in coding gesture as well as sign language. As in the Duncan (2005) and Goldin-Meadow et al. (2012) studies, it helps to know a great deal about the gestures that hearing speakers produce on a task when trying to code a signer's gestures on that task.

There is, however, a caveat to this coding strategy. Many of the studies comparing sign to gesture have focused on what we have called "silent gesture" – the gestures hearing speakers produce when they are told not to use their mouths and use only their hands to communicate. These gestures are qualitatively different from co-speech gesture and cannot be used as a guide in trying to identify co-sign gestures, although they can provide insight into whether particular structures in current-day sign languages have iconic roots (see, e.g., Brentari et al. 2012). Silent gesture is produced to replace speech, not to work with it to express meaning (see sect. 4.3). The most relevant finding is that, when told to use only their hands to communicate, hearing speakers immediately adopt a more discrete and categorical format in their silent gestures, abandoning the more imagistic format of their co-speech gestures (Goldin-Meadow et al. 1996; Singleton et al. 1995). As a result, we see some, but not all (more on this point later), of the properties found in language in silent gesture: for example, systematic use of location to establish co-reference (So et al. 2005) and consistent word order (Gershkoff-Stowe & Goldin-Meadow 2000; Gibson et al. 2013; Goldin-Meadow et al. 2008; Hall et al. 2013; Langus & Nespor 2010; Meir et al. 2010).

7.2 Speech can take on the properties of gesture; gesture can take on the properties of sign

Why is it important to make a distinction between gesture and sign? Although there may be descriptive phenomena that do not require a categorical division between gesture and sign, there are also phenomena that depend on the distinction; for example, predicting who is ready to profit from instruction on the math task depends on our ability to examine information conveyed in gesture in relation to information conveyed in sign language (Goldin-Meadow et al. 2012).[8] In addition, making a distinction between gesture and sign language allows us to recognize the conditions under which the manual modality can take on categorical properties and the oral modality can take on imagistic properties.

For example, there is now good evidence that speech can take on the properties of gesture; in other words, that there is gesture in the oral modality. Shintel and her colleagues (Shintel et al. 2006; Shintel & Nusbaum 2007; 2008; see also Grenoble et al. 2015; Okrent 2002) have found that speakers can continuously vary the acoustic properties of their speech to describe continuously varying events in the world. Faster events are described with faster speech, slower events with slower speech. This kind of analog expression can be used to describe a wide range of situations (e.g., raising or lowering pitch to indicate the height of an object). Moreover, not only do speakers spontaneously produce analog information of this sort, but also listeners pay attention to this information and use it to make judgments about the meaning of an utterance and who is expressing it. Speech then is not exclusively categorical, as many linguists have previously suggested (e.g., Bolinger 1946; Trager 1958). The gradient properties of language are important for expressing who we are, as seen in the burgeoning field of sociophonetics (Thomas 2011), in our affiliations with others (Sonderegger 2012), and in the future directions of historical change (Yu 2013).

In addition, there is evidence that gesture can take on properties of sign. We have already described the silent gestures that hearing speakers produce when told to use only their hands to communicate (sect. 4.3). These gestures take on linguistic properties as soon as the hearing speaker stops talking and, in this sense, are categorical (Goldin-Meadow et al. 1996). In addition, deaf children whose hearing losses prevent them from acquiring the spoken language that surrounds them, and whose hearing parents have not exposed them to a conventional sign language, invent gesture systems, called *homesigns*, that contain many of the properties of natural language (Goldin-Meadow 2003b). Homesign has been studied in American (Goldin-Meadow & Mylander 1984), Chinese (Goldin-Meadow & Mylander 1998), Turkish (Goldin-Meadow et al. 2015b), Brazilian (Fusellier-Souza 2006), and Nicaraguan (Coppola & Newport 2005) individuals, and has been found to contain many, but not all, of the properties that characterize natural language – for example, structure within the word (morphology, Goldin-Meadow et al. 1995; 2007b), structure within basic components of the sentence (markers of thematic roles, Goldin-Meadow & Feldman 1977; nominal constituents, Hunsicker & Goldin-Meadow 2012; recursion, Goldin-Meadow 1982; the grammatical category of subject, Coppola & Newport 2005), structure in how sentences are modulated (negations and questions, Franklin et al. 2011), and prosodic structure (Applebaum et al. 2014). The gestures that homesigners create, although iconic, are thus also categorical.

It is likely that all conventional sign languages, shared within a community of deaf (and sometimes hearing) individuals, have their roots in homesign (Coppola & Senghas 2010; Cuxac 2005; Fusellier-Souza 2006; Goldin-Meadow 2010) and perhaps also in the co-speech gestures produced by hearing individuals within the community (Nyst 2012). Language in the manual modality may therefore go through several steps as it develops (Brentari & Coppola 2013; Goldin-Meadow et al. 2015a; Horton et al. 2016). The first and perhaps the biggest step is the distance between the manual modality when it is used along with speech (co-speech gesture) and the manual modality when it is used in place of speech (silent gesture, homesign, and sign language). Gesture used along with speech looks very different from gesture used as a primary language (Goldin-Meadow et al. 1996; Singleton et al. 1995). The question is why.

As we have discussed, the gestures produced along with speech (or sign) form an integrated system with that speech (or sign). As part of this integrated system, co-speech gestures (and presumably co-sign gestures) are frequently called on to serve multiple functions – for example, they not only convey propositional information (e.g., describing the height and width of a container in the conservation of liquid quantity task, Church & Goldin-Meadow 1986), but also they coordinate social interaction (Bavelas et al. 1992; Haviland 2000) and break discourse into chunks (Kendon 1972; McNeill 2000). As a result, the form of a co-speech (or co-sign) gesture reflects a variety of pressures, pressures that may compete with using those gestures in the way that a silent gesturer, homesigner, or signer does.

As described earlier, when asked to use gesture on its own, silent gesturers transform their co-speech gestures so that those gestures take on linguistic properties (e.g., word order). But, not surprisingly, silent gesturers do not display all of the properties found in natural language in their gestures, because they are invented on the spot. In fact, silent gestures do not even contain all of the linguistic properties found in homesign. For example, silent gesturers do not break their gestures for motion events into path and manner components, whereas homesigners do (Goldin-Meadow 2015; Özyürek et al. 2015). As another example, silent gesturers do not display the finger complexity patterns found in many conventional sign languages (i.e., that classifier handshapes representing *objects* display more finger complexity than those representing how objects are *handled*), whereas homesigners do show at least the beginning of this morpho-phonological pattern (Brentari et al. 2012). The interesting observation is that silent gesture, which is produced by individuals who already possess a language (albeit a spoken one), contains fewer linguistic properties than homesign, which is produced by children who do not have any model for language (Goldin-Meadow 2015). The properties that are found in homesign, but not in silent gesture, may reflect properties that define a linguistic *system*. A linguistic system is likely to be difficult for a silent gesturer to construct on the spot, but it can be constructed over time by a homesigner (and perhaps by silent gesturers if given adequate time; see sect. 4.3).

By distinguishing between gesture and sign, we can identify the conditions under which gesture takes on the categorical properties of sign. One open question is whether homesigners (or silent gesturers) ever use their hands to convey the imagistic information captured in co-sign gesture and, if so, when in the developmental process this new function appears. The initial pressure on both homesigners and silent gesturers seems to be to convey information categorically (Goldin-Meadow et al. 1996; Singleton et al. 1995), but the need to convey information imagistically may arise, perhaps at a particular point in the formation of a linguistic system.

7.3. *Which aspects of sign are categorical? Why technology might be needed to study motion and location*

It is generally accepted that handshape, motion, and location constitute the three parameters that characterize a manual sign (orientation may be a minor parameter, and non-manuals are relevant as well). Sign languages have two types of signs – a set of frozen signs whose forms do not vary as a function of the event being described, and a set of productive signs whose forms do vary. There is good evidence that handshape functions categorically in both sign types. For example, handshape is treated categorically in both the productive lexicon (Emmorey & Herzig 2003) and frozen lexicon (Emmorey et al. 2003), despite the fact that the forms vary continuously. However, using the same paradigm, we find no evidence that place of articulation is treated categorically in either the frozen (Emmorey et al. 2003) or productive (Emmorey & Herzig 2003) lexicon (motion has not been tested in this paradigm). Moreover, as noted earlier, when hearing that individuals are asked to describe scenes with their hands, the motions and locations that they use in their gestural descriptions resemble the motions and locations that signers use in their descriptions of the task (Schembri et al. 2005; Singleton et al. 1993), suggesting that at least some of these forms may be gestural not only for hearing gesturers, but also for signers. In contrast, the handshapes gesturers use differ from the handshapes signers use, a finding that is consistent with evidence, suggesting that handshape is categorical in sign languages.

However, it is possible that motion and location forms may be less continuous than they appear if seen through an appropriate lens. Some evidence for this possibility comes from the fact that different areas of the brain are activated when hearing gesturers pantomime handling an object and when signers produce a sign for the same event – even when the sign resembles the pantomime (Emmorey et al. 2011). Different (linguistic) processes appear to be involved when signers create these forms than when gesturers create what appear to be the same forms. We have good methods for classifying (Eccarius & Brentari 2008; Prillwitz et al. 1989) and measuring (Keane 2014; Liddell & Johnson 2011) handshape, but the techniques currently available for capturing motion are less well developed. For example, linguistic descriptions of motion in sign typically do not include measures of acceleration or velocity (although see Wilbur 2003; 2008; 2010).

We suggest that it may be time to develop such tools for describing motion and location. Just as the analysis of speech took a great leap forward with the development of tools that allowed us to discover patterns not easily found by just listening – for example, the spectrograph, which paved the way for progress in understanding the acoustic properties of speech segments (Potter et al. 1947), and techniques for normalizing fundamental frequency across speakers, which led to progress in understanding prosody ('t Hart & Collier 1975) – we suspect that progress in the analysis of motion and location in sign is going to require new tools.

For example, we can use motion analysis to compare the co-speech gestures that a hearing speaker produces with a signer's description of precisely the same event (taking care to make sure that the two are describing the same aspects of the event). If the variability in the hearing speakers' movements is comparable to the variability in the signers' movements, we would have good evidence that these movements are gestural in signers. If, however, the variability in signers' movements is significantly reduced relative to the variability in speakers' movements, we would have evidence that the signers' movements are generated by a different (perhaps more linguistic) system than the speakers' gestures. This analysis could be conducted on any number of parameters (shape of trajectory, acceleration, velocity, duration, etc.).

Motion analysis is already being used in analyses of signers' movements, which is an important step needed to determine which parameters are most useful to explore. For example, Malaia and Wilbur (2011) used motion capture data to investigate the kinematics of verb sign production in ASL and found more deceleration in verbs for telic events (i.e., events with an end-point, e.g., throw, hit) than in verbs for atelic events. The interesting question from our point of view is whether the co-speech gestures that hearing speakers produce when describing a throwing or hitting event also display these same deceleration patterns. More generally, does motion in sign display a characteristic signature that distinguishes it from motion in gesture? If so, there may be more categorical structure in motion (and perhaps location[9]) than meets the eye.

At the same time, there may also be more grammatical structure in gesture than we currently recognize. For example, elements thought to be gestural in sign have been shown to contribute to the grammaticality of an utterance. Take the height of the ASK sign described earlier, which is considered gestural in Liddell's (2003) analysis. Schlenker (forthcoming; see also Schlenker et al. 2013) have found that the height of a sign can provide information relevant to the set of logical semantic variables known as *phi*-features, which introduce presuppositions into an utterance and contribute to their truth-value. If a signer first signs that his cousin *knows* his brother is tall, and then that the cousin wrongfully thinks the brother (indicated by a point) is a basketball player, the height of the point for the brother can have either a neutral locus or a high locus. However, if the signer signs that his cousin *wrongfully thinks* his brother is tall, and then signs that the cousin thinks the brother (indicated by a point) is tall, the height of the point for the brother can *only* have a neutral locus; the high locus is ungrammatical. In other words, the high point is grammatical only if the cousin knows that the brother is tall, not if the cousin incorrectly thinks the brother is tall. The height of the point is thus constrained by semantic properties of the sentence. The interesting question then is whether the pointing gesture that hearing speakers produce to accompany a spoken reference to the brother is similarly constrained. If not, we can conclude that signers' pointing gestures are more grammatical than speakers' pointing gestures. However, if speakers' gestures are also constrained, we would have evidence that grammatical structure (semantic presuppositions) can play a role in conditioning gesture in speakers just as it does in signers.

A final strategy that can help us discover similarities and differences between gestures produced by signers versus speakers is to watch the behaviors as they change. For example, it is commonly thought that speakers gesture less with talk that is becoming rote. If so, we can compare speakers and signers as they continue to repeat the same discourse to the same communication partner. If gesture does indeed decrease in speakers, we can then examine the changes that take place in speech over time (which information is lost, which transferred from gesture to speech) and look for comparable changes in sign over time. Whether sign language can be stripped of its gestural elements and still be as effective as speech is when it is delivered without its gestural elements (e.g., over the radio or the phone) is an open question. Comparing speakers and signers in situations that are more, or less, likely to elicit gesture could give us an experimental handle on which aspects of sign are, in fact, gestural, and how those gestural aspects are comparable.

8. Conclusion

In sum, we believe that it is too early to say whether our view of what human language is must be altered to accommodate sign languages. We suggest that the field may be ignoring categorical structure that underlies motion in sign language simply because our current tools are insufficient to capture this structure (much as we were unable to adequately describe the structure of spoken language before the spectrograph). At the same time, recent work in speech analysis has emphasized the crucial importance of gradient properties in speech for language change (Yu 2013) and sociophonetics (Thomas 2011); in other words, there appears to be more gradient structure in spoken language than previously thought (whether gradient properties play the same role in language as imagistic properties is an open and important question). Taken together, these observations lead us to suggest that the study of language is undergoing a paradigm shift – the full communicative act includes, at the least, both categorical (speech or sign) and imagistic (gesture) components, and our comparisons should be between speech-plus-gesture and sign-plus-gesture.

Our tour through the recent history of sign language and gesture studies has brought us to the conclusion that the two fields need to be talking to one another. Sign language, at times, has been viewed as a language of gestures and is therefore very different from spoken language and, at other times, as a language characterized by structures just like those found in spoken language. More recently, researchers have recognized that sign language has gestural components just as spoken language does. The fact that sign's gestural components are produced in the same (manual) modality as its linguistic structures makes it more difficult to separate the two than in spoken language. We believe, nevertheless, that separation is a useful goal. Although there are undoubtedly phenomena that can be captured by not making a categorical divide between gesture and sign, there are also phenomena that depend on the divide; for example, predicting who is ready to learn a particular task (Goldin-Meadow 2003a; Goldin-Meadow et al. 2012) – in order to predict who is ready to learn, we need to be able to distinguish information that is conveyed in an imagistic (gestural) format from information that is conveyed in a categorical (linguistic, be it sign or speech) format. The two formats together form the whole of a communicative act. However, by acknowledging the gestural components in sign, and comparing them to the gestural components in speech (cf. Okrent 2002), we can discover how the imagistic properties of language work together with its categorical properties to make human communication what it is.

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NOTES

1. By 1982, when Newport did the first categorical perception study in sign, sign was, in many circles, already recognized as a language. She was therefore able to make the opposite argument. She found it striking that sign languages have structure at higher levels (in particular, morphological structure), despite the fact that this structure did not appear to be based on phonological distinctions that are categorically perceived.

2. It is important to point out that Klima & Bellugi (1979) recognized that ASL, although clearly a language, did have features not found in spoken language; see, for example, their chapter on the structured use of space and movement.

3. Note that the precise mechanisms by which pro-drop is achieved are different in Italian and ASL – ASL uses space and movement through space; Italian uses markings on the auxiliary verb. Importantly, the hypothesis here is not that sign language must be identical to spoken language in all respects – only that it contain structures that parallel the structures in spoken language and serve the same functions.

4. The example in the text is a particularly straightforward one; see Mueller (2009), Sowa (2006), and Calbris (2003) for different analytic systems devised to determine how a gesture comes to represent the features of an object or action in more complex situations, and see Lascarides & Stone (2009) and Calbris (2011) for analyses of the semantic coherence between gesture and speech in an utterance.

5. See chapters 12–13 in Kendon (2004) for examples of other types of gestures that carry out pragmatic functions (e.g., performative functions, modal functions, parsing functions).

6. Determining whether gesture is temporally coordinated with speech is not always a simple matter, in large part because it is often difficult to align a gesture with a particular word in the sentence; the unit of analysis for gesture is rarely the lexical item (see McNeill 1992 for discussion). For a comprehensive discussion of the issues, see Kendon (2004, Ch. 7–8) and Calbris (2011).

7. We find the same effect for listeners – children are more likely to learn from a math lesson containing two strategies, one in speech and another in gesture, than from a lesson containing the same two strategies, both in speech (Singer & Goldin-Meadow 2005). In other words, the modality of expression matters even when the information conveyed is held constant.

8. It is important to point out that a single form can have properties of both sign and gesture (as in Duncan 2005). As an example, a child in the math studies conducted by Goldin-Meadow et al. (2012) produced an ADD sign in neutral space, which was classified as a sign. As described earlier, another child produced the ADD sign over the numbers that she had summed; this sign was classified as both a sign (conveying the summing notion) and a gesture (conveying the numbers to be added). When the ADD sign was combined with the other signs she produced on this problem, her signs conveyed an *add-to-equal-sign* strategy. When this information was combined with her other gestures, the gestures conveyed an *add-subtract* strategy. She thus had conveyed different information in her signs and her gestures and had produced a gesture-sign mismatch.

9. For similar kinds of technology used to study location, see Tyrone & Mauk (2010); Grosvald & Corina (2012), who used motion capture to examine location in ASL; and Ormel et al. (2013), who used the cyberglove and Ascension Flock of Birds technology to examine co-articulation and hand height in Sign Language of the Netherlands.

Open Peer Commentary

The influence of communication mode on written language processing and beyond

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Abstract: Empirical evidence suggests a broad impact of communication mode on cognition at large, beyond language processing. Using a sign

language since infancy might shape the representation of words and other linguistic stimuli – for example, incorporating in it the movements and signs used to express them. Once integrated into linguistic representations, this visuo-motor content can affect deaf signers' linguistic and cognitive processing.

We welcome Goldin-Meadow & Brentari's (G-M&B's) view that communication mode influences the structure of language, and we suggest that it might spread its influence to cognitive processes beyond language.

Accumulating evidence indicates that, within the population of deaf peoples, there are differences with respect to the *frequency of use* of a signed mode of communication. The preference for a signed or an oral modality to communicate might expand to language-related tasks apparently not directly linked to social communication – for example, on the processing of written language and visual word recognition. Barca et al. (2013) compared the performance of young adults with different communication modes (i.e., deaf individuals with a preference for signed language, and deaf individuals using an oral modality and with less or no competence in signed language) in a visual lexical decision task. The lexicality decision task is an established paradigm in psycholinguistics and consists of the speeded categorization (with key-press responses) of visually presented real words and nonwords. It is typically used to assess the ease of access and retrieval of stored lexical information from memory, with the basic finding of faster and more accurate processing of words than of nonwords and pseudowords (Balota & Chumbley 1984; Barca & Pezzulo 2012; 2015; Ratcliff et al. 2004).

In recruiting participants for the study, Barca et al. (2013) put forth an effort in controlling for individual factors heavily affecting performance in linguistic and cognitive tasks, such as the age of deafness diagnosis, the degree of hearing impairment, the age of exposure to sign language, and the preferred language modality. Deaf individuals were either those deaf individuals who communicate using mainly sign language, which they learned since infancy (before 3 years of age) in a natural environment, or deaf with a preference for spoken language (learned via formal instruction) and were poorly proficient in sign language. Results illustrate that different recognition strategies are in play between these groups, because the lexicality effect was present only in deaf individuals using mainly sign language to communicate. In a subgroup of participants (Napolitano et al. 2014), communication mode appears also to shape *functional connectivity of cerebral networks* related to language and cognitive processes (Laird et al. 2011; Smith et al. 2009), with increased activity in intrinsic connectivity among deaf signers compared to deaf individuals using oral language in an auditory network and a fronto-parietal network.

These findings converge within an *embodied framework* that sees action and language networks as deeply interconnected (Barca et al. 2011; Barca & Pezzulo 2012; Pezzulo et al. 2014; Pulvermüller et al. 2006; Pulvermüller & Fadiga 2010; Willems & Hagoort 2007). In such a perspective, words are not represented or processed in amodal format. The same neuronal networks are in play supporting perception and action performance (Barsalou 1999) – which would also explain why, for example, the processing of action verbs like "lick," "pick," or "kick" activates motor regions that mediate the execution of the corresponding actions (Hauk et al. 2004; Meteyard et al. 2008). This implies that *language modality* (oral or signed) deeply influences the way linguistic representations are formed and processed. Specifically, the use of a sign language since infancy might shape a person's motor and language neural circuits resulting in specific visuo-motor representations of words that are different from (and perhaps richer than) those of oral speakers. For example, creating "signed-based representations" that include the movements of the hands and other body parts, which in turn would enhance the involvement of cerebral regions related to the coding of motor acts and praxis information (e.g., inferior parietal lobule) (Corina et al. 2007; Pobric et al. 2010). Such visuo-motor representations might be elicited automatically during online linguistic processing or rehearsal and overlap with the perceptual-motor processes required to execute the task (in the case of Barca et al. 2013 study, the hand movements required to click a response button), thus potentially producing interference or facilitation effects.

From the point of view of a *predictive coding* and *active inference framework*, language makes use of *generative models* to predict how linguistic stimuli unfold in time: for instance, sequences of speech sounds and the proprioceptive states and motor commands required to utter them, or sequences of eye movements required to read a text (Donnarumma et al. 2017; Friston & Frith 2015; Lupyan & Clark 2015; Pezzulo et al. 2015). In signers, such generative models might predict the unfolding of hand movements and other (perceptual and proprioceptive) content associated with signs and gesture, or the eye movements required to track them – and this is why these latter visuo-motor predictions would be automatically elicited during language processing and rehearsal. What's more, given the established role of language in modulating various aspects of (nonlinguistic) cognition (Carruthers 2002; Spelke 2003; Vygotsky 1962), the fact that "pragmatically rich" visuo-motor content becomes integrated within linguistic representations (e.g., word representations) can have profound effects on deaf signers' cognitive processing at large. For example, if the online processing (or internal rehearsal) of linguistic stimuli elicits visuo-motor representations (e.g., of hand movements), these can become part and parcel of (say) the categories or the episodic memories that are formed in the meantime. The embodied/motor cognition literature highlights the importance of perceptual and motor representations in higher order cognitive processes such as categorization, memory, and planning (Barsalou 1999; Jeannerod 2006; Pezzulo 2012; Pezzulo et al. 2010; 2011; 2013). Analogously, "signed-based" visuo-motor content originally associated with language processing can potentially extend well beyond it and affect a wide range of cognitive processes. This hypothesis remains to be tested empirically.

Language is tightly connected to the perceptual and motor processes involved in the expression and recognition of communicative signs. As "language directly interfaces with the mental representations that are used in perception and action" (Lupyan & Bergen 2016, p. 7), the extensive use of a signed-based communication learned through social interaction in a natural environment might have a broad impact on shaping mental representations. In the case of signed language, the motor actions that are deeply tied with communication mainly comprise upper limb and hand movements (expression) and visuo-spatial processes of gesture recognition and speech reading (recognition). As this repertoire of motor acts can be automatically enacted during language processing or rehearsal, it can affect signers' linguistic skills and, potentially, cognitive processing at large.

Where does (sign) language begin?

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Abstract: Goldin-Meadow & Brentari (G-M&B) outline several criteria for delineating the boundaries between (discrete) signs and (continuous) gestures. However, the complex links between linguistics forms and their phonetic realizations defy such heuristics. A systematic exploration

of language structure by mouth and by hand may help get us closer to answering the important challenge outlined in this target article.

Where does (sign) language begin and where do (nonlinguistic) gestures end is a critical theoretical question that is central to an account of sign language, specifically, and the language faculty, broadly. Goldin-Meadow & Brentari's (G-M&B's) target article makes important strides toward its resolution. At the theoretical level, the authors convincingly demonstrate that linguistic forms and gestures exhibit stark differences that are suggestive of distinct computational origins, and these distinctions are evident irrespective of language modality – manual or aural. This conclusion is significant, because it shows that the differences between manual and spoken language might be smaller than what meets the eye/ear. Methodologically, G-M&B also outline several criteria for demarcating the boundaries between sign and gesture.

We applaud the authors' theoretical efforts and pioneering empirical work. However, it is important to recognize that their criteria for distinguishing signs and gestures are merely useful empirical heuristics – they will not suffice in and of themselves to define the boundaries of the language faculty.

G-M&B seek to distinguish signs and gestures by contrasting their phonetic forms, meanings, and pragmatic functions. Signs, in their view, exhibit discrete phonetic form, whereas gestures are continuous; signs' meanings are at least partly conventional and arbitrary, whereas gestures convey imagistic information using nonarbitrary means; hence, they are largely independent of experience with sign language. Finally, signs and gestures differ pragmatically inasmuch as they can convey different (and even contradictory) aspects of thought (e.g., during problem solving).

Although these three criteria can help identify (nonlinguistic) gestures, their utility for defining linguistic forms is less clear. Critically, these difficulties are expected even if signs and gestures do in fact originate from distinct computational mechanisms – an algebraic grammar versus an analog conceptual interface, respectively.

Considering first the phonetic criteria, the links between discrete linguistic categories and their phonetic realizations are far from transparent. Although analog nonlinguistic computations (e.g., for gestures) are likely to give rise to "phonetic" gradience, gradience could also result from the realization of grammatical categories that are discrete and abstract. To use an example from spoken language, *scenery* and *chicanery* are each equally good members of the *Noun* category; these exemplars are equally admissible to grammatical computations that apply to the category as a whole (e.g., regular inflection). But at the phonetic level, these exemplars will likely acquire gradient phonetic manifestations – high frequency forms, for example, are more likely to undergo schwa reduction (e.g., *scenery→scenry*) than low-frequency forms (e.g., *chicanery→chicanry*; Bybee 2002). Accordingly, a phonetic inspection of these exemplars may not necessarily inform us of their grammatical status.

Extending this logic to G-M&B's own example from signs, the fact that the phonetic realization of verb agreement (i.e., height in signing space) varies continuously depending on the addressee (adult or child) does not negate the possibility that the categories that inform syntactic computations are discrete and abstract, free of that analog information. Similarly, the gradient phonetic implementation of movement and location does not necessarily inform phonological processes, so phonetic gradience is entirely consistent with the possibility that the phonological grammar of sign languages is algebraic and abstract (Berent et al. 2014). The disyllabic noun ASL *seat*, for instance, is likely represented algebraically, as fully reduplicative (i.e., as XX), even if the location and movement features

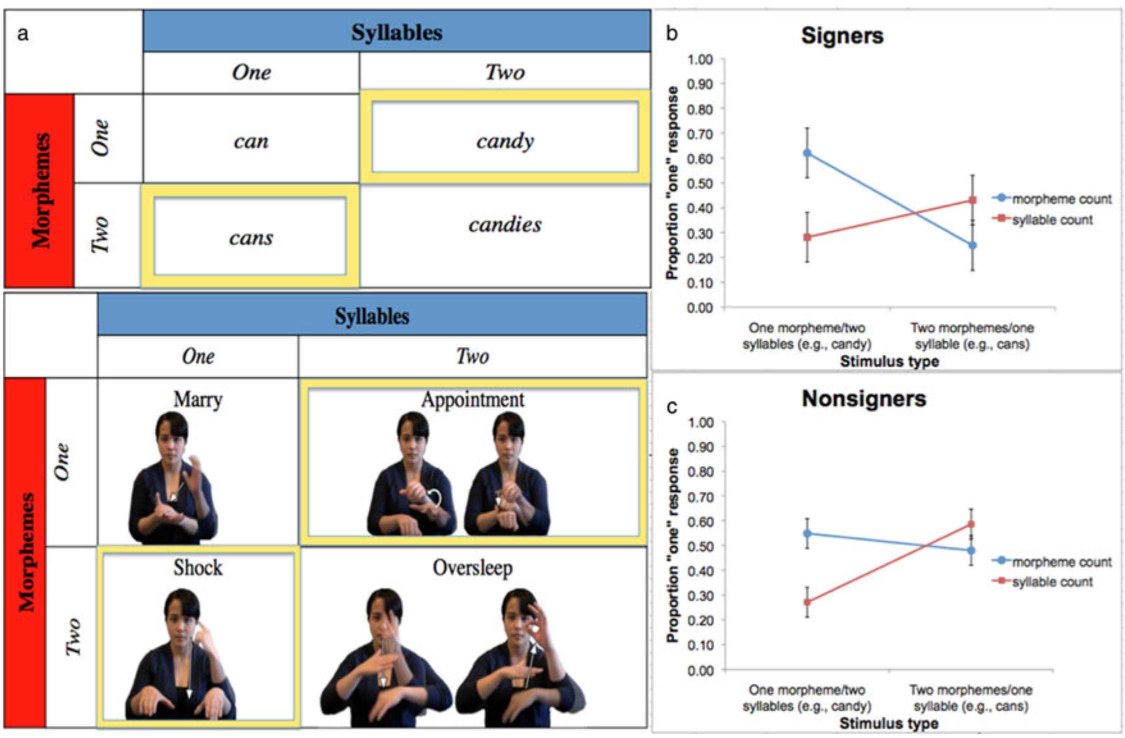

Figure 1 (Berent & Dupuis). Amodal restrictions on syllable structure. (a) Signed and spoken languages contrast syllables and morphemes; syllables are defined by phonological elements that correspond to energy peaks – either vowels (in English) or movements (in American Sign Language). Furthermore, signers (b) and nonsigners (c) can track the number of syllables and novel signs. Accordingly, when presented incongruency between the number of syllables and morphemes (see the highlighted cells), people shift their response (shown as the proportion of "one" responses, either one syllable or one morpheme) depending on whether they are asked to count syllables or morphemes. Data from Berent et al. (2013).

of its two syllables are phonetically distinct, and these differences are noticeable by signers in some other context (e.g., phonetic categorization). Accordingly, the phonetic realization of a manual form cannot transparently indicate its mental representation by the grammar. While gestures are likely to take continuous phonetic forms, phonetic gradience might also realize linguistic signs that are discrete and abstract.

In fact, judging by the literature from spoken language, any given sensory form may well acquire multiple representations at different levels of analysis – the dual percepts of speech analogs (as either linguistic speech, or nonlinguistic nonspeech) attest to this fact (Remez et al. 2001). Furthermore, speakers of different languages (e.g., Russian vs. English) demonstrably project their linguistic knowledge to the perception of nonlinguistic stimuli (i.e., nonspeech) – the better formed the stimulus in their native language, the more likely its perception as speech (Berent et al. 2010). These observations are significant because they suggest that the functional role of a given input – as linguistic sign (spoken or manual) or nonlinguistic element (e.g., gesture/nonspeech) is determined (at least in part) by grammatical constraints, and consequently, it is unpredictable solely from its phonetic form.

Experience-dependence (e.g., differences between signers and nonsigners) may likewise fail to reveal the status of a stimulus as "linguistic." G-M&B show that the silent gesturing of nonsigners has many characteristics of grammatical signs. Other evidence suggests that nonsigners' representation of signs relies not only on visual strategies, but also on shared grammatical constraints. For example, our past research (Berent et al. 2013) shows that signers and nonsigners both define signed syllables by the number of sonority peaks (i.e., movement) – an amodal principle that likely forms part of universal grammar (UG). Critically, these biases are linguistic, rather than merely visual, as nonsigners selectively apply them to syllables, but not to morphemes (see Fig. 1). Furthermore, while nonsigners readily learn this UG-consistent regularity (syllables are defined by movements; morphemes by handshape), they are unable to learn the reverse (syllables are defined by handshapes; morphemes by movements). In another set of experiments, we have recently shown that speakers extend the linguistic restrictions on doubling to both speech and signs (Berent et al. 2016). The potential for some linguistic principles to extend across modality and linguistic experience suggests caution in applying these criteria in the definition of signs.

Where, then, does (sign) language begin? We do not have a hard and fast solution to this question. However, it is important to recognize that the identification of linguistic inputs as such might be partly the product of linguistic computations rather than sensory and motor mechanisms alone. We thus believe it might be useful to complement G-M&B's empirical heuristics by a deductive approach that departs from a formal account of the language faculty and experimentally compares its implementation across modalities. A systematic exploration of language structure by mouth and by hand may help get us closer to answering the important challenge outlined by this target article.

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Sign, language, and gesture in the brain: Some comments

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Abstract: In contrast with two widely held and contradictory views – that sign languages of deaf people are "just gestures," or that sign languages are "just like spoken languages" – the view from sign linguistics and developmental research in cognition presented by Goldin-Meadow & Brentari (G-M&B) indicates a more complex picture. We propose that neuroscience research suggests that a similar approach needs to be taken and offer some examples from research on the brain bases of sign language perception.

Goldin-Meadow & Brentari's (G-M&B's) article uses evidence from sign linguistics and cognitive development to indicate how sign language processing may be accommodated within cognitive science. We propose that, in addition to perspectives from those disciplines, brain imaging has provided some important leads, as have neuropsychological case studies of patients who sign. In one brain imaging study, for example, deaf native signers were shown signed utterances and brachial gestures (specifically, the traditional tic-tac signalling system used by bookies to communicate odds), which could not be interpreted linguistically (MacSweeney et al. 2004). Whereas tic-tac activated posterior and inferior regions of the temporal lobe, signed utterances additionally activated superior temporal and inferior frontal sites, implicating left-hemisphere-dominant perisylvian regions associated with language processing in hearing nonsigners. Further studies also point to a distinction between those manual actions that can be construed as language and those that do not (i.e., signers vs. nonsigners; (Cardin et al. 2015; Newman et al. 2015). Again, these implicate greater activation in left-hemisphere-dominant perisylvian regions for the processing of linguistically structured gestures contrasting with greater activation in posterior/inferior regions for manual gestures that are not linguistically construed. Such studies also lead us to distinguish regions that provide essential sensory input to the language system, and which may be distinct from language processing itself (Corina et al. 2007,1992; Emmorey et al. 2002).

Such sign-focussed studies set up an interesting context for considering co-speech gestures in hearing speakers. Co-speech gestures can be "sign-like" and carry communicative significance. These include emblems such as "thumbs-up," as well as gestures indicating action dynamics and spatial relationships. Behavioral studies show that such gestures modulate the spoken message. Left-hemisphere-dominant perisylvian language regions are specifically activated by co-speech gestures such as these (Özyürek 2014). So, and in contrast with the studies that indicate different processing networks for (sign) language and gesture, these findings emphasize some common processing circuitry for gestures and (heard) speech, and raise issues of interpretation. For example, might gestures that sign linguists have appropriated to language analysis be actions that, in people who do not sign, are nevertheless processed by brain circuits associated with language processing? Such considerations drive us to take a more integrative view of language-as-communication.

Co-sign gesture. In sign language, face and head actions accompany manual signs and can be construed as "co-sign gestures" (Baker & Padden 1978). Are such co-sign gestures readily dissociated cortically from sign-as-language? The question has not yet been tackled directly, but we offer two insights from our own work. The first is a case-series study of three left-hemisphere-lesioned signers (LH-lesion) and three right-hemisphere-lesioned signers (RH-lesion), who were early or native users of British Sign Language (BSL). Their pattern of sparing and impairment led to a specific interpretation of the linguistic status of an utterance (Atkinson et al. 2004).

Is negation in sign syntactic? In BSL, as in many other sign languages, headshake can indicate negation of a manually expressed statement, with no accompanying manual marker of negation. We hypothesised that if this is syntactically processed, a headshake accompanying a manual expression should not be interpreted accurately in the LH-lesioned patients, in line with their other linguistic deficits. By contrast, if negation is managed as a prosodic feature, then accuracy may not be predicted by site of lesion, or RH lesions may adversely affect the perception of headshake negation.

In contrast to their many other language perception deficits, LH-lesioned patients were accurate at distinguishing video clips of signed negative (marked with headshake-only) utterances. RH-lesioned patients were unable to identify headshake-only negation utterances – although all of their other (manual) sign-language-processing skills were unimpaired. These findings suggest that headshake negation is not processed syntactically – at the very least, that it is not readily accommodated by left hemisphere language processing hitched to a damaged right hemisphere. In this way, neuropsychological investigations may constrain and help develop conceptualisations of those processes that may be construed as "core linguistic" (which, nevertheless, make use of *some* gestures) and others that may function in rather different ways, with greater reliance on right hemisphere processes.

Mouth actions can be more or less linguistic in sign language. Using functional magnetic resonance imaging (fMRI), we investigated facial actions accompanying the presentation of lexical manual signs in native deaf users of BSL (Capek et al. 2008). One type of facial action, where mouth actions disambiguate sign homonyms (in BSL, the signs UNCLE and BATTERY have the same manual expression but different mouth actions), has "lexical" import. This type of display generated activation in the same LH-dominant perisylvian regions as manual signs, which had no accompanying face action. However, a different type of face action was also investigated. Here, the facial action mimics the dynamics of the manual action ("echo-phonology"). For example, the BSL sign SHUT is a manual gesture of the hands coming together, accompanied by mouth closure. This may not be obligatory for lexical interpretation. In contrast to the "disambiguating mouth" signs, the echo-phonology signs showed less activation in LH perisylvian regions and more activation, bilaterally, in posterior and inferior regions associated with the analysis of visual, nonlinguistic signals (Capek et al. 2008).

While these findings can be interpreted in other ways (Capek et al. 2009, 2010), they suggest that conceptual processes underlying linguistic processing can be expressed and interpreted through means other than speech/manual sign and that these processes leave their mark in the brain of the language user. Questions remain about how gestural elements interact with linguistic elements within the manual component of sign language (see Cormier et al. 2013 on pointing gestures in BSL). It will be interesting to explore gesture more systematically in relation to sign language using brain imaging techniques – alongside linguistic and cognitive explorations, which, as the target article shows, now offer powerful models of cognitive and linguistic function.

Is it language (yet)? The allure of the gesture-language binary

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Abstract: Goldin-Meadow & Brentari (G-M&B) challenge the traditional separation between gestural and categorical language by modality, but they retain a binary distinction. However, multiple dimensions, particularly discreteness and combinatoriality, better carve up the range of linguistic and nonlinguistic human communication. Investigating transformation over time along these dimensions will reveal how the nature of language reflects human minds, rather than the world to which language refers.

Goldin-Meadow & Brentari's (G-M&B's) cogent and timely article reviews how the study of gesture and the study of sign language proceed synergistically, and inform our understanding of the nature of language. We agree wholeheartedly that the classical division of language by the physical channel of production, that is, "speech" versus "manual gesture," is not the best means of assigning representational format. As their examples illustrate, speech can take on properties of gesture, gesture can take on properties of sign language, and sign languages show aspects of both categorical and gradient language in a single manual-visual channel. Kendon (2014) resolved this issue by putting speech and gesture together into one superordinate category of representational format. G-M&B propose that we should retain the divide, but that it should not be drawn strictly according to the channel of production, that is, of spoken versus manual communicative behavior. We agree with this point and suggest that G-M&B have not gone far enough in reconceptualizing the boundaries. Fortunately, once we cast off the dichotomy based on channel, we are no longer restricted to a bipartite system, and we can consider multiple factors to determine the subsystems of language.

In forcing representational format into two types, G-M&B conflate multiple dimensions into a single contrast. On one side are forms that are categorical, conventionalized, and listable, while on the other side are forms that are gradient, imagistic, and spontaneously generated. This division results in the somewhat awkward assignment of signed spatial-relation expressions (which have internal structure) with holistic and imagistic expressions – and it leaves nowhere for emblem gestures, which are inconveniently highly categorical and highly conventionalized, yet have no internal structure, and cannot combine with other elements.

We propose that there is more than a single cut across the space of multimodal expressions. Figure 1 illustrates the divisions resulting from separation according to what we believe are the two most relevant dimensions: (1) whether a form is categorical, or gradient, and (2) whether it participates in a combinatorial system or is holistic and noncombining. The first dimension characterizes not the physical makeup of an expression but rather how the expression maps to its meaning or referent, whether in a discrete or analog way. The second dimension characterizes whether an expression includes any elements that combine grammatically in the construction of words and phrases. The examples in the four quadrants of Figure 1 demonstrate that aspects of vocal and manual communication, in both signed and spoken language, appear in every permutation of these two dimensions.

One might be tempted to define "gesture" as everything except the upper left quadrant, or as only the lower right quadrant. One end of each of these dimensions feels like the "gestural" end of the scale. Some forms feel gestural because they are gradient; others, because they don't combine. These are not the only dimensions that exhibit this contrast between prototypical nongesture and gesture, and different researchers have emphasized different factors when making their defining cut. Relevant dimensions can also include whether a form is conventionalized or produced *ad hoc*, whether it iconically references the real world and models of real world space, whether it is informed by semantic presuppositions, whether it is listable or infinite, and whether it is highly imagistic (e.g., de Vos 2015; Duncan 2005; Emmorey & Herzig 2003; Liddell 2003; Lillo-Martin & Meier 2011; Okrent 2002; Schlenker et al. 2013; Wilcox & Xavier 2013). Yet these dimensions can vary independently; a form can be both highly imagistic and highly conventionalized. Gesture is not a single phenomenon.

Utterances can be the product of multiple productive systems, bundled together into a composite stream to communicate a complex meaning (Enfield 2009). Defining gesture requires

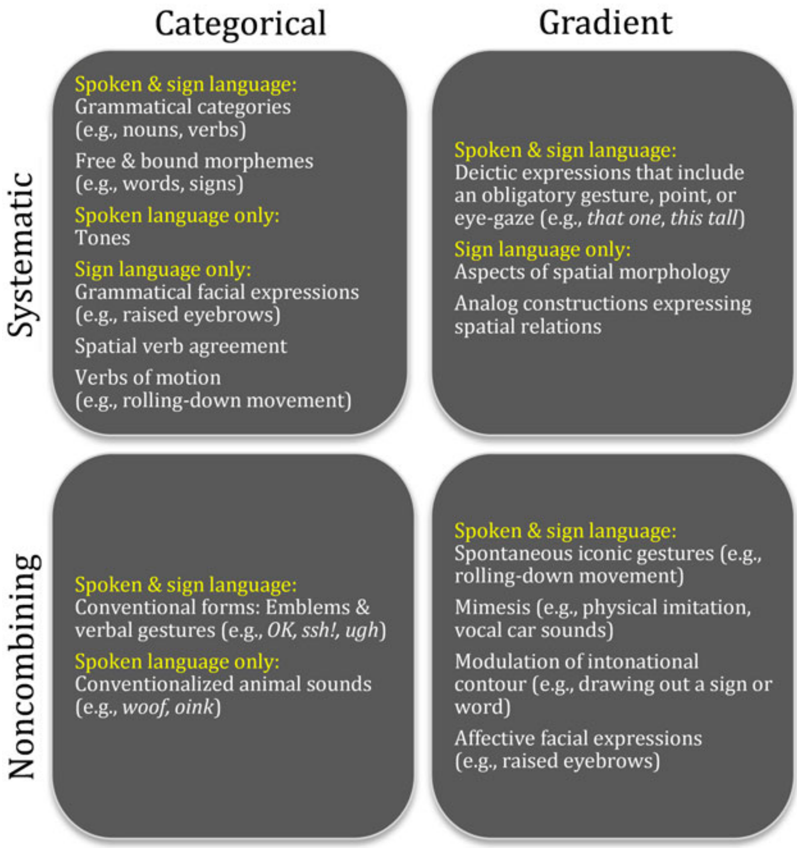

Figure 1 (Coppola & Senghas). A schematic providing examples of unimodal and multimodal phenomena in sign and spoken language according to the dimensions of Systematic-Noncombining and Categorical-Gradient. Importantly, each quadrant contains examples attested in both sign and spoken language. Some quadrants also present examples of phenomena attested in spoken language only or in sign language only.

Figure 2 (Coppola & Senghas). Two descriptions of the same rolling-down motion event: a holistic co-speech gesture produced by a Nicaraguan Spanish speaker (left) and a combinatorial sign produced by a deaf signer of Spanish Sign Language (Lengua de Signos Española, LSE). We can characterize these forms as differing in format only by considering how they relate to other forms within their respective systems, and whether they have subcomponents that map to meaning.

more than selecting the right thread from the composite. Inviting both extremes of multiple dimensions into linguistic analyses by characterizing the whole as "language plus gesture" does not resolve the problem. Much of the core grammar of sign language would inevitably be slotted into the "gesture" part, along with material very different in nature.

G-M&B's proposed next step of developing new technologies to measure utterances more finely will not clarify the distinction. As even they mention, the same form can be generated by either a gradient or categorical system (sect. 4.2, para. 3). Take their example of wiggling fingers moving along a path to indicate a person running (sect. 5, para. 3). Nothing in the form itself determines whether it has internal combinatorial structure; what matters is whether pieces of that form map holistically and veridically to the world (where legs, internal movement, and path of movement all occur together) or according to a system used to generate this and other utterances, using recombinable handshape, manner, and path elements. Figure 2 illustrates that the same manual utterance can be iconic and holistic in one linguistic context, and morphological and combinatorial in another.

We agree with the importance of creating a unified account of language that includes all aspects of its production, whether manual or vocal. We suggest that the study of spoken and signed languages at moments of change – particularly language acquisition, emergence, and change – offer a better view of the sources of language structure. The dimensions of discreteness and combinatoriality are of interest not because they help define gesture, but because they represent an abstraction and reconfiguration of information from how it is organized in the world. Accordingly, these dimensions are sites of qualitative shifts as language is created and changed. Forms appearing in new contexts constitute evidence of corresponding changes along these dimensions. For example, at some point learners transformed the onomatopoeic verbal gesture "mooo," allowing it to participate in combinatorial expressions like "The cow moo-ed all day." The path that elements follow as they become linguistic reveals human language-making capacity at individual, community, and multigenerational timescales. The world offers a continuous and image-rich stream of experience; representations that derive their structure directly from the world will be correspondingly gradient and holistic. Our own work demonstrates that gradient, context-dependent, and imagistic forms are reshaped by learners into discrete, recombinable elements (Coppola & Senghas 2010; Senghas et al. 2004). Investigating transformation over time along these dimensions will reveal how the nature of language reflects human minds, rather than the world to which language refers.

The physiognomic unity of sign, word, and gesture

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Abstract: Goldin-Meadow & Brentari (G-M&B) are implicitly going against the dominant paradigm in language research, namely, the "speech as written language" metaphor that portrays vocal sounds and bodily signs as means of delivering stable word meanings. We argue that Heinz Werner's classical research on the physiognomic properties of language supports and complements their view of sign and gesture as a unified system.

Goldin-Meadow & Brentari's (G-M&B's) view of sign and gesture as a unified system is more revolutionary than it might outwardly seem. They part with the prevailing backdrop of contemporary language studies and embrace instead the long-neglected (if not poorly understood) tradition of conceiving language as a human activity instead of a chain of thing-like lexical pieces. The undergoing paradigm shift the authors call for draws much of its force from leaving behind the extant framework that has dominated language research for the past 300 years, namely, the "speech as written language" metaphor (Ingold 2007) that portrays vocal sounds and bodily signs as means of delivering stable word meanings. At the dawn of modernity, the invention of the printing press and subsequent availability of books progressively inspired the idea that human speech was ultimately a variant of printed word production: Our mind uses sound units (i.e., words) whose semantic content does not vary across contexts and users. Thus, contextual cues of utterance, melodic aspects of the voice (such as rhythm and prosody), and certainly the accompanying gestures were dismissed from the framework of language production and comprehension except as peripheral information sources.

Shortcomings of the metaphor of speech as written language become blatant whenever the meaning intended by the user differs from the lexical meaning. Co-speech gestures constitute one of these cases, since they modify or complement verbal expression. This leads to the problem of combining two purportedly antinomical types of meaning: lexical and gestural (McNeill 1992). G-M&B contribute to close the artificial theoretic divide between objective meaning bearers (words and signs) and idiosyncratic and contextually dependent meaning (gestures). This divide, pervasive since Saussure's definition of *langue* as the subject matter of modern linguistics, fails to reflect that language, first and foremost, emerges organically among the humans who use it. The meaning of words is wholly dependent on "their always insistent actual habitat, which is not, as in a dictionary, simply other words, but includes also gestures, vocal inflections, facial expression, and the entire human, existential setting in which the real, spoken word always occurs" (Ong 1982, p. 46). Though the heritage remains tacit in the article, G-M&B are heirs to this contextual and organic conception of language; they reveal so by stressing that in real communicative acts, signs and words often behave like gestures and vice versa.

This tradition can be traced back to Wilhelm von Humboldt, who maintained that language "is no product (*Ergon*), but an activity (*Energeia*). Its true definition can therefore only be a genetic one" (Humboldt 1836/1988, p. 49). Language is not a set of prefabricated meaning units ready to be deployed for communication; one cannot replace the living utterance with tokens whose content has been described and preserved outside the stream of the real communicative situation. While the *language-as-action* tradition has known remarkable advocates during the 20th century – Peirce, Bühler, and Wittgenstein among the most prominent – it is in the writings of Heinz Werner, a lesser-known but crucial figure (Valsiner 2005; Wagoner 2013), where several of G-M&B's claims find the most relevant support.

Through a variety of experiments, Werner identified "physiognomic features" of words that grant them connotative values in a direct, immediate way (Werner 1978b). Just as when we see a face, we perceive words as hard or soft, sweet or dry, energetic or tired, and so on. Such physiognomic features of words do not correspond to their semantic representation; they rather include dynamic contents, imprecise but intermodal and synesthetic. Therefore, when the words "climbing" and "raising" are displayed centered on a monitor, they are perceived upwardly, while "falling" and "plunging" are perceived downwardly (Kaden et al. 1955). For Werner, the physiognomic qualities are what make symbol formation possible: "We submit that even the most conventionalized units of speech – words and sentences – are still part and parcel of an articulatory process, bodily postural activity, which, through its dynamic features, links those conventionalized units to their referents" (Werner & Kaplan 1963, p. 207). The pervasiveness of the physiognomic qualities consequently blurs the formal distinction between signifier and signified: "the 'arbitrariness' of linguistic forms seems to us to be unwarranted" (Werner & Kaplan 1963, p. 16). This is particularly salient in the case of gesture, since "the material moment of bodily posture and motion, and the moment of meaning, are an indissoluble unity, i.e., a gesture cannot be significantly analyzed into a bodily displacement and a meaning arbitrarily related to it" (Werner 1978a; 1978b, p. 424). G-M&B seem to share this view, as they reveal when they approvingly cite Waugh's (2000) indictment of arbitrariness in a text that calls for the reconciliation of form and meaning.

But how are we to harmonize the call for unity that pervades the target article with the authors' claim that it is necessary to distinguish between imagistic gestures and categorical sign (or speech) for the sake of predicting learning potential? While there doubtless is enormous practical value in their experimental insight (Goldin-Meadow et al. 2012), it seems an insufficient ground on which to proclaim a univocal imagistic/gesture, categorical/sign mapping, and particularly so in a field that is just coming of age. Imagistic and categorical are not separate positions across a schism but rather the fuzzy endpoints in a continuum. The brain's responses to uni- and crossmodal mismatches are fundamentally the same (Cornejo et al. 2009; Kelly et al. 2004). As the physiognomic nature of words makes clear, imagistic properties are also to be found in linguistic formats. The imagistic-categorical distinction is not an empirical claim but an axiom that assumes that meanings are products instead of processes. It is a tenacious residuum of the inherited metaphor of speech as written language that persists in gesture studies.

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Building a single proposition from imagistic and categorical components

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Abstract: Bimodal bilingual language provides further evidence for the viewpoint advocated by Goldin-Meadow & Brentari (G-M&B) that sign, speech, and gesture work together to create a single proposition, illustrating the potential in each set of articulators for both imagistic and categorical components. Recent advances in formal semantics provide a framework for incorporating both imagistic and categorical components into a single compositional system.

Goldin-Meadow & Brentari (G-M&B) highlight the relationship between imagistic properties and categorical properties in communication, focusing on how they emerge from and interact in speech, sign, and gesture. Indeed, it does seem clear that the appropriate comparison in forthcoming research on this topic should be the combinations of (a) speech and gesture with (b) sign and gesture, given increasingly sophisticated theoretical and experimental tools able to distinguish gesture and sign, and because imagistic gestures and categorical properties of speech and sign form complementary aspects of the communicative signal.

One important piece of evidence in favor of this view comes from a combination of sign and speech that was not discussed in the target article: sign-speech ("bimodal") bilingualism. Communication between individuals who are native users of both a signed and spoken language frequently involves natural "code blended" utterances (simultaneous signed and spoken analogs of unimodal bilingual "code switches") that exhibit aspects of the grammar of both languages. Studying code blends can provide unique insight into the ways that combinatorial ("linguistic") and imagistic ("gestural") signals can combine through oral and manual articulators, because in bimodal bilingual utterances each set of articulators has the potential to carry a full linguistic signal.

The flexible relationship between language and gesture is perhaps most clearly highlighted in code blends involving sign language classifier predicates, which are signs that involve a categorical/linguistic *handshape* that bears a grammatical/linguistic relation to the sentence's subject pronounced with a *movement and location* that have imagistic properties of gesture (see sect. 4 of the target article). When combined in code blends with a spoken language, these classifier predicates can either serve the place of a typical co-speech gesture (when the overall structure is based on the spoken language), or they can serve as a main predicate (when the overall structure is based on the sign language) with an accompanying gesture in the spoken language.

Consider example 1 below: in that example, English is the language providing the structure of the utterance and the mouth produces most of the words, while the hands merely provide an accompanying gesture but one that includes categorical, linguistic components from ASL (the classifier handshape for legs using the "V" handshape, CL-V). In another kind of blend, ASL provides the dominant underlying structure in example 2, and (whispered) English provides a sound effect – a verbal gesture of sorts – to accompany classifier constructions (contrast this with the English word *golf* that accompanies the nonclassifiers sign GOLF).

(1) *English speech*: And my mom's you know walking down.
ASL sign: CL-V(walking down stairs)
(Emmorey et al. 2008)

(2) *ASL Sign:* GOLF CL-1(path of ball going up) BALL CL-1 (path of ball going up)
English Whisper: golf (sound-effect) ball (soundeffect)
"In golf the ball goes high up, the ball goes like this … "
(Petroj et al. 2014)

Both (1) and (2) are examples of co-opting articulators typically used for combinatorial information in each language, now for imagistic, gestural purposes. Both blends using classifiers support the view that the oral and manual modalities are each capable of providing either imagistic or combinatorial components; that the manual modality is sometimes considered to be primarily gestural is a result of the traditional focus only on spoken language.

Bimodal bilingual code blends also support a second claim from the target article: that multimodal utterances convey a single proposition. Although unimodal (sign or speech only) bilingualism leaves open the question whether with, for example, two mouths, a bilingual could or would simultaneously produce two separate propositions in two languages, in the case of bimodal bilinguals the answer is evident: Despite separate articulators, many studies of bimodal bilingualism have shown that the two channels combine to produce a single proposition (de Quadros et al. 2015). It is crucial, then, to understand how a compositional semantic system should handle all of the components of such a proposition, both the imagistic and discrete, in sign and/or in speech.

It is unfortunate that in the target article the authors discuss the difficulties of accounting for imagistic components of sign (and speech) at various levels of linguistic analysis: the phonological, morphological, and syntactic, but have no dedicated discussion about meaning (semantics). However, very recent theoretical linguistic advances within formal semantics and pragmatics have provided tools to address precisely this question of how to incorporate both the gestural and linguistic aspects of meaning in many areas of semantics, including binding, scales, anaphoric reference, speech reports, and sign language classifier predicates.

Classifier predicates have especially been the focus of one account that directly compares the sign and gestural components of classifiers with the combination of speech and co-speech gesture, in an implementation of one of the primary suggestions of the target article. This is accomplished within a formal framework by modeling the gestural component as a *demonstration* that functions as a manner adverbial: Just like someone can run quickly or happily (which are categorical linguistic descriptions), they can also run in a manner consistent with an imagistic gesture that is provided (essentially, a gestural description). In speech, the gesture can be part of asserted content through such demonstrational adverbials, dependent on pragmatics; in sign language classifier constructions, the handshape provides the combinatorial/linguistic structure of a verb with minimal meaning on its own, which takes as a modifier the location and movement provided by the classifier (Davidson 2015; Zucchi Cecchetto & Geraci 2012). A similar event semantic analysis may be able to be extended to ideophones, which convey both imagistic and combinatorial information completely within the oral mode (Henderson 2016).

It is important to include bimodal bilingual "code blends" as a unique source of further evidence for the viewpoint advocated by G-M&B that sign, speech, and gesture all work together to create a single proposition, and to illustrate how imagistic and categorical components are both possible in both sets of articulators. Furthermore, recent advances in semantics provide a framework for incorporating gestural components meaningfully into a model of linguistic communication, as long as the analysis begins with the appropriate comparison of speech+gesture and sign+gesture.

Perspectives on gesture from autism spectrum disorder: Alterations in timing and function

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Abstract: The target article highlights the utility of new technology to study sign language and gesture. Research in *special populations* – specifically, individuals with autism spectrum disorder, ASD – may further illuminate sign/gesture similarities and differences and lead to a deeper understanding of the mechanisms of growth and change. Even verbally fluent speakers with ASD display distinctive qualities in sign and gesture.

Goldin-Meadow & Brentari (G-M&B) emphasize technology's utility in revealing common features and differences in sign language versus co-speech gesture. We propose a complementary approach: the study of gesture use in individuals with language and communication deficits, particularly autism spectrum disorder (ASD). In most populations exhibiting language impairment, affected individuals compensate for speech difficulties via increases in gesture; this is observed in expressive language delay (Thal et al. 1991), Down syndrome (Stefanini et al. 2007), Williams syndrome (Bello et al. 2004), and Specific Language Impairment (Mainela-Arnold et al. 2006).

In sharp contrast, individuals with ASD have broad deficits in social-communication skills including salient and striking differences in gesture production. Deficits in nonverbal communication (including, but not limited to, gesture) are required for a diagnosis of ASD (American Psychiatric Association 2013), and are codified on gold-standard ASD diagnostic measures and screeners such as the Autism Diagnostic Observation Schedule (Lord et al. 2012), the Autism Diagnostic Interview (Lord et al. 1994), and the Modified Checklist for Autism in Toddlers (Robins et al. 2014); on these measures, the absence or infrequency of gesture is rated as symptomatic.

Gesture impairments have been part and parcel of ASD symptomatology since the very earliest descriptions of the disorder (Asperger 1944; Wing 1981). Gesture delays, most notably reductions in declarative deictic gestures, have consistently been reported in studies of toddlers with ASD (Luyster et al. 2007; Mundy et al. 1987; Mundy & Stella 2000) and in high-risk infant siblings of children with ASD (Iverson & Kuhl 1995), who are statistically more likely to themselves develop ASD.

A number of studies have failed to find differences in gesture frequency in older individuals with ASD compared to control groups (Attwood et al. 1988; Capps et al. 1998; de Marchena & Eigsti 2010; Garcia-Perez et al. 2007; Morett et al. 2016), with some exceptions as noted below (de Marchena & Eigsti, in press). Research on ASD thus offers an opportunity to investigate the relationship between gesture and language production. As discussed by G-M&B, studies of gesture timing suggest systematicity in the amount of time between the onset of a gesture stroke and of the relevant word in speech (Nobe 2000).

Narrative data from teens with ASD, however, suggest that even when utterance and gesture rates are comparable to those of typically developing peers, and even when language and gesture share semantics, the stroke phase of iconic gestures is asynchronous, such that gestures both precede and follow the relevant speech (de Marchena & Eigsti 2010). Furthermore, naïve raters are sensitive to the degree of speech-gesture asynchrony: The more asynchronous the gestures, the more "difficult to follow" they rate videorecorded narratives, across diagnostic groups. These findings demonstrate not only that gesture and speech are intricately coordinated, but also their coordination and timing matters for communicative quality.

Currently, our group is evaluating the ability of teens with ASD to deliberately synchronize their gestures with highly rhythmic speech (nursery rhymes), in order to discover whether the asynchrony reflects a broad motor difficulty with smooth coordination across multiple motor systems (Bhat et al. 2012), or instead, resides with the communicative function of gesture. The mechanism relating gesture impairments to broader communication skills (and deficits) remains undefined; evidence that gesture-vocalization coordination develops slowly in ASD (Parlade & Iverson 2015) suggests that, regardless of mechanism, synchrony differences are apparent early in life and are part of a larger suite of communication delays. The work described here, and by G-M&B, suggests that speech-gesture synchrony is central to communication development more broadly (e.g., Özyürek et al. 2007).

In addition to illuminating subtle qualitative aspects of gesture, research on gestures in ASD can highlight the aspects of gesture that are integral to language production within a syntactically well-formed system versus the aspects that arise as part of social interaction – similar to the distinction between sign language and gestures as addressed in the target article. Children with ASD may have a reduced gestural repertoire (Capps et al. 1998; Wetherby & Prutting 1984), such that they produce a similar number of gestures but do not use their gestures to fulfill as many communicative *functions*, even at 9–12 months (Colgan et al. 2006). Compared to gestures serving a purely sociocommunicative function, individuals with ASD produce relatively more gestures to serve cognitive functions, such as self-monitoring (de Marchena & Eigsti 2014)

A small body of research characterizes the errors in sign language produced by fluent speakers of American Sign Language who also have ASD. Despite the iconic transparency of signed pronouns, which are points to oneself or others, signing children with ASD tend to avoid producing pronouns, instead spelling out names or using name signs, even to refer to themselves (Shield et al. 2015). This research has the potential to reveal the role of iconicity and self-representation in sign language and delays in development.

Gestures help speakers develop better internal representations of what they are attempting to communicate (Kita 2000). Accordingly, gestural differences in ASD may illuminate both language acquisition in general, and fundamental aspects of cognition and representation in that population.

How to distinguish gesture from sign: New technology is not the answer

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Abstract: Linguistic and psycholinguistic tests will be more useful than motion capture technology in calibrating the borders between sign and gesture. The analogy between motion capture (mocap) technology and the spectrograph is flawed because only vocal articulators are hidden. Although information about gradience and variability will be obtained, the technology provides less information about linguistic constraints and categories. Better models are needed to account for differences between co-speech and co-sign gesture (e.g., different degrees of optionality, existence of beat gestures).

Goldin-Meadow & Brentari (G-M&B) call for new technology to analyze motion and location as a means to distinguish between co-speech gestures and signs. I am not so optimistic about this approach. G-M&B suggest an analogy between the development of motion analysis tools for sign/gesture and the importance of the development of the spectrograph for advancing our understanding of speech. However, this analogy is flawed because (1) unlike sign/gesture, the articulators are not observable for speech and thus visualizing acoustic information was particularly crucial for spoken language, and (2) spectrograms and motion capture data provide a great deal of information about variability in the signal, but less information about linguistic or cognitive categories. For example, G-M&B argue that if the variability of signers' movements is less than speakers' movements when describing the same motion event, this finding would constitute evidence that signers' movements are generated by a different system (possibly linguistic) than speakers' gestures. However, reduced variability could simply be due to the motor expertise of signers who have much more experience producing communicative information with their hands (see Hilger et al. 2015). Although motion capture technology may be essential for investigating the phonetic and phonological properties of sign language (e.g., Jantunen 2013; Tyrone & Mauk 2010), this technology is less likely to provide the data necessary to understand the relationship between gesture and sign.

Rather, I suggest that the field will be advanced more by linguistic analyses (e.g., assessing whether syntactic or semantic structures constrain the interpretation of variations in location or motion, such as Schlenker 2011) and psycholinguistic experiments (e.g., testing whether and how signers or nonsigners categorize gradient information expressed in signs/gestures, such as Emmorey & Herzig 2003). Even then, more theoretical work is needed to establish models of language and gesture processing in order to determine how sign and gesture are combined and whether this combination is parallel to how speech and gesture are integrated.

For example, according to the gestures as simulated action (GAS) framework (Hostetter & Alibali 2008), gestures arise from perceptual and motor simulations that underlie embodied cognition, and they are produced when the level of motor and premotor activation exceeds a preset threshold (influenced by individual and contextual factors). Such a framework assumes that gestures are not obligatory, and this seems to be true except under certain (rare) deictic circumstances (e.g., "I caught a fish this big" is ill-formed without a size-illustrating gesture). In contrast, as noted by G-M&B, most linguistic analyses of sign language assume that directional ("agreeing") verbs and pronouns comprise both a linguistic and a gestural component, although whether the gestural component (indicating the location of a referent) is always expressed is an empirical question. G-M&B suggest that the difference in the optionality of gestures may be a matter of degree, but nonetheless the difference is quite large – many more signed than spoken language expressions are ill-formed without the gestural referential component. Further, the size of this difference indicates that perceptual and motor simulations are unlikely to be the source of both co-speech and co-sign gesture production. The point here is that it is unclear how current models of co-speech gesture production – including other proposals, such as the interface model (Kita & Özyürek 2003) – account for the high degree of obligatory gestural expression in signed compared to spoken language. It is unlikely that motion capture technology can help much with this question.

Interestingly, G-M&B do not discuss beat gestures, which are small movements of the hand (or head) that contain little semantic information (unlike deictic or iconic gestures) but have pragmatic or discourse functions such as marking prominence (McNeill 1992). Beat gestures are ubiquitous for speakers, but it is unclear whether the parallel exists for signers. One possibility is that the head movements of signers constitute beat gestures. Puupponen et al. (2015) recently used motion capture technology to identify the prosodic, grammatical, and discourse functions of head movements in Finnish Sign Language. They found that some head movements (e.g., a head thrust or pull) were produced primarily as prosodic cues signaling the prominence of a manual sign in an utterance. However, it is unclear whether these head movements should be analyzed as beat gestures or as prosodic markers in Finnish Sign Language. The primary problem is that sign and gesture cannot be separated by articulatory systems, unlike speech and gesture. Although motion capture technology was able to characterize small changes in head movements, Puupponen et al. (2015) were unable to find noticeable differences between head movements that seemed more gestural (e.g., nods indicating affirmation) and those that were likely to be more linguistic (e.g., nods occurring at syntactic boundaries).

Linguistic analyses may be more fruitful in determining whether particular head or manual movements constitute part of the prosodic system in a sign language, and psycholinguistic experiments can help determine how signers interpret these movements. Perhaps more importantly, better models of the relation between language and gesture can provide clearer hypotheses about how gradience is expressed in both the vocal and manual modalities and whether certain questions might even be ill-posed, e.g., perhaps there is no functional difference between beat gestures and prominence marking for sign languages, and spoken languages simply have the ability to spread prominence marking across two articulatory systems.

Emoticons in text may function like gestures in spoken or signed communication

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Abstract: We draw parallels between emoticons in textual communication and gesture in signed language with respect to the interdependence of codes by describing two contexts under which the behavior of emoticons in textual communication resembles that of gesture in speech. Generalizing from those findings, we propose that gesture is likely characterized by a nuanced interdependence with language whether signed, spoken or texted.

Goldin-Meadow & Brentari (G-M&B) argue that we can learn about cognition and language by examining interactions between sign or speech and gesture and highlight the changing view of these representational formats as independent and distinct. Conditions under which gesture takes on properties of sign or speech are revealing about the integral coordination of gesture and language. In this commentary, we focus on the written modality and incorporate the contrast between the mimetic, imagistic representational format characteristically applied to gesture and the discrete, categorical format characteristically applied to signed or spoken language. Our goal is to designate ways in which emoticons in textual communication invite comparisons with gesture. We propose that recent evidence on the comprehension and production of emoticons suggests that it parallels the functions of gesture. That observation contributes to a broader conceptualization of gesture, one that anticipates a nuanced interdependence with language whether signed, spoken, or texted.

Why might emoticons play a gestural role in written language? Recent studies of bimodal bilinguals, individuals who speak or read a written language in addition to a signed language, provide compelling support for an abstract level at which information across modalities is integrated during both language comprehension and production (e.g., Emmorey et al. 2015; Morford et al. 2011). Research on spoken bilingualism demonstrates that bilinguals activate the two languages in parallel even when only a single language is required (e.g., Kroll et al. 2015). The surprising finding is that bimodal bilinguals reveal many of the same cross-language interactions that characterize spoken bilingualism, suggesting that the principle of disparate forms that converge at an abstract level not only governs interactions within written or spoken language alone, but also applies to bimodal communication.

Emoticons can obviously function simply as "emblems" with stereotyped and context invariant meanings, but this should not distract us from the evidence that emoticons can function as "illustrators" and be integral to the intentional act: social and linguistic coordination. Vandergriff (2014) and Yus (2011; 2014) described the way that emoticons in text extend beyond their iconic characteristics so that a smiley face can indicate a request for acceptance or agreement and not simply that the writer is happy. Likewise, patterns of emoticon use can be revealing about the producer and their social standing, similar to dialectal variation in speech (Schnoebelen 2012).

In a recent study, Aragon et al. (2014) analyzed the presence of emoticons in a spontaneous written corpus of an online work environment derived from the texting behavior of an international group of French and American scientists who communicated in English, the first language (L1) of the Americans and the second language (L2) of the French. Over time, the L2 speakers altered their repertoire of nonverbal behavior (viz., emoticon vocabulary size) depending on the ratio of L1 and L2 speakers in the chat room audience. Like spoken communication, where there is evidence for a progression from the use of iconic signs for grounded shared meanings to a form that is more abstract and limited to a particular context and set of interlocutors (Galantucci & Garrod 2011; Garrod et al. 2007), the data on texting revealed alignment between interlocutors. The mutual influence of interlocutors has been variously termed coordination (Clark 1996), alignment (Pickering & Garrod 2004), or accommodation (Shepard et al. 2001). This pattern of increasing similarity has been documented at the levels of the syntax (Branigan et al. 2000), the acoustics of speech (Giles 1973), and the lexicon (Niederhoffer & Pennebaker 2002; Wilkes-Gibbs Clark 1992) as well as gesture (Mol et al. 2012). Convergence is often influenced by social factors, including the relative dominance or perceived prestige of each speaker (Gregory et al. 1997; Gregory & Webster 1996). The study by Aragon et al. demonstrates that nonverbal emoticon vocabulary, like many other aspects of language and gesture, is subject to social and linguistic interlocutor alignment.

In a smaller-scale experimental study, Feldman et al. (2015) examined the mutual influences of words and emoticons. They discovered an asymmetric interaction between emoticons and text in visual word recognition. Whereas emoticon valence (☹☺😐) had little influence on the time to recognize a word, word valence (BALMY, DUSTY) influenced decisions as to whether an emoticon reflected an emotion that was positive, negative, or neutral. Positive emoticon targets were facilitated by word valence, while negative emoticon targets were marginally slowed. Experimental demonstrations of how text influences the interpretation of emoticons are more robust than demonstrations of the effect of emoticons on text. A striking aspect of the Feldman et al. results was that a manipulation of timing had no effect on the observed asymmetry, suggesting that the pattern was not contingent on the time required to comprehend the emoticons.

Although research on processing emoticons in text is at an early stage of development, the preliminary findings are promising in suggesting that emoticons interact with text in ways that resemble other reported interactions of nonverbal gesture with language. There are many questions that have not yet been investigated, including those related to relative contributions such as how proficiency in emoticon production is likely to modulate the emoticon-text interactions in online communication. Like gesture in sign and spoken language, emoticon use in text may come to reveal the subtle interplay between linguistic and social aspects of communication. But critically, like research on bimodal bilingualism, these results show that gestural features of language are not bound by input modality. The interactions between emoticons with text, and between gesture with sign and speech, suggest that gesture, in its different forms, is indeed an integral component of language.

Why space is not one-dimensional: Location may be categorical *and* imagistic

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Abstract: In our commentary, we raise concerns with the idea that location should be considered a gestural component of sign languages. We argue that psycholinguistic studies provide evidence for location as a "categorical" element of signs. More generally, we propose that the use of space in sign languages comes in many flavours and may be both categorical *and* imagistic.

In their target article, Goldin-Meadow & Brentari (G-M&B) discuss several observations suggesting that the use of space is imagistic and may not form part of the categorical properties of sign languages. Specifically, they point out that (1) the number of locations toward which agreeing verbs can be directed is not part of a discrete set, (2) event descriptions by users of different sign languages and hearing nonsigners exhibit marked similarities in the use of space, and (3) location as a phonological parameter is not categorically perceived by native signers. It should be noted that G-M&B acknowledge that categorical properties of location and movement may simply not have been captured yet because the proper investigative tools are not yet readily available.

Here, we argue that there already is compelling evidence from psycholinguistic studies demonstrating that the location parameter of lexical signs, like handshape, plays an important role in lexical processing and therefore should not be considered a gestural element of signs. For example, Carreiras et al. (2008) showed that pairs of signs that share the same place of articulation yielded inhibition effects in a phonological priming experiment (see also Corina & Emmorey 1993; Corina & Hildebrandt 2002). Critically, inhibition was observed only for signs and not for nonsigns, suggesting that the inhibition effects were driven by *lexical* competition processes, similar to what has been found for spoken and visual word recognition (for related electrophysiological evidence, see Gutiérrez et al. 2012). Therefore, location seems to play an important role in the activation and subsequent selection of lexical representations in the mental sign lexicon, whereby signs that are less familiar and that reside in larger phonological neighborhoods are more sensitive to lexical competition effects (cf. Caselli & Cohen-Goldberg 2014).

Moreover, although the findings are slightly more mixed, the location parameter in signs not only impacts sign recognition, but also production processes. For example, using the sign-picture interference paradigm, Baus et al. (2008) found inhibition effects for distractor signs that shared the same location as the target sign, whereas Baus et al. (2014) found facilitation effects for distractor signs that shared both location and movement (cf. Corina & Knapp 2006), and argued that the combination of these two phonological parameters form an important functional unit in lexical access in sign production.

More generally, these psycholinguistic studies provide clear evidence that location forms an important component of the phonological-lexical organization of sign-based forms in the mental lexicon (further support, e.g., comes from studies of "slips of the hands" and "tip of the fingers" experiences [Hohenberger et al. 2002; Thompson et al. 2005]). The empirical finding that this parameter is not categorically perceived by signers may be analogous to the situation for vowels in spoken languages, which are more continuously represented and are not categorically perceived to the same degree as consonants (e.g., Fry et al. 1962; Stevens et al. 1969), but are not considered a gestural component of spoken languages. Furthermore, even dynamic handshape contrasts appear to be less categorically perceived than consonant *or* vowel contrasts (see, e.g., Best et al. 2010, for discussion), suggesting that categorical perception paradigms have limited applicability in the study of sign perception.

We thus strongly believe that there is abundant evidence from psycholinguistic studies that location forms an integral part of the lexical organization of signs. At the same time, however, we would like to warn against viewing all uses of space in sign languages through the same lens. Location as a phonological parameter of signs is both conceptually and empirically different from the use of space beyond the lexicon. For example, the use of referential locations in signing space or of classifier constructions may be either categorical (as the expression of linguistic features) or imagistic (in the form of isomorphic mappings). More importantly, both types of spatial exploitation frequently co-occur, and we need to work toward a better understanding of how categorical and imagistic uses of space interact. Both the pronominal system and verbal agreement rely upon the association between a referent and a location in the signing space. Fundamentally, this association is an expression of referential identity that may be best captured in terms of features (Costello 2015; Kuhn 2015). Additionally, space may be divided to encode semantic notions, such as specificity (Barberà 2014).

This categorical use of locations in space does not preclude less categorical uses of space, such as the use of metaphoric schemes ("high is powerful, low is weak") or discursive functions such as contrast (Engberg-Pedersen 1993), or even clearly imagistic uses of space, evidenced by the isomorphic mappings of spatial descriptions and classifier constructions. The fact that these different uses of space can occur simultaneously, as in Liddell's (2000) notorious examples of the type "I asked a (tall) man" (in which the location associated with the referent is visually motivated by the referent's height), does not detract from the fact that some uses of space are indeed categorical.

These observations lead us to believe that there is a more general conceptual problem with the distinction between categorical and imagistic (i.e., gestural) components of language that G-M&B posit. In particular, we question its underlying assumptions that each element of an utterance can be clearly categorized as belonging to either of these two categories, and that the linguistic functions of categorical and gestural elements in signed construction can always be clearly separated. In conclusion, we therefore advocate that the distinction between categorical and gestural uses of space in sign languages itself should not be perceived categorically. Instead, spatial exploitation by sign languages is better captured by a continuum between linguistic structures with more categorical-like properties on one end (e.g., location as a phonological parameter) and more imagistic-like properties on the other end (e.g., classifier constructions in event descriptions). In between, there are many structures with both types of properties but without a clear boundary between them (e.g., referential locations in verb agreement).

Pros and cons of blurring gesture-language lines: An evolutionary linguistic perspective

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Abstract: The target article's emphasis on distinguishing sign from gesture may resolve one important objection to gesture-first theories of language evolution. However, this approach risks undervaluing the gradual progression from nonlanguage to language over hominin evolution, and in emerging sign systems today. I call for less emphasis on drawing boundaries and more emphasis on understanding the processes of change.

The target article by Goldin-Meadow & Brentari (G-M&B) emphasizes the importance of maintaining a firm distinction between sign and gesture; I suggest that this has consequences that are both helpful and unhelpful for those who wish to understand the cognitive and communicative roots of linguistic structure. These questions can be asked at multiple timescales, ranging from the earliest systems used by our hominin ancestors, to the kinds of systems that arise *de novo* among modern humans today.

On the helpful side, G-M&B's proposal may resolve one objection to gesture-first theories of language emergence over the course of human evolution. Under such theories, human language is thought to have achieved crucial milestones in the manual modality, with potential explanations including the greater intentional control of the manual articulators relative to the vocal tract in primates and the iconic affordances of the manual modality for accomplishing reference, and so forth. Variations on this theme figure prominently among both classical (de Condillac 1798; Jastrow 1886) and contemporary (Arbib 2005; Corballis 2003; Hewes 1973) theories of language evolution.

One important objection to such views is captured in McNeill et al. (2008). They argued that because modern language crucially integrates codified linguistic forms (speech) with synthetic/imagistic forms (gesture), any evolutionary trajectory that fails to involve this "dual semiosis" from the very beginning ends up predicting what did not evolve (speech-only, or gesture-only) instead of what did (a tight coupling of speech+gesture). However, by demonstrating that both modes of semiosis are in fact available in the manual modality, G-M&B's target article provides a possible resolution to the concerns raised by McNeill et al. (though other objections remain).

On the unhelpful side, G-M&B's perspective on the relation between silent gesture and language is puzzling. For example, in section 4.2, they suggest that the signature of language is uniformity (adhesion to standards of form), whereas gesture is characterized by variability. They then proceed to argue that handshape must be linguistic, because it shows variability from system to system, whereas movement and location may be gestural, because they are so uniform. This is precisely the opposite of their earlier argument. Then, in the very next section, we are encouraged to believe that silent gesture "might be more appropriately called spontaneous sign" (sect. 4.3), despite later acknowledgments that silent gesture does not contain all of the properties of even homesign, let alone conventional sign languages. (I note that silent gesture may also have additional properties that homesign doesn't, and that such differences could be an important source of insight.)

I suspect that this lack of clarity stems from a tension between wanting to delineate what is gestural from what is linguistic in the face of a reality in which the lines between language and gesture are often blurry, as G-M&B periodically acknowledge. But from my perspective, and from the perspective of evolutionary linguistics, these lines *should* be blurry. Phenomena in synchronic analyses are often more clear in the light of diachrony, in which change happens gradually and continuously. G-M&B themselves suggest that conventional sign languages have their roots in homesign systems, perhaps also influenced by the co-speech gestures of hearing people. (I would submit that the silent gestures of hearing people may also influence a developing system in some contexts.) In my view, the ability to clearly delineate gesture *from* language is less important than the ability to understand how gesture *becomes* language.

This process-oriented view need not undercut the key insight that the manual modality contains more than one semiotic mode. But it does free us to worry less about precisely where to draw the line, as biologists gave up doing long ago regarding speciation (De Queiroz 2007; Irwin et al. 2001). We can instead recognize a gradient from loosely concatenated, paratactic orderings in silent gesture to grammatically constrained syntactic forms in conventional sign languages. Sandler (submitted) presents an exemplary illustration of this approach as applied to several generations of an emerging sign language. It may also be profitable to consider whether such a progression from less language-like to more language-like also characterizes deaf homesigners as they grow from infancy to adulthood. A similarly gradual process is likely to have characterized the progression from no language to protolanguage to language, as early hominins moved from less-organized to more-organized forms of representation and communication.

With sign language and other gestural systems (e.g., homesign, silent gesture) among our best models of human language evolution, some "line blurring" may be necessary to understand the progression from nonlanguage to language. G-M&B's challenge for us is to figure out how to do so without sacrificing the important insights to be gained from cases where gesture and sign operate in different semiotic modes.

Good things come in threes: Communicative acts comprise linguistic, imagistic, and modifying components

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Abstract: Gesture and sign form an integrated communication system, as do gesture and speech. Communicative acts in both systems combine categorical linguistic (words or signs) with imagistic (gestures) components. Additionally, both sign and speech can employ *modifying components* that convey iconic information tied to a linguistic base morpheme. An accurate analysis of communicative acts must take this third category into account.

We agree that gesture and sign, like gesture and speech, form an integrated communication system. Communicative acts in both spoken and signed languages combine categorical linguistic (words or signs) with imagistic (gesture) components. Still, gestures contribute different types of information from signs or spoken words. Our analysis of communicative acts should respect this. Therefore, we should aim to tell apart categorical from imagistic components.

In spoken language, the distinction between them is rather straightforward as two different modalities are involved, forming two different channels. Linguistic components are conveyed in the auditory domain; imagistic ones are conveyed visuo-spatially. For communicative acts in sign language, however, the distinction is not so straightforward. Gesture and sign occur in the same modality such that linguistic and imagistic components get blended together. However, a comparative analysis of signed and spoken communication will only get off the ground once we can disentangle linguistic and gestural components in this single visuo-spatial channel.

To achieve this, we propose including a third category of components in the analysis of communicative acts: modifying components. Rather than independent gestures, modifying components are imagistic modifications of linguistic components. Like gestures, they can convey additional information iconically. Unlike gestures, however, they are not independent imagistic units. They are bound to linguistic components exploiting their available degrees of freedom to add meaning without changing the core categorical meaning altogether. As a simple illustration in spoken language, consider extending the length of a vowel (e.g., l-o-o-o-o-ong) to emphasize duration of an event (Okrent 2002). While this modification is merely amplifying the meaning of the linguistic component "long," we can also think of modifications adding information. Depending on how a speaker modulates voice and intonations, the utterance "Sarah be-e-e-e-e-ent the metal" conveys not only that Sarah bent the metal, but also that it took her a lot of effort to do so.

Analogously, signers can modify, for example, the handshape, movement, or location of signs while retaining categorical linguistic morphemes (as Duncan 2005 discussed in the context of signers' descriptions of Tweety Bird cartoons). This way, essential categorical information is preserved while iconic information is added through spontaneous and idiosyncratic modifications. Signers intuitively know the degrees of freedom they can exploit in their variations of signs as speakers know what the permissible variations of words are in the preceding examples. The modified signs embody both lexical and imagistic features; they form units that have both linguistic (lexical) and imagistic (gestural) aspects. Importantly, here the gestural aspects are not separable from the linguistic ones; they are bound to their linguistic base morphemes.

Not all variations of signs are spontaneous and idiosyncratic, though. Just as in spoken language, there are systematic differences between dialects, accents, and so on. For current purposes, however, we are not concerned with these. Rather, we are interested in how speakers purposefully modify individual signs imagistically. There are cases where variations in how a sign is performed lead to lexicalized changes in meaning while the basic linguistic morpheme remains unchanged. Consider the verb "to email" in British Sign Language. Here, the agent-patient relation is determined by the orientation of the sign: If the index finger of the signer's dominant hand is flicking at you and the index finger of the nondominant hand is flicking at her, she signs "I e-mail you." If she performs the sign the other way around (with the dominant finger flicking at her), she signs "You e-mail me." These, too, are modifying components, but they have become conventionalized; they are no longer idiosyncratic.

In spoken language, we find modifying components not only in vocal gestures like extending a vowel; there are also cross-modal modifications. For illustration, consider demonstratives accompanied by pointing gestures. Suppose we are looking at a set of three keys on a table. We will usually expect an instruction like "Take this key!" to be accompanied by some kind of pointing, handing over a key, nodding at a key, and so on. Whatever we do to indicate which of the keys we refer to, it is a modification of "this" which forms a single, cross-modal unit. Again, the gestural and lexical aspects may be easier to dissociate in spoken than signed language, but the phenomenon is the same.

A critic may object that we should simply consider the pointing at a key as a gestural component. But this would be to ignore that the demonstrative "this" is lexically required to be accompanied by some kind of indication (though the exact format can vary significantly). Besides, such a move would render gestural components much too inclusive. In principle, gestures also convey information independently of the linguistic components they accompany. For the pointing in the scenario at issue, this is not the case. Pointing here only gets its meaning through combination with the spoken demonstrative.

Modifying components may occur in different modalities in sign language, too. Take the mouth forms that Sandler (2009) reported in signers describing Tweety Bird cartoons. These are, like the pointing that accompanies spoken demonstratives, imagistic aspects directly modifying linguistic components. Again, the reason to treat them as modifying components rather than imagistic components is that they add imagistic aspects to a lexical base morpheme rather than functioning as an additional imagistic component within a communicative act.

The crucial characteristic of modifying components is that they deliver imagistic information as part of a modified lexical unit. They can be lexically required to form meaningful units (as in the case of demonstratives) or they can be added spontaneously. They can take different forms, some of which may (have) become conventionalized, and they may even occur in different modalities from the base morphemes. But they always remain bound to a linguistic component.

By adopting modifying components as a third category, we are much better placed to disentangle linguistic and imagistic components of communicative acts. This allows us to better assess and systematically compare the role that gesture plays in both signed and spoken languages.

Languages as semiotically heterogenous systems

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Abstract: The target article is consistent with seeing languages as semiotically heterogenous, using categorial, depictive, and analogic semiotic signs. "Gesture," used in the target article, is shown to be vague and not useful. Kendon's view, criticised in the target, is restated. His proposal for comparative semiotic analyses of how visible bodily action is used in utterance production is reexplained.

An important conclusion to be drawn from Goldin-Meadow & Brentari's (G-M&B's) article is that languages, spoken and signed, are semiotically diverse systems. As they show, there is increasing recognition that sign languages are incompletely described using the same framework as that used for spoken languages. Although there are many features of sign comparable to those found in spoken languages, there are also expressions that lie outside this framework. To mention two of their examples, Duncan (2005) described signers modifying signs to express meanings not given by a lexical sign in its citation form; and Schembri et al. (2005) observed that in classifier constructions, although the referent referred to by a classifier (vehicle, person, etc.) uses a categorically distinct handshape, this handshape can be moved about to depict the behaviour of the referent, rather than describing it with discrete morphemes. In addition, speakers, ignorant of sign, asked to express the same thing, but with hands only, did not use standardised handshapes (no surprise), but depicted the referents' behaviour much as did the signers, showing that in the kinesic medium signers and speakers use similar methods for depictions of this sort. G-M&B also mention studies that show that speakers, by modifying their vocal expression – loudness, pitch, speed – are able to express meanings beyond what is in words alone. In producing utterances, signers and speakers both use a range of different semiotic devices, relying upon expressions with categorial referents as well as those that are gradient. As G-M&B say, this leads us to question whether the meaning of "language" should not be changed. Others have also raised this point. For example, Liddell (2003, p. 362) wrote that "spoken and signed languages both make use of multiple types of semiotic elements… our understanding of what constitutes language has been much too narrow."

I argue in the same way (Kendon 2014), showing that manual actions that speakers often use while speaking, when contributing directly to an utterance's referential content, may be seen as elements in their utterance's construction. Just as signers, using several different body articulators differentially in producing utterances may engage in so-called "simultaneous constructions" (Vermeerbergen et al. 2007), so speakers can do the same, not only vocally, but also with their kinesic resources. Parallels and differences in how utterances are constructed by speakers and by signers can be more fully understood when we consider not only speakers' vocal productions, but also the kinesics they use. In this way we can develop precise descriptions of how and when these resources are employed and how their semiotic properties vary by circumstance of use and how they differ between signers and speakers.

In the target article here being commented on, the authors make use of "gesture" which they tend to regard as categorically different from "sign." I think this is unfortunate. "Gesture" is so muddied with ambiguity, and theoretical and ideological baggage, that its use in scientific discourse impedes our ability to think clearly about how kinesic resources are used in utterance production and interferes with clarity when comparing signers and speakers. The authors refer to my article (Kendon 2008) wherein I argued that we should get rid of the categories "gesture" and "sign" and proposed, instead, that we develop a comparative semiotics of visible bodily action (kinesis), as it is used in utterances by speakers and by signers. To do this, I suggested, would resolve and clarify the otherwise rather fraught discussions of how "gesture" and "sign" are related, as well as the problems encountered when, in a signed utterance, we sometimes have difficulty in deciding whether a given expression is a "gesture" or a "sign." Visible bodily action in utterance is semiotically diverse in both speakers and signers. Our task as analysts is to set about developing a differentiated vocabulary describing this diversity and to undertake comparative studies of the contexts in which these different forms are used.

G-M&B say (para. 4) that my article (Kendon 2008) provides "an excellent review" of what has led "gesture" and "sign" to be considered distinct categories (and they say they agree with it), yet they seem to have missed the implications of that review. In that review I pointed out the different ways in which the term "gesture" has been used, showing the vagueness of the concept that this word refers to. The authors' conclusion was that my approach might lead me to blur necessary distinctions. A closer consideration of what I had actually written in that article (and also of what I have written elsewhere about "sign" and "gesture" – e.g., Kendon 1980a, 1988a, 1988c, 2004, 2008, 2012, 2014, 2015) might have allowed them to see that I have never been in danger of such blurring. On the other hand, looking at how they employ the word "gesture" in their target article, we find that, like many other writers, they use it in several different ways but without seeming to notice that they do so. For example, G-M&B define "gesture" as "manual movements that speakers produce when they talk" (para. 3), later they indicate (sect. 4.2, para. 3) that gestural forms in signing are "analog and gradient." But then they say that hearing non-signers "can invent gestures that resemble signs" (sect. 4.2, para. 6). They talk of "imagistic gestures" and at one point they say "there is gesture in the oral modality" (sect. 7.2, para. 2). It is thus not clear what their concept of "gesture" amounts to.

As I have already said, because of the ambiguity of the word "gesture," because it often embraces many different phenomena and thus encourages one not to think about the differences between them, and because of the theoretical and ideological connotations this word often brings with it, its use impedes clear discussion and makes more difficult the recognition of both the continuities and discontinuities in the various ways humans employ kinesis as they engage in languaging or utterance production. The comparative semiotic approach that I propose would make for better progress in our understanding of these matters.

Why would the discovery of gestures produced by signers jeopardize the experimental finding of gesture-speech mismatch?

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Abstract: Mismatch occurs when there is a discrepancy between produced gestures and co-occurring speech. In this commentary, I explore why research on mismatch might be called into question by changing views of what constitutes a gesture. I argue that the experimental procedure for producing mismatch, through its coding methods, is blind to the tight temporal coordination of gesture and affiliated talk.

Goldin-Meadow & Brentari (G-M&B) provide a concise summary of how our thinking about sign and gesture has shifted over the past century. The latest installment in this history involves evidence gathered by multiple researchers of gesture production within sign-based interaction (Duncan 2005; Emmorey 1999; Goldin-Meadow et al. 2012; Liddell & Metzger 1998). G-M&B, however, caution in their target article against blurring the "categorical division between gesture and sign," warning that there are "phenomena that depend on the divide, for example, predicting who is ready to learn a particular task" (sect. 7.2, para. 1). The particular phenomenon at issue is "gesture-speech mismatch" (e.g., Alibali & Goldin-Meadow 1993; Goldin-Meadow et al. 2012). In this commentary, I will explore why research on gesture-speech mismatch might be challenged by changing views of what constitutes a gesture.

Mismatch is a phenomenon that arises when there is a perceived discrepancy between produced gestures and co-occurring speech. In the example provided by G-M&B, a subject has been asked to provide an explanation for her solution to the equivalence problem, 6+3+4=___+4. The subject reports that she added the three numbers on the left-hand side and produced their sum as a solution, but as she does so she points not only to the three numbers on the left side of the equation, but also to the number 4 on the right. This is taken by the authors as evidence that the child is in a "discordant" (Alibali & Goldin-Meadow 1993, p. 496) cognitive state, that she is on "the verge of learning" (p. 470). The child, in such circumstances, is thought to entertain "two different hypotheses at the same moment" (p. 477). The hypotheses constitute different "representations" of the problem, some being theorized to be "accessible to gesture but not to speech" (p. 510).

Over the years some extravagant claims have been made regarding gesture-speech mismatch – that learners convey information through gesture of which they may not be aware: that mismatch provides a window into the learner's mind. The detection of mismatch, however, faces a large and difficult challenge. Calbris (2011, pp. 23–30) reported that a single gestural form can represent different ideas (polysemy), while a single concept can be evoked using different forms (polysign). Gestural forms, therefore, are inherently "inscrutable" (Quine 1968, p. 196), there being no one-to-one correspondence between signifier and signified.

Experimenters seeking evidence of mismatch have attempted to overcome this by cataloguing the gestures commonly seen with regard to a particular task and using coders familiar with those catalogued gestures. The experimental protocol employs a double-coding technique (Alibali & Goldin-Meadow 1993). Videotapes of the subject producing an explanation at the board are first coded, working solely off the audio track, by someone familiar with the strategies children commonly employ for the problem in question. The recording is then recoded, now with the sound off, by a different coder familiar with the gestures associated with these same strategies. When the codes generated by the two methods are discrepant, the subject's explanation for that problem is classified as exhibiting a mismatch. In more recent work with signing subjects (Goldin-Meadow et al. 2012), the videos are viewed first by an American Sign Language (ASL) coder and again by a coder familiar with the problem-specific gestural "formulations" (Koschmann et al. 2007).

There are several concerns with this way of operationalizing mismatch. The experimental protocol does not really resolve the inscrutability problem, but merely seeks to control it by tightly limiting the range of gestural formulations that might arise. This strategy rests on a number of assumptions: that subjects have finite gestural repertoires, that the ways of understanding (or misunderstanding) the problem are fixed, and so forth. The interview is rigidly structured, and there is no built in "proof procedure" for meaning construction. When interaction is constrained in this way, there is no opportunity to pursue intersubjectivity (Interviewer: "I notice that you have pointed at four numbers, but your sum only includes three. How does that 4 to the right change your answer?"). The errant gesture produced by the subject in the example performs the work of "disclosing the world in sight" (Streeck 2009, pp. 8–9). Gestures that function in this way do so through tight temporal coordination with co-occurring talk (Hindmarsh & Heath 2000; Streeck 2009). The experimental procedure for producing mismatch, however, is blind to this coordination owing to its method of coding gesture and speech/sign independently.

So, the returns are still out on how the discovery of gesture production by signers will impact further research on learning and gesture. Educational psychology has, from its inception, treated learning as an "occult" (Koschmann 2002, p. 2) matter. The experimental finding of gesture-speech mismatch is provocative in that it takes up learning as something witnessable. What we need, however, is to find new ways of studying gesture in learning, ways that treat gesture as an interactional matter and that honor what G-M&B identify as "the principle that speech and gesture form an integrated system" (sect. 5, para. 3).

Understanding gesture in sign and speech: Perspectives from theory of mind, bilingualism, and acting

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Abstract: In their article, Goldin-Meadow & Brentari (G-M&B) assert that researchers must differentiate between sign/speech and gesture. We propose that this distinction may be useful if situated within a two-systems approach to theory of mind (ToM) and discuss how drawing upon perspectives from bilingualism and acting can help us understand the role of gesture in spoken/sign language.

We agree with Goldin-Meadow & Brentari (G-M&B) that researchers must differentiate between sign/speech and gesture and believe that this distinction may be useful if situated in the context of theory of mind (ToM) use. Gesture is an important component that individuals must consider when predicting others' mental states. We agree with G-M&B that gesture is imagistic, not linguistic. In addition, there seems to be a preferred method of using gesture to communicate, as in the silent gesturers described by G-M&B. While we concur that those individuals were replacing language, not supplementing it, the degree of similarity in direction and space without any American Sign Language (ASL) practice in attempts to communicate a thought to another person suggests the use of an automatic ToM system. Apperly and Butterfill (2009) proposed that two systems of ToM use exist in typically functioning people. The first system is fast and efficient, developed early in life, but relatively inflexible and is used in tasks not requiring language. This system explains the success of infants and some primates on simple ToM tasks, some of which include the use of eye gaze. The second, a more effortful system, is cognitively demanding, yet more flexible and is used for linguistic tasks demanding inference, memory recall, and executive function. Complex tasks may require elaboration on an infinite number of possible explanations for someone's behavior, suggesting that this is a central process (Fodor 1983).

Research on sequential bilingualism has provided strong evidence for linguistic (first-language-based) transfer effects. The evidence from the few studies on first-language (L1) gestural transfer (in descriptions of motion events) suggests that L1 transfer also impacts gesture, even in contexts of long-term immersion in the L2 speech-community (Brown & Gullberg 2008; Choi & Lantolf 2008; Gullberg 2006; Negueruela et al. 2004). Analyses of L1 gestural transfer effects in differing conditions of L2 linguistic convergence can help tease apart the connections between gesture and language (speech/sign). If gesture primarily derives from an automatic system, L1 gestural transfer may persist even when L2 learners have converged upon the target linguistic patterns. Interestingly, Casey et al. (2013) compared the effects of learning ASL versus a Romance language on co-speech gesture in L1 (English) story narrations. They found an increased gesture rate, iconic gestures, and a number of handshape types employed only in the case of the ASL learners, suggesting that learning ASL may lower the neural threshold for co-speech gesture production in the L1. Casey et al. (2008) compared bimodal bilinguals (native users of ASL and English) and nonsigning native-English speakers, and found that bimodal bilinguals produced more iconic gestures, fewer beat gestures, more gestures from a character's viewpoint and a greater variety of handshapes when narrating stories (in English) to a nonsigner. We suggest that it would be fruitful to compare simultaneous unimodal and bimodal bilinguals, in a monolingual versus bilingual communication mode, to shed light on the interaction between language (sign/speech) and gesture (see Emmorey et al. 2005 for evidence of code-blending rather than code-switching in bimodal bilinguals).

The theater community is a unique context to examine the role of gesture in ToM performance. Recent work has been investigating factors that impact ToM skills. Actors must imagine a character's enduring dispositions, life purpose, and overall objectives, and then use this understanding about what motivates the character throughout the play and in each moment (Noice & Noice 2006). Early in their career, many actors are told by directors that they perform some gesture repetitiously. Oftentimes these gestures are not repeated on purpose, and therefore, to correct this, actors must practice awareness, inhibition, and substitution of the old gesture with a more appropriate action. Actors and directors appreciate the whole body and gesture as a tool to help tell a story, and to help the audience better understand the characters in a production. Gestures (and facial expressions), potentially aided by a mirror neuron system (Montgomery et al. 2007), may emphasize or aid in the understanding of language and the beliefs/intentions of others.

In our own research comparing actors and nonactors (Pilot 2015; Pilot & Lakshmanan 2015), differences were observed on a ToM task requiring the use of nonverbal facial cues, the Reading the Mind in the Eyes (RME) task (for similar findings, see Goldstein & Winner 2012). However, when asked to judge the emotions of a woman shown from the waist up, in short muted video clips, actors and nonactors did not differ. Goldstein et al. (2009) used a similar video task, but with audible speech, and found a difference between actors and nonactors, revealing the use of a more effortful ToM system. When there is reliance on an automatic system, with interpretations informed only by facial expression and gesture, it may be more difficult to detect differences compared to effortful tasks, due to a common system that may be less subject to influences such as acting experience.

G-M&B propose studying how gestural frequency is impacted when a passage becomes rote. The rote context is similar to the form of acting most are familiar with and contrasts with improvisational theater. It would be interesting to teach one group gestures that help convey the passage and teach another group gestures that do not fit with the overall narrative. Examining gestural omissions in these contexts will provide insight into the use of gesture in communicating a salient message. Innovative research involving theater games based on improvisational performances may provide additional insights into gesture and its role where it doesn't merely replace language or supplement it. Incorporating improvisational elements into research can enable us to observe how gestures are employed to convey the use of objects that aren't physically present (e.g., gripping an imaginary steering wheel and performing a turning motion to convey that the performer is driving) while simultaneously gesturing and speaking to convey a narrative.

Gesture and facial expression pervade many forms of communication: that is, sign, speech, and text (emojis). Parsing out the gestural component from sign/spoken language may provide insight into ToM development and use and may open the door to new behavioral treatment options for addressing difficulties in social functioning, including autism spectrum disorder (ASD).

What is a gesture? A lesson from comparative gesture research

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Abstract: Research into nonhuman primates' gestures is often limited by the lack of clear criteria to define a gesture and by studying gestures separately from other communicative means. Despite the fundamental differences between the gestural communication of humans and other primates, I argue that sign language research might benefit from the lessons learned from these drawbacks and the current developments in primate communication research.

How can we distinguish between gestures and other behaviors? Should we identify them based on their form or function? Are gestures limited to the visual modality? Does it make a difference whether a gesture is produced in isolation or whether it is combined with a facial expression or a sound? How do these different types of communicative behaviors contribute to the conveyed meaning? These questions reflect some of the current debates in the field of primate communication research (Liebal et al. 2013; Slocombe et al. 2011), which investigates if and how the communicative patterns of our closest relatives, apes and monkeys, provide insight into the evolution of human language (Arbib et al. 2008; Hewes 1973; MacNeilage 1998; Tomasello 2008; Zuberbühler 2005). Although nonhuman primates' gestures are fundamentally different from human co-speech or co-sign gestures, I propose that taking a comparative perspective to human communication might be beneficial to answer the issues I want to raise with regard to the article by Goldin-Meadow & Brentari (G-M&B). This commentary specifically refers to the question regarding which criteria should be used to define a gesture and whether it is sufficient to focus on manual gestures only, while not considering the information conveyed by other body parts than the hands.

In comparative gesture research with nonhuman primates (hereafter: primates), much attention has been dedicated to differentiating communicative gestures from other, noncommunicative behaviors (Liebal & Call 2012). However, definitions of gestures and the criteria used to identify them vary substantially across studies (Liebal et al. 2013; Slocombe et al. 2011). For example, some researchers define primate gestures as expressive movements of the limbs or head, as well as body postures that appear to initiate a desired action (Pika et al. 2003). Others refer to them as discrete, mechanically ineffective physical movements of the body, which include the whole body or only the limbs and head, but they exclude facial expressions and static body postures (Hobaiter & Byrne 2011). And yet others also consider facial movements as gestures (Maestripieri 1999). As a consequence of the current lack of agreement about which sensory modalities (visual, tactile, auditory) and which body parts (whole body, manual gestures, postures, face) should be considered when defining a gesture, systematic comparisons of findings across studies and species are difficult if not impossible.

Furthermore, the majority of primate gesture research investigates gestures in isolation and neglects the fact that they might be accompanied by other communicative behaviors, such as facial expressions and vocalizations (Slocombe et al. 2011). Consequently, there is currently very limited knowledge about whether a gesture produced alone conveys different information than a gesture combined with other facial expressions or vocalizations (but see Taglialatela et al. 2015). Although it is currently debated whether primate gestures have specific meanings (Hobaiter & Byrne 2014), or whether their meaning is defined by the context they are used in (Call & Tomasello 2007), it is a crucial question if and how the combination with other behaviors modifies the communicative function of a gesture (Liebal et al. 2013).

These two current drawbacks in primate gesture research – the lack of a shared, comprehensive gesture definition and the dominance of a unimodal approach to primate communication – also become evident in the article by G-M&B. For example, they define gestures as "manual movements that speakers produce when they talk" (para. 3), but seem to largely ignore other body parts that might contribute to the linguistic information conveyed by the hands. A more critical discussion as to why G-M&B limited their scope to manual, visual gestures would have been helpful to better understand why they defined a gesture the way they did – also in regard to the challenge of differentiating between signs and gestures. For example, did they not consider facial gestures because they would not refer to facial movements as gestures? This would reflect a similar debate in primate communication research, since facial expressions are often referred to as a distinct class of signals compared to visual, tactile, or auditory gestures (Liebal et al. 2013), because unlike gestures, facial expressions seem to represent expressions of emotional states rather than voluntarily produced communicative behaviors (Tomasello 2008).

There are, however, sign language studies that highlight the role of the body, the head, or the face, and their contribution to the linguistic message primarily provided by the hands (Liddell & Metzger 1998; Nespor & Sandler 1999). For example, Sandler (2009) showed that mouth gestures can function as linguistic symbols, which co-occur with the linguistic description of an event. Similarly, movements of the upper face, like squints or brow raises, are part of the intonational system of Israeli Sign Language (Dachkovsky & Sandler 2009). Although Dachkovsy and Sandler (2009) did not refer to these upper-face movements as gestures, they defined them as linguistic facial expressions, which are fundamentally different from emotional facial expressions. Finally, Sandler (2012a) proposed that different body parts contribute to the articulation of grammatical information in Al-Sayyid Bedouin Sign Language. In this emerging sign language, younger signers isolate different parts of the body for linguistic functions, while older signers use their body gesturally (Sandler 2012a). Although these are just some examples from a limited set of studies, they impressively demonstrate that by focusing on one modality only, it is difficult to capture the complexity of a communicative system. With regard to the G-M&B target article, the focus on manual gestures only might not be sufficient for a comprehensive discussion of the similarities and differences between signed and spoken languages and their relationship with gesture, as long as it remains unclear what a gesture is.

Current and future methodologies for quantitative analysis of information transfer in sign language and gesture data

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Abstract: State-of-the-art methods of analysis of video data now include motion capture and optical flow from video recordings. These techniques allow for biological differentiation between visual communication and noncommunicative motion, enabling further inquiry into neural bases of communication. The requirements for additional noninvasive methods of data collection and automatic analysis of natural gesture and sign language are discussed.

In their target article, Goldin-Meadow & Brentari (G-M&B) ask in section 7.3 what technology is needed to further study sign language and gesture. There are several novel methods recently developed or under development that focus on investigating the biological and information-transfer properties of dynamic visual data, such as that produced in sign language and gesture.

1. Motion capture methods have evolved from trajectory-tracing to analysis of multiple dynamic features, such as velocity, acceleration, or within- and between-participant indices of movement stability; to date, these approaches have been applied to American Sign Language, Croatian Sign Language, and Finnish Sign Language (Malaia &

Wilbur 2010; Malaia et al. 2013; Puupponen et al. 2015). Recent analyses indicate that kinematics of natural narrative production (from a single signer) produces results equivalent to analyses of multiple signers in controlled elicitation phrases (Wilbur & Malaia, in press), which makes the technique generalizable to single-subject studies of lesser-known sign languages, as well as clinical cases. Another method that has been proven useful is analysis of eye-tracking in combination with stimulus data or video recording of dyadic interactions (Oben & Brône 2015; Romero-Fresco 2015).

2. Current technology and software make possible use of natural stimuli (e.g., gestures with movement, or signed-sentence videos), rather than degraded (static) versions, for neuroimaging and neurophysiological experiments. This is important for identifying the roles of language and sensory perception in the processing of complex input (Malaia et al. 2012; 2016); use of degraded stimuli, on the other hand, does not yield sufficient information about natural processing of sign language or gesture (Malaia 2014a; 2014b).

3. Analysis of optical flow in video data allows quantitative evaluation of content, both at specific temporal or spatial frequencies (speeds of motion, size of articulator) and with regard to mathematical information content (Shannon entropy in visual signal) (cf. Malaia et al. 2016). This method does not require intrusive wearable markers, can be used on natural video data, and allows separation of communicative signal (e.g., sign language) from other biological motion in the data.

The need for additional technology development is driven further by unanswered research questions on sign language and gesture. It is still unclear as to how information is encoded in the communicative visual signal. What parameters of the visual stimuli (e.g., frequencies of visual spectrum, or timing of motion in sign language syllabification and phrasing) are used by the brain during perception to extract linguistic information from the signed visual input, and extralinguistic information from gesture? Further, how is that information integrated with other (auditory or haptic) input? To answer the larger questions in the field, improved technologies for data collection and analysis are needed; in comparison with spoken language research, the capabilities of the visual communication field still lag behind.

The data collection stage of visual communication research would be significantly enhanced by a capability of automatic capture for motion of hands, head, body, and face (separately and coordinated) without the need of sensors, gloves, or markers. Hypothesis testing requires software equivalent to Praat (http://praat.org) for spoken language, aimed at analyzing spectral components of the visual signal across spatial and temporal frequencies, including motion, recognition of meaningful handshapes and nonmanuals, and data annotation (see McDonald et al. 2016 for a prototype). Such techniques should be applicable to noisy real-world data (the "cocktail party" problem is as real in visual communication as it is in the auditory domain). One of the directions to solve this problem is the use of biologically inspired cognitive architectures. For example, quantitative analysis of visual properties of the signal (cf. Bosworth et al. 2006) can be combined with neural data during perception (electroencephalography [EEG], functional magnetic resonance imaging [fMRI], etc.) to investigate the models of information transfer between complex systems using, for example, complex systems analysis and machine learning techniques (cf. Malaia et al., in press; Barbu et al. 2014).

Development of technologies (quantitative analysis methods) and their acceptance in research is based on a feedback loop with testable, predictive hypotheses, which can ground (sign) language and communication in neural processing and biological development. Parallel studies of natural perception and production in communication, such as correlational measurements of Shannon entropy in neural (EEG, fMRI) and linguistic (speech and signing) data to assess information transfer are likely to yield the most insight into the unique phenomena of human communication, such as sign language and gesture.

Same or different: Common pathways of behavioral biomarkers in infants and children with neurodevelopmental disorders?

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Abstract: The extent to which early motor patterns represent antecedents to later communicative functions, and the emergence of gesture and/or sign as potential communicative acts in neurodevelopmental disorders (NDDs), are research questions that have received recent attention. It is important to keep in mind that different NDDs have different neurological underpinnings, with correspondingly different implications for their conceptualization, detection, and treatment.

Ontogenetic origins of certain motor patterns and their communicative functionality do not necessarily go hand in hand. The ability to extend the index finger, for example, is present already prenatally (e.g., Marschik et al. 2013, Fig. 1), but becomes functional only

Figure 1 (Marschik et al.). Ultrasound video print of a 13-week-old fetus extending the index finger.

several months later (e.g., Behne et al. 2012; Matthews et al. 2012). Physiological studies on the antecedents of later communicative functions, along with research on pathophysiological profiles, suggest the need for caution in assigning and interpreting the communicative intent of early emerging gestures. From a perspective valuing age-specificity, be it developmentalist or neuroconstructivist, for example, it is clear that an "adult-cognitive-linguistic-brain perspective" fails to explain the pathway to functionality.

As with verbal abilities, gestures and/or signs have to be seen and studied as emerging age-specific phenomena. At which point in development can we claim that an extension of the index finger, for example, represents indexical pointing, is requisitive, and/or is intentional or informative? Considering development beyond the "pure" index finger, how can we assume, from an adult theorist perspective, that and when a beginning communicator is creating or acquiring "communicative units" or "multimodal communication packages"? How does he/she use these units or "packages," be they signs or gestures? And does this differentiation of signs and gestures help to understand communicative development in children with neurodevelopmental disorders (NDDs) who often do not develop speech and instead rely mainly on nonverbal and prelinguistic means to communicate?

In searching for the keys that might enable children with NDDs to better communicate, it is admittedly a struggle to understand the wealth of theoretical frameworks on cognition and linguistics that have been brought to bear on the many questions that arise in this search. For example, should toddlers be viewed as "mini-linguists" or "constructivists"? Without dwelling on this fundamental query, we have to re-stress that the attempts to conceptualize development applying theoretical approaches from adult linguistic systems need to be reframed. To this end, an autopoietic structure-function model that integrates bootstrapping and idiosyncrasy components might be useful for the earlier and more accurate detection of NDDs, especially those NDDs where the diagnosis is usually not made until later toddlerhood (e.g., autism spectrum disorder [ASD], Rett syndrome, and fragile X syndrome). Such a model intends to decipher early gesture development and gesture-word dependencies as sensitive markers to evaluate the integrity of the developing nervous system.

Studying (mal)development of communicative forms as "potential communicative acts" in individuals with NDDs faces great challenges, but could have enormous potential for understanding the development of gestures and signs, as well as enabling earlier and differential diagnosis of neurodevelopmental disorders. To date, few studies have conducted systematic comparisons across different NDDs. Existing studies in this area have found that the presence or absence of communicative gestures is a significant predictor of language in Down syndrome, ASD, and specific language impairment, but less predictive for Williams syndrome and fragile X syndrome (Luyster et al. 2011), suggesting syndrome-specific developmental patterns. Our own studies (Bartl-Pokorny et al. 2013; Marschik et al. 2012a; 2012b; 2014a; 2014b) are consistent with this suggestion, but also indicate the need to be cautious in attributing communicative intent or functionality to the gestures and signs of such children. Not only do we have to define the onset of functionality of certain behaviors as being communicative, but we also have to consider the cause for the paucity of communicative gestures that is associated with many NDDs. It is possible that this paucity could be related to impairments in symbolic representation or deficiencies in motor planning rather than cognitive functioning.

Goldin-Meadow & Brentari (G-M&B) stated in the target article that gesture is an integral part of language – it forms a unified system with speech and, as such, plays a role in processing and learning language and other cognitive skills. Is it then appropriate to talk about gestural development – "the manual movements that speakers produce when they talk" (para. 3) – in infants and toddlers with NDDs who fail to achieve even the earliest speech-language milestones? Or is it more useful to consider relevant behaviors a *visible action as utterance* (Kendon 2004), a superordinate term for gestures and signs?

In the discussion about modality and iconicity, G-M&B stated, by referring to the work of Ferdinand de Saussure, that "having iconicity in a system does not preclude arbitrariness, which is often taken as a criterion for language" (sect. 1., para. 2). From a developmental/nonadult point of view, how far is iconicity an enhancing factor to acquire basic socio-pragmatic functions for children with NDDs? And how far is the typical Gestalt perception, and thus the ability to delineate the iconic character of a sign or gesture, perceived in a similar way in children with NDDs (Bölte et al. 2007)? An icon may be equally hard to acquire as a conventional form, be it a word or a gesture/sign, for somebody who is atypically structuring their communicative domain. In other words, onomatopoetic sounds (e.g., meow) or arbitrary words (e.g., cat) may even have similar levels of arbitrariness in children with NDDs.

Given the importance of theoretical frameworks of socio-communicative abilities, for us – as behaviorally oriented neuroscientists – it is important to keep in mind that different NDDs may have different neurological underpinnings. They need to be interpreted from a developmental perspective, each disorder in its own right, with correspondingly different implications for their conceptualization, detection, and treatment.

An evolutionary approach to sign language emergence: From *state* to *process*

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Abstract: Understanding the relationship between gesture, sign, and speech offers a valuable tool for investigating how language emerges from a nonlinguistic state. We propose that the focus on linguistic status is problematic, and a shift to focus on the processes that shape these systems serves to explain the relationship between them and contributes to the central question of how language evolves.

How does language emerge from a prior state in which no language exists? This is the central question for the field of language evolution. Although early attempts to address this question focussed on biological evolution, the current consensus is that cultural evolution plays a fundamental explanatory role (Tamariz & Kirby 2015). To understand language evolution, we need to understand how individual humans improvise solutions to communicative challenges, how groups of individuals create conventions through interaction, and how these conventions are transmitted over time through learning.

The manual modality provides the best hope we have of understanding how these processes work and answering the central question of language evolution. It offers a broad range of phenomena, from fully conventionalised sign languages to cases where a conventionalised system has not yet been established. In particular, research into homesign systems and emerging sign languages such as Nicaraguan Sign Language, but also the silent gesture paradigm in the laboratory, allow observation of human communication systems from their point of origin, and directly allow us to investigate how linguistic structures evolve.

We recognise that it is essential to have clear terminology, and to be aware of the differences between sign and gesture. However, the rigid dichotomy between gesture as pictorial and sign as categorical is problematic when it comes to determining the characteristics of the aforementioned cases: silent gesture, homesign, and possibly also emerging sign languages. Because on which side of the dividing line do these fall? As Goldin-Meadow & Brentari (G-M&B) note (sect. 7.1 and 7.2), homesign and silent gesture are language-like in some respects but not in others.

An evolutionary perspective shifts emphasis away from problematic questions about the *status* of silent gesture, homesign, and the early stages of emerging sign languages as being either pictorial and gesture-like or categorical and sign-like. Instead, we argue that the emphasis should be on the continuity of cultural-evolutionary *processes* involved in shaping these various systems.

These phenomena are ultimately rooted in situations of communicative stress; they emerge because no existing conventional language system is available. Where they differ is in which cultural forces have the upper hand in the situations in which they emerge. For example, silent gestures elicited in laboratory experiments are not subject to the routinisation that occurs from using a system repeatedly, whereas homesign systems are. This may be the explanation behind differences found between the two phenomena, such as that for motion events mentioned by the authors (sect. 7.2): Silent gesturers do not break their gestures for motion events into path and manner components, whereas homesigners do.

This shift of emphasis that is at the heart of an evolutionary approach to language – a shift from considerations of *state* to considerations of *process* – can be extended to the silent gesture laboratory paradigm. We propose augmenting this paradigm by implementing different cultural processes, such as communicative interaction and cultural transmission. To do this, we can borrow from the experimental techniques developed in the field of language evolution more broadly.

The iterated learning paradigm (Kirby et al. 2014), in which a participant learns a language from the output of a previous participant, has been used to probe the role that learning plays in shaping linguistic structure, specifically through modelling the transmission of language to new learners. More recently, this experimental framework has been expanded to investigate the effects of interaction in conjunction and in comparison with transmission to new learners. Kirby et al. (2015) studied pairs of participants organised into transmission chains (a condition with both interaction and transmission) compared with isolated pairs of participants (an interaction-only condition). Their results showed that when both transmission and interaction processes were at play, the compositional structures found in natural languages emerged. Isolating these processes, however, had different effects: The participants in the interaction-only condition produced "holistic" systems, useful for expressive communication, but not compositionally structured. Similarly, studies looking only at transmission to new learners, but without interaction between pairs (Cornish et al. 2013; Kirby et al. 2008), found that easily learnable but nonexpressive, unstructured languages were the result.

We have now begun to apply this framework to the manual modality, assessing the effects of cultural processes in the laboratory alongside data from homesign and emerging sign languages. Following research into motion events in Nicaraguan Sign Language, Smith et al. (under revision) examined the effect of cultural transmission on motion events in silent gesturers. Supporting previous results, the gestures produced by participants became more regular and structured as they were transmitted to new learners, showing increasingly language-like properties.

Expanding this paradigm, Motamedi et al. (submitted) studied the emergence of systematic category structures in silent gesturers, looking at the effects of iteration alone, interaction alone, and the effects of both processes working together. Corroborating the work by Kirby et al. (2015), Motamedi et al. (submitted) concluded that participants in the iteration and interaction condition produced fully systematic systems, which did not emerge in the conditions where these processes were isolated.

These findings make it clear that silent gesture elicited from single participants is a very temporary phenomenon: They are the structures that participants produce in the lab when they are asked to do this *for the first time*. The patterns that are observed can be seen as representative of an individual's cognitive preferences for structuring information (Schouwstra & de Swart 2014). When these utterances are subject to cultural processes such as communicative interaction and cultural transmission, they will be transformed to become more systematic and increasingly regular. Being able to witness these processes at play in the lab is extremely exciting and informative. At the same time, we are convinced that we should not restrict our view to laboratory data alone (Schouwstra 2012). Combining the precision of laboratory experiments with the naturalness of field data is a promising next step in uncovering the cultural processes that shape emerging language.

Gesture or sign? A categorization problem

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Abstract: Goldin-Meadow & Brentari (G-M&B) rely on a formalist approach to language, leading them to seek objective criteria by which to distinguish language and gesture. This results in the assumption that gradient aspects of signs are gesture. Usage-based theories challenge this view, maintaining that all linguistic units exhibit gradience. Instead, we propose that the distinction between language and gesture is a categorization problem.

The relationship between signed languages and gesture poses a thorny problem. Goldin-Meadow & Brentari (G-M&B) bring to bear important contributions regarding how and what to call the "gestural" and "linguistic" pieces of this puzzle. We agree with their suggestion that speech and gesture should be considered an integrated multimodal construction. Where we disagree is with their assumptions, first that this dichotomy is itself categorical (we contend it is not), second that language (signed or spoken) is wholly categorical while gesture is wholly gradient, and third, that the (putative) gradient elements of signed languages are therefore gesture.

False dichotomies, arising from false assumptions, lead to false conclusions. The world presented by G-M&B is one of a clear dichotomy between categorical, discrete, countable, invariable, and stable on the one hand (i.e., language), and gradient, uncountable, variable, and idiosyncratic on the other (i.e., gesture).

This dichotomy is too simplistic to describe gesture. Studies from co-speech gesture have called into question the assumption that gesture is holistic. Calbris (1990), for example, showed that quotable gestures in French can be decomposed into meaningful units of handshape, location, and movement. Gesture is clearly not wholly idiosyncratic. Núñez and Sweetser (2006) have shown that metaphorically motivated co-speech gestures have highly regular forms referring to the past or the future. The question is to what extent do gestures, functioning within a multimodal system alongside speech, become entrenched within speakers and conventionalized across the speech community. As G-M&B point out, when taken out of this multimodal and multifunctional context, gestures become more language-like (Singleton et al. 1993). Thus, we have a gradient from gesture to language.

The dichotomy is also too simplistic to describe language. G-M&B cite morphology as an exemplar of discreteness. Hay and Baayen (2005), however, showed that people's behavior in experimental tasks judging morphological complexity is not categorical. They concluded that gradedness is part and parcel of grammar.

G-M&B's dichotomies are the historical remnants of structuralist/formalist approaches. These approaches assume an almost exclusive reliance on digital representations composed of discrete and listable symbols; the division of language into separate, building block components such as phonetics, phonology, lexicon, and morphology; and a default assumption of classical categories with strict boundaries, as opposed to prototype categories with degrees of membership. The dichotomies arose because these approaches set up a distinction between a mental object, whether *language* versus *parole* or *competence* versus *performance*. This ideal linguistic object "consists of well-defined discrete categories and categorical grammaticality criteria," while "real language can be highly variable, gradient, and rich in continua" (Bod et al. 2003, p. 1).

Usage-based approaches to language (Bybee 2001; 2010; Langacker 2008) move beyond these dichotomies, leading to a more cognitively sound view of language and its mental representation. As Bybee (2010, p. 2) noted, "All types of units proposed by linguists show gradience, in the sense that there is a lot of variation within the domain of the unit (different types of words, morphemes, syllables) and difficulty setting the boundaries of that unit." Langacker (2008, p. 13) concluded that the world of discrete units and sharp boundaries has been imposed on language, rather than discovered in its use.

Usage-based approaches take *language in use* as the source material from which language users construct grammars. Rather than assuming a priori categorical and nongradient building blocks that are rendered fuzzy and gradient when performed, usage-based approaches contend that networks with varying levels of complexity, specificity, and schematicity emerge as language users extract the commonality in multiple experiences. G-M&B point to the high variability of location, for example, in agreeing verbs, and argue that location is therefore gestural. A usage-based approach would suggest that variability of locations in verb agreement constructions leads to schematic representations in signers' grammars. These schematic locations exist alongside more specific elements of the construction – for example, the handshape. When highly schematic elements such as location are also highly productive, as is the case for agreeing verbs, the result is high variability when these constructions are put to innovative use.

If criteria such as discreteness versus gradience cannot be used to categorize elements of use as language versus gesture, how can this determination be made? Typologists identify categories across languages in terms of shared function (Croft 2001). But identifying shared function across speech-gesture constructions and sign constructions is not easy. As G-M&B admit, researchers are still using hearing speakers' gestures, as determined by hearing researcher judgment, as a guide. The approach is to categorize certain elements of a usage event as speech and others as gesture, then to search in signed languages for forms similar to those categorized as gesture in spoken language. The danger lies in making the unwarranted assumption that similar forms share the same function. Recent brain studies suggest the contrary. Newman et al. (Newman et al. 2015) found that lifelong experience with a visual language alters the neural network, so that gesture is processed more like language in native signers – what is gesture for a hearing person is language for a deaf person.

Classifying a particular usage event as language or gesture is a categorization task. When making a categorization judgment, people compare a structure extracted from experience and stored in memory to a new experience. To the extent that the new experience is judged to be similar to the stored experience, it is categorized as an instance of that structure. When categorization is applied to language constructions, speakers and signers are, in effect, making grammaticality judgments.

Whether intentionally or not, assumptions have been carried forward from structuralist/formalist theories that impede our ability to understand the nature of signed and spoken language and their relation to gesture. Although G-M&B offer an excellent case that speech and gesture are inseparable parts of an integrated system, we are not convinced that the elements they classify as gesture in spoken language function as gesture in signed languages.

Language readiness and learning among deaf children

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Abstract: We applaud Goldin-Meadow & Brentari's (G-M&B's) significant efforts to consider the linkages between sign, gesture, and language. Research on deaf children and sign language acquisition can broaden the G-M&B approach by considering how language readiness is also a social phenomenon and that distinctions between imagistic and categorical formats rely on language practices and contexts.

Language is inherently social. Human interaction shapes language acquisition and use (Ochs & Scheiffelin 2008), and thus it shapes the cognitive and neural mediators of language. But those human interactions are not neutral. Research on signed and spoken languages underscore the dynamism of language, by investigating the way humans use languages (or not), who gets to use certain languages, and which languages are promoted or suppressed (LeMaster & Monaghan 2004; Ramsey & Quinto-Pozos 2010). As Goldin-Meadow & Brentari (G-M&B) demonstrate through their arguments and the use of mathematical examples, gestural components of signing can predict some types of learning readiness. However, language readiness is also a social-political phenomenon, not just a cognitive one.

The authors suggest that sign-based gestures often communicate different kinds of information than do speech-based gestures. This point highlights the fundamental role that social information and interpretation play in how language learning develops among deaf children. Educators who are deaf or near-native (i.e., children of deaf adults) or fluent signers may use gesture differently than nonnative signers, which lines up with the authors' point that gesture can be (a) incorporated into signing and (b) exist as something separate and utilized in conjunction with signing. Thus, a teacher's skill and experience with sign language may affect their ability to understand and/or interpret information conveyed through sign-based gesture. In effect, an educator or interpreter's fluency in sign language may enhance (or inhibit) their ability to predict the steps that learners take (please see also Pfister, in press). Therefore, in educational environments for deaf students, fluent signers – such as children and adults capable of modeling sign language vocabulary and syntax – as well as the availability of well-trained sign language interpreters, are additional factors that influence learning readiness and meaning making among deaf students (Pfister 2015a; 2015b; Pfister et al. 2014).

The authors state in the target article that "whether sign language can be stripped of its gestural elements and still be as effective as speech is when it is delivered without its gestural elements (e.g., over the radio or the phone) is an open question" (sect. 7.3, para. 7). We believe that an emphasis on face-to-face communication for deaf learners illustrates how sign and gesture convey meaning together, to "form an integrated system," precisely because the information conveyed depends on the social context and the fluency of the partners engaged in communication.

One limitation the authors face in extending their model in the directions they indicate – where gesture and sign form an integrated system that conveys meaning – is their emphasis on an information-based and internal approach to cognition. This approach does permit powerful modeling and in-depth consideration of how imagistic and categorical types of information might play out in linguistic cognition. However, language – as an integrated system – extends beyond internal cognition, as recent work on language evolution and neurobiology indicates (Christiansen & Chater 2008; Evans & Levinson 2009). Recognizing how cognition works in the wild (Hutchins 1995) through more interactive, extended, and embodied models (Clark 2008) might offer a starting point for achieving the authors' overall goals. Subsequently, to more fully consider the social, political, and cultural side of language learning, G-M&B could utilize recent work in neuroanthropology, which integrates cognitive science with anthropology and related fields (Lende & Downey 2012a; 2012b). For example, the concept of language readiness might be transformed by considering it not just in terms of individual readiness, but also through the embodied acquisition of gestures and signs in specific situations and specific times (Downey 2010). The social practices that differentiate gesture and sign would then shape, at a fundamental level, how categorization works within the brain (Roepstorff et al. 2010).

Accordingly, we suggest that the authors could extend the presentation of their research by recognizing that signing is a skill best learned and promoted in social settings. In communities of practice, members learn through mutual engagement, joint enterprise, and (particularly germane to this discussion) a shared repertoire (Wenger 1998). In other words, the concept of communities of practice brings together context, sociality, and meaning, to emphasize the interactivity of language and socialization (Pfister 2015b). Only by attending to the dynamics of skill within a community of practice is it possible to understand how gestures paired with signs may convey meaning differently. The authors miss this crucial aspect of language by promoting an overly formulaic "communicative act" that they suggest consists of only imagistic and categorical formats. Research among deaf youth who experience language socialization among signing peers in Mexico City has provided an example of how community participation and sociality cannot be divorced from understanding (Pfister 2015a; 2015b; 2015c; in press; Pfister et al. 2014). We argue that the social components of language influence meaning making because the context, sociality, and shared experience conveyed within communities of practice factor heavily into better understanding, and researching further, G-M&B's emphasis on the "whole of a communicative act" (sect. 8, para. 2).

Finally, we understand that the authors' aim is not to equate sign with gesture, but instead to establish the role of gesture when paired with sign language. Yet, early in the target article, they draw our attention to recent history when signs were considered "nothing more" than gestures. Recognizing the important status of signed languages as legitimate forms of human language, we caution of the potential danger in sign languages becoming too closely associated with gesture once again. We challenge readers to consider how the consequences of such an association might affect the political economy of sign language. This is seen most clearly in educational settings, where some languages are valued, elected, and funded (i.e., spoken languages), while others are simultaneously devalued, discouraged, and underfunded (i.e., signed languages). In Mexico, for example, sign language is often misunderstood to be mimicry (*mímica*), which is not gesture, per se, but nonetheless occupies a position precariously distant from bona fide language. Mexican educational policy is influenced by oralist and inclusion ideologies, and public schools are not mandated to provide an education accessible to deaf students in Mexican Sign Language. Thus, as in many parts of the world, sign language is not readily accessible for many deaf Mexicans (Pfister 2015a; 2015b; 2015c). Language readiness among deaf learners, therefore, is social and political as well as cognitive.

Are gesture and speech mismatches produced by an integrated gesture-speech system? A more dynamically embodied perspective is needed for understanding gesture-related learning

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Abstract: We observe a tension in the target article as it stresses an integrated gesture-speech system that can nevertheless consist of contradictory representational states, which are reflected by mismatches in gesture and speech or sign. Beyond problems of coherence, this prevents furthering our understanding of gesture-related learning. As a possible antidote, we invite a more dynamically embodied perspective to the stage.

The complexity of demarcating speech, sign, and gesture is elegantly surveyed in the target article. The analysis promises to be a valuable roadmap for research in multimodal communication. However, we doubt whether the analysis – as currently presented – achieves one of its other goals, that is, to enhance our ability to make "predictions about learning" (para. 5).

Goldin-Meadow & Brentari (G-M&B) argue that regardless of whether information is expressed via the manual or vocal system, a distinction should be made between speech/sign and gesture on the basis of whether categorical or imagistic representations are underlying their expression. This distinction should help explain gesture-related learning, such that mismatches between gesture *and* speech or sign (and their correlation with learning) are driven by "distinct representational formats – a mimetic, imagistic format underlying gesture versus a discrete, categorical format underlying language, sign, or speech." (sect. 6, para. 14).

Yet we observe that there is a tension in the target article in that it also stresses an "integrated," "single," and "unified" gesture-speech system (sect. 5 & 6). In the case of learners who are producing mismatches in gesture and speech, it is argued "that [the] mismatch is generated by a single gesture-speech system" (sect. 5, para. 15). G-M&B argue that, although learners are unaware of the mismatches they produce, the fact that they are more receptive to learning after they produced mismatches suggests a unified system: "if gesture and speech were two independent systems, the match or mismatch between the information conveyed in these systems should have no bearing on the child's cognitive state" (sect. 5, para. 12).

Unfortunately, in their overview we see no clear arguments (other than stating the case) for resolving the apparent logical contradiction of positing two representational devices (categorical vs. imagistic) that differ and contradict in their informational content (as reflected by gesture and speech mismatches) but are nevertheless part of an integrated system.

Beyond problems of coherence, this contradiction is potentially problematic for understanding learning. Note that learning fundamentally involves a change in the cognitive system. Further note that G-M&B make no attempt to specify how the imagistic information that is supposedly accessed by gesture (and not speech/or sign) is potentially transformed and fed back into the system (cf. Goldin-Meadow 2003a; Pouw et al. 2014). If gestures do not transform the cognitive system but are only reflective of its underlying imagistic representation, then mismatches reflect that the gesture-speech system is disintegrated (hence the contradiction). Moreover, G-M&B see the fact that mismatches have bearing on the child's cognitive state as evidence for a unified system, but they fail to account for how the gesture producing the mismatch has any causal force in changing the cognitive system (i.e., how it predicts learning). In other words, the current account begs the question: Why do gesture and speech mismatches have a bearing on the child's cognitive state if gestures reflect information that is already integrated?

What is the alternative? Insights from embedded and embodied cognition challenge the idea that action should be regarded as the mere output of the cognitive system (e.g., Hurley 2001). Such insights have been applied to gesticulation (Cappuccio et al. 2013; Clark 2013; Pouw et al. 2014). If these accounts are on track, the cognitive system is distributed over brain and body, wherein any state that this distributed brain-gesture system enjoys is brought about by loops of circular causation of perception and action (Clark 2013).

Such approaches can be brought in line with G-M&B's proposal that gesture can access distinct information that is not available to speech. Yet it requires rethinking in which way this distinct information is "accessed" and believed to be "present" in an underlying "representation," and relatedly to which degree this information is integrated with the speech system. As mentioned, G-M&B's current presentation fosters a static understanding of gesture wherein mismatching gestures merely access and output imagistic information. From a more dynamically embodied perspective, gesturing may bring forth imagistic information that is not in any cognitively potent way present in an underlying representation before the act of gesturing. From this perspective, gestures add something to the neural precursors from which they emerge. Namely, gesturing adds kinematic information that is being fed back through the visual and proprioceptive system (Pouw et al. 2014).

In sum, we think a more complete account of gesture-related learning requires the specification of how a gesture-speech system integrates incongruent information that is brought forth by the act of gesturing rather than assuming that this information is already integrated. In pursuit of such an account, we support G-M&B's call to develop more sophisticated measures to assess kinematic regularities expressed in gesture, as this allows researchers to further pinpoint what, in the act of gesturing, it is that is cognitively potent for learning. For example, problem solvers have difficulty in judging verbally when cups of different sizes spill water, but they drastically improve when they are allowed to gesture (Schwartz & Black 1999). It is likely that this performance is dependent on the ability to correctly physically enact the laws that govern the task (which involves being sensitive in gesticulation to relevant properties of the objects gestured about, such as the size of the cups, and rotational inertia). Possibly, the kinematic invariants that are present in such gestures may become more stable over time as expertise develops, and it may be the case that such increasing kinematic regularities are predictive for the susceptibility for categorical integration in speech (e.g., Chu & Kita 2008). We thereby submit that understanding learning from gesture-speech mismatches at least requires specifying how gesture's emergent kinematic regularities (i.e., embodied information) related to the learning task becomes categorizable (and thus transformed) through time, as well as understanding how this affects the potentiality of integration with speech.

Vocal laughter punctuates speech and manual signing: Novel evidence for similar linguistic and neurological mechanisms

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Abstract: Vocal laughter fills conversations between speakers with normal hearing and between deaf users of American Sign Language, but laughter rarely intrudes on the phrase structure of spoken or signed conversation, being akin to punctuation in written text. This *punctuation effect* indicates that language, whether vocal or signed, is dominant over laughter, and that speech and manual signing involve similar mechanisms.

Conversations between speakers with normal hearing and between deaf users of American Sign Language (ASL) are filled with vocal laughter, but the placement of laughter in these vocal and manual conversations is not random. The *speaker* – the person sending a vocal or signed message – typically laughs before and after complete statements and questions, seldom interrupting phrase structure. Thus, a speaker may say or sign, "I have to go now – ha-ha," but rarely, "I have to – ha-ha – go now." The placement of laughter in vocal or signed conversation is akin to punctuation in written text and is termed the *punctuation effect* (Provine 1993; 2000; 2016; Provine & Emmorey 2006). Observations of conversational laughter reveal common features of speaking and signing beyond punctuation. For example, in both hearing speakers (Provine 1993) and deaf signers (Provine & Emmorey 2006), males are the best laughgetters (Provine 1993), and most laughter does not follow humor (Provine 1993). For hearing and deaf people, the essential requirement for laughter is playful social relationships, not jokes or other attempts to stimulate laughter (Provine & Fisher 1989).

Punctuation has significant neurolinguistic implications. Laughter rarely intrudes on the phrase structure of spoken (Provine 1993) or signed conversation (Provine & Emmorey 2006), indicating that language, whether vocal or signed, is dominant over laughter. When laughter competes with speech/signing during conversation, language usually wins. Punctuation is also present in the visual domain of text, a nonvocal linguistic medium. Emoticons (visual symbols of emotion such as LOL, "Laughing Out Loud," etc.) seldom disrupt phrases in online text messages (Provine et al. 2007). Emoticons occur in positions like this ☺. But not ☺ like this. Unlike the case of speech and laughter that involves competition for the vocal tract, neither manual signing nor text messaging competes with laughter for a shared organ of expression. The presence of punctuation across this diverse range of expressive behaviors (speaking, signing, texting) indicates that it is the product of a higher-level neurolinguistic mechanism, not a lower-level gatekeeping mechanism that regulates motor acts competing for an organ of expression such as the vocal tract.

Punctuation is not unique to laughter in speech, signing, and texting, indicating the generality of the effect. Airway maneuvers other than speech show punctuation and the priority of linguistic over other forms of expression. Speech involves breath-holding and redirecting the respiratory apparatus to vocalizing. People either speak or breathe during conversation, with breaths coming at linguistically significant punctuation points similar to those described for laughter (McFarland 2001). (It is not known whether breathing punctuates signing.) This complex respiratory, vocal, and linguistic choreography occurs automatically; we do not consciously plan when to breathe, talk, or laugh. Significantly, laughter is under weak voluntary control. When asked to laugh on command, most individuals comment that they cannot do it, or gamely provide unrealistic, fake laughter (Provine 2012, pp. 217–20). Laughing is not a matter of deciding to say "ha-ha." In the proper social context, laughter simply happens.

Goldin-Meadow & Brentari argue for the value of broadly based, comparative analyses of signing, gesturing, and speaking. I consider the benefits of further extending the range of communicative acts to include the utterance of laughter and its associated neurolinguistic phenomena.

Toward true integration

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Abstract: Whether in sign or speech, language is more integrative than the target article suggests. A more integrative view embraces not only sign/speech and co-sign/speech gesture, but also indicative gestures irrespective of modality, and locations along with movements in the signed modality, as suggested by both linguistic acquisition and pathologies. An extended integrative view also proves advantageous in terms of conceptual coherence.

The integrative machinery that language contributes to human cognition in either the gestural-visual modality (sign) or in the mainly vocal-auditory modality (speech) is more inclusive than Goldin-Meadow & Brentari (G-M&B) propose. We suggest that language includes components that are (1) discrete and categorical, (2) imagistic, (3) topographic (location) and gradient (movement), and, finally, (4) deictic. G-M&B, on the other hand, do not single out location(-movement) (3) or deixis (4), but include them under the co-sign imagistic gesture component (2), which in turn is denied a true linguistic status. We suggest, to the contrary, that all four components are inherently linguistic and that location(-movement) (3) and deixis (4), in contrast to co-speech/sign (2), are used for purposes of grammatical reference – with location(-movement) (3) contributing to supralexical iconicity, a hallmark of sign languages. Finally, gestural deixis (4) and co-speech/sign gesture (2) are common to sign and speech, with both having concurrent oral counterparts in the latter (pronouns, demonstratives, etc., and prosody, respectively). In their gestural versions, these two components are then a natural nexus between both modalities although it is deixis (4) that is inherently integrated with grammatical development.

In the view of long-standing debates on the divide between sign and gesture and on the degree of similarity between linguistic modalities, G-M&B attempt to satisfy both the side that gives primacy to gesture in the signed modality and the side contending that sign "is just like spoken language." They propose that the comparison between modalities "needs to include both the more categorical (sign or speech) and the more imagistic (gestural) components regardless of modality" (para. 5) – that is, our discrete and categorical (1), imagistic (2), components mentioned above. However, G-M&B nonetheless wish to keep them distinct, as mismatches between these components observed in the learning of hearing and deaf children could otherwise not be seen. Still, they would be part of a "single gesture-speech system" (sect. 5, para. 15) at least in the spoken modality (Alibali & Goldin-Meadow 1993), rather than "two distinct sets of representations". However, what this single system amounts to is not clear. Is it language, as said occasionally (para. 5; sect. 8, para. 2); is it communication with language as a subset (section 8, para. 1) or is it communication taken as coextensive with language (section 8, para. 2)? Neither is it clear whether the distinctness and integration of speech and co-speech gesture extends to sign and co-sign gesture (in this regard, the interrogative title of sect. 6 contrasts with the assertion made in sect. 5). In fact, the idea of an overall linguistic system embracing sign and co-sign gesture is already questioned in section 4.2, where G-M&B restrict language to sign in the signed modality. Signs are linguistic as they are "discrete" and "categorical"; gestures, instead, are imagistic. But what about indicating gestures, whether incorporated into lexical roots as in agreement verbs or independent, as in deictic gestures?

G-M&B, citing Liddell (2003), take these as gestural. However, indicating gestures could not technically qualify as gestures by G-M&B's definition, being discrete and categorical. Only through a distortion of what "discrete" means, namely by wrongly equating discrete with "finite or listable" (sect. 4.2, para. 2), can G-M&B conclude that indicating gestures, being nonlistable, are nonlinguistic. With regard to "categorical," G-M&B go for a relaxation of the proposed divide by accepting "categorical gestures" that would almost reach the status of sign ("spontaneous sign" sect. 4.3, para. 2) – the case of homesigners and silent gesturers.

Our alternative would avoid these problems while maintaining G-M&B's insights. Indicating gestures, (4), are part and parcel of language irrespective of modality. Goldin-Meadow et al. (Cartmill et al. 2014) have shown that the individual onset of different deictic gestures, (4), combined with first words (e.g., *dog* or *eat*), (1), predicts the individual onset of correlating phrases (determiner phrases, e.g., *the dog*, and sentences, respectively) in speech (Goldin-Meadow & Morford 1985; Mattos & Hinzen 2015; Özçalışkan & Goldin-Meadow 2009).Therefore, not only *mismatches* between imagistic gestures (2) and speech are able to make predictions about learning in different domains but also *right* combinations of speech and both imagistic (2), and deictic (4), gestures make predictions about learning in the domain of language. Furthermore, these predictions about linguistic learning point to a *single* system integrating these different gestural formats, an integration that is not only toward depiction but also grammar. Problems with deixis in both gestures and spoken words in autism suggest that language, and grammar itself, is multiformat – and bimodal (sound and gesture) in speech.

As for the topographic component (3), should we really wait for a "motiongraph" that does for sign what the spectrograph has done for speech? Actually, the spectrograph showed that categorically perceived segments were not acoustically categorical, whereas G-M&B speculate in the opposite direction, namely on uncovering potentially hidden categorical components in the continuous perception of movement. Following Klima & Bellugi (1979), we contend that "the structured use of space and movement" which goes along with classifiers is a hallmark of sign languages. Neither its absence in speech nor the fact that right-hemisphere processing is involved only when classifiers are used to convey information on location(-motion) suggest its nonlinguistic nature (Emmorey 2013). Handshape is categorical, mainly processed by the left hemisphere, and then linguistic. Classifiers have a handshape, but they go with nonlistable locations (and continuous movement). Are they then linguistic and nonlinguistic at once? This hardly makes sense.

The right hemisphere's normal contribution (suprasegmentals, deixis [Mizuno et al. 2011], space/movement in sign) is contrastively illuminated when language malfunctions. Deaf schizophrenic patients natively signing in British Sign Language have difficulties in depicting dynamic or static locations with classifiers. They make many more handshape errors than location or movement errors, while being free of errors in lexical (without classifiers) descriptions of the same locative relationships (static, in this case) (Chatzidamianos 2013). This suggests that a well-functioning language and cognition obtains when the four components we distinguish interact correctly, and across hemispheres.

In sum, taking the four components at face value is less problematic than thinking of language as exhausted by sign/speech and co-sign/speech gesture. Conceptual inconsistencies, exceptions regarding deixis, and unlikely hopes of a hidden categoricity for the location(-motion) component would all vanish, and we could focus on how the four representational formats unite to yield human language.

Iconic enrichments: Signs vs. gestures

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Abstract: Semantic work on sign language iconicity suggests, as do Goldin-Meadow & Brentari (G-M&B) in their target article, that "sign should be compared with speech-plus-gesture, not speech alone" (sect. 7.1). One key question is whether speech-plus-gesture and sign-with-iconicity really display the same expressive resources. This need not be the case, because gestural enrichments are typically not at-issue, whereas iconic enrichments in sign language can often be at-issue. Future research should thus focus on the "projection" properties of different sorts of iconic enrichment in both modalities.

Goldin-Meadow & Brentari (G-M&B) write that "sign should be compared with speech-plus-gesture, not speech alone" (sect. 7.1). We explain, first, why recent studies of sign language semantics converge on the same conclusion and, second, how semantic methods could offer a typology of iconic enrichments in both modalities (see Schlenker 2016).

An expression (in any modality) may be termed *iconic* if there exists a structure-preserving map between its form and its denotation. In (1)a, the length of the talk is an increasing function of the length of the vowel. In the American Sign Language (ASL) example in (1)b, the outcome of the growth is an increasing function of the maximal distance between the two hands realizing the verb *GROW*.

1. a. The talk was long / loooooong. (cf. Okrent 2002)

b. POSS-1 GROUP GROW- / GROW- / GROW-.

"My group has been growing a bit / a medium amount / a lot." (ASL; video 8, 263; see Schlenker et al. 2013)

Recent work in sign language semantics has argued for two claims (Schlenker, forthcoming).

Logical visibility. When iconic phenomena are disregarded, speech and sign share the same "logical spine," including in cases where sign language makes visible the "Logical Forms" of spoken language sentences – for instance, by making overt use of logical indices realized as "loci," whereas indices are mostly covert in spoken languages (Lillo-Martin & Klima 1990).

Iconicity. Sign language makes use of rich iconic resources, including at its logical core. For instance, sign language loci were argued in recent research to be *both* logical variables and simplified representations of what they denote (see Schlenker et al. 2013 and, for some sources, see Liddell 2003 and Kegl 1977/2004).

This could lead to two conclusions.

One conclusion is that spoken language semantics is (along some dimensions) a "simplified," iconically defective version of sign language semantics – simply because the iconic potential of the vocal stream is so limited.

Alternatively, it may be that (a) the "standard" conception of spoken language semantics was insufficiently inclusive, and that (b) when sign is compared to speech-plus-gesture rather than to speech alone, the two systems display similar expressive resources.

So, does speech-plus-gesture really display the same expressive resources as sign? In order to adjudicate the debate, we need a better understanding of the *semantic status* of iconic enrichments. A distinction will prove fruitful: in "internal" enrichments, the form of an expression is iconically modulated to affect the meaning of that very expression, as in examples (1)a–b; in "external" enrichments, an expression is iconically enriched by an extraneous element, as in example (2) (= enrichment of *punish* by a gesture).

2. John _punished his son.

Interesting differences between internal and external enrichments arise upon embedding. The internal enrichments in example (1) behave like standard at-issue (= assertive) contributions and can take scope under logical operators – thus example (3)a means something like "If the talk is *very long*, I'll leave before the end"; and similarly example (3)b means that if my group grows *a lot*, John will lead it.

3. a. If the talk is loooooong, I'll leave before the end.
   b. …IF POSS-1 GROUP GROW_broad, IX-b JOHN LEAD. (ASL; video 33, 71; 2 trials)

Recent discussions suggest that internal enrichments can *also* have other types of contributions – for instance, presuppositional ones (Schlenker et al. 2013).

External enrichments seem to be more constrained, as illustrated in example (4) (the picture represents a gesture that *co-occurs* with the expression that immediately follows it).

4. a. None of these 10 guys punished his son like _this.

   b. None of these 10 guys _punished his son.

   => for each of these 10 guys, if he had punished his son, slapping would have been involved
   c. None of these 10 guys punished **his son** / **regrets coming**
   => each of these 10 guys has a son / came

In the baseline in example (4)a, *like this* is an at-issue modifier; what is denied is thus that any of the relevant individuals punished his son by slapping him – hence if any punished his son, it was in some other way. The target example in (4)b arguably triggers the opposite inference: For each of the relevant individuals, if he had punished his son, it would have been by slapping him. In this case, the iconic enrichment "projects" (in universal form) beyond the negative expression *none*. I have argued (Schlenker 2015; under review) that this behavior is reminiscent of presuppositions, illustrated with the presupposition triggers *his son* and *regrets* in example (4)c: These, too, yield universal inferences under *none*.

A similar behavior is obtained with the disgusted face :-(in example (5)a: It too gives rise to a universal inference under *none*. Interestingly, this case of external enrichment can be extended to ASL, as in example (5)b; while the latter is slightly degraded, it gives rise to a universal inference as well – and since the iconic enrichment of the manual sign is facial, it too counts as external.

5. a. None of my friends goes :-(_[skiing with his parents]
=> in my friends' case, skiing with one's parents is no fun
b. ? YOUNG NONE IX-arc-a **:-(**_[SPEND TIME WITH POSS-arc-a PARENTS]
=> spending time with one's parents is disgusting (ASL; video 33, 0472, 2 trials)

Finally, the gestures in examples (6)a(1)–(6)b(1) *follow* rather than co-occur with the expression they modify, and they arguably behave like the appositives in examples (6)a(2)–(6)b(2) (Schlenker under review; but see Ebert & Ebert 2014). For example, both constructions can modify *a bottle of beer* in the scope of *a philosopher,* but not of *no philosopher* – a standard property of appositives (see Potts 2005; Nouwen 2007).

6. a. A philosopher brought a bottle of beer

(1) –  / (2) , which was _this large.

b. ??No philosopher brought a bottle of beer

(1) –  / (2) , which was _this large.

A generalization suggests itself: *internal enrichments may have any semantic status, and in particular they may be at-issue, whereas external enrichments are not normally at-issue.* If correct, this has an important consequence: Since internal enrichments are so impoverished in spoken language, even when co-speech gestures are reintegrated into spoken language semantics, there will be far-reaching expressive differences between speech-plus-gesture and sign.

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The categorical role of structurally iconic signs

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Abstract: Goldin-Meadow & Brentari (G-M&B) argue that, for sign language users, gesture – in contrast to linguistic sign – is iconic, highly variable, and similar to spoken language co-speech gesture. We discuss two examples (telicity and absolute gradable adjectives) that challenge the use of these criteria for distinguishing sign from gesture.

In their target article, Goldin-Meadow & Brentari (G-M&B) present a subtle view of the distinction between gesture and "categorical" properties of sign language. In both spoken and sign language, illustrative gesture and linguistic material interact within a single unified system that combines meanings in real time. For example, if one were to say the English sentence "a drunk man is walking around" while gesturing with one's hand in a swervy motion, a listener would need to integrate the meaning of the sentence with that of the gesture to correctly interpret the utterance. On the other hand, language and gesture generate meaning in distinct ways. Language is said to use categorical elements that can combine into higher-order structures (e.g., using grammatical rules), while gesture is said to express meaning holistically.

G-M&B argue that the same two expressive categories exist in sign language as in spoken language. However, since many gestures are implemented in the manual modality, it can be difficult to distinguish gesture from the "categorical" elements of sign language. Accordingly, G-M&B provide three heuristics for distinguishing between these. First, gesture tends to be highly variable within a linguistic community while linguistic signs tend to be uniform. Second, gesture tends to be iconic and imagistic whereas sign does not. Finally, gesture in signers tends to be accessible to nonsigners, and is often expressed via co-speech gesture in spoken language.

Although these criteria can be useful for some examples, here we want to focus on a set of "problem" cases that do not neatly fit within the heuristics laid out by G-M&B. In each example, a representation used by signers is highly uniform within signing communities while nevertheless being iconic/imagistic in systematic ways. We argue that careful consideration of these cases requires altering the G-M&B theoretical model and also suggests that cleaner criteria should be adopted for distinguishing between gesture and sign.

First, we consider the case of telicity. Wilbur (2003; 2008) argued that the phonetic form of verbs in several sign languages systematically reflects the telicity of the predicate: Telic verbs (like *decide*, whose meaning has an intrinsic culmination point) are marked with rapid deceleration to an abrupt stop; atelic verbs (like *ponder*, with no intrinsic culmination) are not. Strickland et al. (2015) has confirmed this generalization across several sign languages (including Italian Sign Language, LIS), and show that even hearing people with no exposure to sign language are able to infer the telicity of a predicate based on the phonetic form of a verb. Following G-M&B's criteria, the accessibility of this correspondence to nonsigners likely qualifies it as a gestural component of sign languages.

On the other hand, the phonetic marking of telicity interacts with fully grammaticalized signs in LIS, in a manner invariant from speaker to speaker within a linguistic community. Specifically, in LIS, the phonetic marking of telicity is in complementary distribution with the perfective aspectual marker DONE. Signs like LEAVE, DECIDE, or SELL may express perfectivity either by the presence of a clear boundary or by using the lexical sign DONE. In the latter case, telic predicates do not end in an abrupt stop.

Next, we consider absolute gradable adjectives like "full." What defines absolute adjectives is that the adjectival scale includes a maximum degree: When something is completely full, it cannot be any more full. This contrasts with relative adjectives like "rich," which have no maximum degree.

In LIS, many absolute adjectives include an iconic component that indicates that the maximum degree of the scale has been reached. Unlike their spoken language counterparts (and other, noniconic adjectives in LIS), these signs do not allow for imprecise readings (Aristodemo & Geraci 2015). For example, the LIS equivalent of the English sentence *this glass of wine is full but you can still pour a bit more* is not grammatical because the sign FULL iconically conveys the meaning that the glass is maximally full. The same effect can be obtained in spoken Italian by accompanying the adjective with a co-speech gesture (an open hand waving on the horizontal plane). This fact shows that an iconic component that is an obligatory part of a sign and an independent co-speech gesture in spoken language contribute similar core meanings to utterances.

In the examples just discussed (i.e., telicity and absolute gradable adjectives), there is an iconic/imagistic representation that is comprehensible to nonsigners (as in the telicity example) and can optionally be employed during co-speech gesture (as in the absolute scale example). On the G-M&B framework, one might therefore conclude that they are a part of the gestural system.

Nevertheless, these representations are not variable across members within signing communities, and they seem to play a key role in determining grammaticality. On these grounds, one might conclude that they are part of the "categorical" signing system.

This leaves open two possible theoretical positions, either of which would represent a substantial alteration of the G-M&B framework. The first possibility is that we treat the markers of telicity and absolute scale in LIS as gesture. On this view, gesture would be capable of interacting with the grammatical system of sign languages in highly intricate ways. In this case, we must accept that some types of gesture do not have a tendency to be variable across speakers within a language, that gesture is not necessarily holistic, and that gesture can have virtually identical functions to well-known grammatical markers in spoken languages (such as event-finality in Slavic languages).

The second possibility is that we treat the markers of telicity and iconic absolute adjectives in LIS as being categorical elements of the signing system. On this view, one would need to accept that some properties of sign are highly iconic, and that overlap with co-speech gestures from spoken language should not be taken as a criterion for distinguishing sign from gesture.

For the moment, both views are plausible. Subsequent research and refinement of analytic techniques would be necessary to distinguish between them.

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Gestures can create diagrams (that are neither imagistic nor analog)

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Abstract: The claim that gesture is primarily imagistic, analog, and holistic is challenged by the presence of abstract diagrammatic gestures, here points and lines, that represent point-like and line-like concepts and are integrated into larger constituents.

Goldin-Meadow & Brentari (G-M&B) have taken us on a tour of the highlights of the history of the study of sign language and gesture, concluding that sign languages are full-fledged languages like spoken ones, and that like speakers, signers gesture when they sign. A full understanding of face-to-face language, whether spoken or signed must consider gesture as part of the meaning-making package. I couldn't agree more.

It is tempting to stop here – what can be added to such a thoughtful and convincing analysis? But like any good analysis, this one keeps you thinking. Just as in real space, I took detours. For example, the discussion of whether sign is pantomime took me to the development of written languages (Gelb 1963). The alphabet, mapping *sounds* to marks, was invented only once, but written languages that mapped *meaning* to marks were invented many times. Reminiscent of sign, the forms began as crude depictions but were gradually schematized so that it became difficult to recognize their depictive origins, and there is little similarity across languages. Similarly, depictive schematizations were never sufficient to express all meanings.

Another place that set me wondering and wandering was a central claim of the target article: "But speech and gesture convey meaning differently – whereas speech uses primarily categorical devices, gesture relies on devices that are primarily imagistic and analog. Unlike spoken sentences in which lower constituents combine into higher constituents, each gesture is a complete holistic expression of meaning unto itself (McNeill 1992)" (sect. 5, para. 3).

Points are undoubtedly the simplest of gestures, accomplished in many ways: a finger, a hand, a nod of the head. Perhaps these are synonyms. The familiar deictic point mastered early by babies refers to something in the world. Those points seem to stand alone as "complete holistic expression[s] of meaning"; perhaps it's easier and more natural to point than to say. Yet other points "combine into higher constituents." As people study descriptions of environments (Jamalian et al. 2013) or describe environments to others (Emmorey et al. 2000), they point successively not to things in the world but to the imagined locations of places integrated in an imaginary space. Landmarks of any kind receive the same undifferentiated point. Similarly, when solving problems alone in a room, people use points to represent the structure of the problem: for example, an array of glasses (Tversky & Kessell 2014). Points can be used to indicate contrasting arguments – *on the one hand, on the other* – or successive events of a story, both integrated at a higher level. These examples challenge the claim that gestures are "holistic … unto itself" that do not "combine into higher constituents" as well as the claim that gestures are imagistic or analog.

Similar issues arise for line-like gestures, gestures used to interrelate points, the relationship between two contrasting arguments, the events of a story, or the paths between landmarks. Like lines in sketch maps, they could be analog but are not (Tversky & Lee 1999). Rather, gestured lines seem to fall into approximate categories, parallel to the ways language coarsely categorizes quantitative concepts: *some, few, many,* or *close, near, far* (Talmy 1983).

Such gestures are not "imagistic" or "analog." The same point-like gestures are used to individuate and arrange a broad range of entities, without differentiating the entities. These points are like the points used in counting. What is being counted makes no difference; all that counts is their quantity. The same line-like gesture is used to indicate a path in the world, a timeline of events, a relationship between arguments. There is no semblance of resemblance as in iconic gestures, nor are the meanings metaphoric. Rather than being "imagistic" or "analog," these point-like and line-like gestures are *diagrammatic* (Tversky 2011; Tversky et al. 2009) or, in Talmy's term, *schematic* (Talmy 1983). They *represent* entities that can be conceived of as points or lines (e.g., Talmy 1983). They are not metaphoric as they are devoid of content; instead, the points and lines and a few other forms common in gesture and graphics are *abstractions*, a point or dot for a place or an idea, a line for a relationship between places or ideas, a blob to contain a set of them (e.g., Tversky 2011; Tversky et al. 2009). Such abstract gestures are ambiguous, similar to the analogous words *point*, *line*, and *set*; for both, context clarifies.

As noted, speech can take on characteristics of gesture. *Soooo* can be elongated just as *very's* can be concatenated to indicate intensity on any dimension. Sooner or later, someone will produce a video titled "50 Shades of *No*." If many gestures are not imagistic or analog and can form integrated constituents of higher-level structures, if speech can be overlaid with sounds that act like gesture and sign with gesture, then how can gesture be distinguished from speech? Even common categories are slippery: what's a slipper, what's a sandal, what's a shoe? They slide into each other. The arts stretch our categories further. There is *conceptual art*, which is typically only words, and *visual poetry*, which often lacks them. Wittgenstein (1953), and Rosch (1978) on his heels, observed that common categories don't appear to have defining features that cleanly assign instances into categories; rather, common categories have a *family resemblance* structure, a set of features that members are more likely to share.

Categories: We can't live with them, we can't live without them.

These observations blur some of the distinctions G-M&B meant to sharpen in their thoughtful and thought-provoking analysis. Yet their primary intent was to show some of the subtleties and varieties of meaning-making. Everyday communication is a harmonious blend of words, spoken or signed; gestures, prosody, and more creating rich, textured, and innovative meanings. Thinking about what does what and how, and how they combine is endlessly fascinating.

Authors' Response

Gesture and language: Distinct subsystem of an integrated whole

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Abstract: The commentaries have led us to entertain expansions of our paradigm to include new theoretical questions, new criteria for what counts as a gesture, and new data and populations to study. The expansions further reinforce the approach we took in the target article: namely, that linguistic and gestural components are two distinct yet integral sides of communication, which need to be studied together.

R1. Introduction

In our target article, we argued for an approach to language in which linguistic and gestural components are two distinct yet integral sides of communication. When the linguistic system is spoken, it is tempting to call the sounds that we produce with our mouths "linguistic" and the movements that we produce with our hands "gestural." But this easy division on the basis of articulators doesn't work for sign language where the hands take on both linguistic and gestural roles. Our tour through the history of sign and gesture research over the last 50 years brought us to the conclusion that we cannot straightforwardly compare sign to speech simply because sign has gestural components embedded within it that are (at least at the moment) difficult to disentangle. For example, particular forms of the hands, face, and body can all be used both linguistically and gesturally in sign, and, within a single handshape, one part of the hand may be morphemic (i.e., linguistic) and another part gestural, as Duncan (2005) has shown in Taiwanese Sign Language narratives. We suggested that the more appropriate alignment is between sign+gesture and speech +gesture. This research strategy has two implications: (1) We need to take gesture seriously in our studies of both spoken and sign languages, and (2) we need to figure out ways to distinguish gestural components from linguistic components in speech and sign. The division into linguistic and gestural components in both spoken and sign languages not only has theoretical import, but also practical significance as it allows us to identify learners who are on the verge of acquiring a new concept.

The thought-provoking commentaries on our target article have led us to expand the paradigm we proposed in a number of important and innovative ways. These expansions can be divided into three areas: (1) Possible theoretical questions that follow directly from our claims (**Barca & Pezzulo**; **Berent & Dupuis**; **Coppola & Senghas**; **Davidson**; **Emmorey**; **Kendon**; **Lakshmanan & Pilot**; **Occhino & Wilcox**; **Pfister & Lende**; **Pouw, van Gog, Zwaan, & Paas [Pouw et al.]**; **Schlenker**; and **Strickland, Aristodemo, Kuhn, & Geraci [Strickland et al.]**); (2) different kinds of gestures observed, and how they fit into the framework we propose (**Cornejo & Musa**; **Giezen, Costello, & Carreiras [Giezen et al.]**; **Kästner & Newen**; **Liebal**; and **Tversky**); and (3) new data and populations to be investigated or old ones revisited (**Campbell & Woll**; **Eigsti & de Marchena**; **Feldman, Aragon, Chen, & Kroll [Feldman et al.]**; **Hall**; **Malaia**; **Marschik, Zhang, Esposito, Bölte, Einspieler, & Sigafoos [Marschik et al.]**; **Motamedi, Schouwstra, & Kirby [Motamedi et al.]**; **Provine**; and **Rosselló, Mattos, & Hinzen [Rosselló et al.]**).

R2. Theoretical questions that expand our claims

Our target article argued that language and gesture function differently but work together as an integrated system. To make our point, we used examples that cleanly highlight the opposition between language and gesture. But several of the commentaries questioned whether gesture can always be distinguished from sign. In this section, we reiterate the features that we take to be important in distinguishing gesture from sign, acknowledging that they are heuristics for isolating the two behaviors rather than strict criteria, as **Berent & Dupuis** point out. We then consider theoretical issues raised in the commentaries that lead us to expand our claims.

R2.1. Distinguishing gesture from sign

The first feature that most of the commentaries focused on, and that we continue to think is essential in identifying a gesture, is gradience (as opposed to discreteness). But gradience is not an easy heuristic to implement simply because, as **Berent & Dupuis** note, although analog nonlinguistic computations (i.e., gestures) give rise to gradience, gradience can also result from the realization of discrete grammatical categories (see also **Occhino & Wilcox**). So gradience per se is not a surefire marker of a gesture. Although gradience is not a sufficient marker of gesture, we suggest that it is a necessary marker. Gestures are analog and not discrete.

Second, gestures are imagistic: The form of a gesture is transparently related to its meaning. But here again the heuristic is not straightforwardly applied, particularly in sign languages where many (grammatical) forms are transparently related to their meanings. Iconicity is found in both signed and spoken grammatical categories and thus cannot, on its own, mark a form as gesture. We suggest that, here again, being imagistic is necessary but not sufficient to signal that a form is gestural.

A third feature, one that we did not stress in our target article, is that gesture typically falls outside of awareness for both producers and receivers. Gestures (or at least the kinds of gestures that we want to focus on; see sect. 3) are produced along with linguistic communicative acts and thus take on the intentionality of those acts. But they are not themselves the focus of attention for either the producer or the receiver, which may be what gives gesture its cognitive traction. We suggest that gesture accesses implicit, nondeclarative knowledge in learning that can ultimately be integrated with declarative knowledge.

Fourth, following from the third feature, gesture (again, the kind we want to focus on; see sect. 3) is parasitic on the language it accompanies. It is meaningful, but the meaning is framed by the speech or sign with which it occurs. Language can stand on its own without gesture (for the most part, although not always, which is why these features are heuristics rather than defining properties), but gesture cannot stand alone without language. As an important corollary, when spoken language is removed and the manual modality is left to take on the full burden of communication (as in silent gesture or homesign), we do not consider the resulting system to be gesture. As we note in the target article, silent gesture is not gesture in the way we use the term here; it is not *co-language* gesture and, at least in terms of discreteness, it is closer to language than it is to gesture (see Goldin-Meadow et al. 1996; Singleton et al. 1995).

Finally, although gestures do combine with one another (as **Tversky** notes), the combinations are characterized by a flat structure rather than a hierarchical structure. The combinatorial system involving different levels of description (i.e., phonological, morphological, syntactic, semantic, pragmatic) that characterize language is not needed to characterize co-speech or co-sign gesture.

R2.2. What variability signals in gesture and sign

Two commentaries raise the issue of variation as it pertains to distinguishing gesture from sign (**Berent & Dupuis, Emmorey**). There are two types of variability that need to be considered, and both types are found within an individual (i.e., the individual varies within herself) and across individuals (i.e., individuals within a group vary). In the first type, there is little consistency in the target form that is used for a particular meaning. Duncan (2005) points to this type of variability in Taiwanese Sign Language. The signers she studied all used the same handshape to refer to a cat, but the ways in which the handshape was modified to indicate that the cat was crawling up a tight drainpipe varied across signers, and in just the same ways that hearing speakers vary their manual gestures when describing the same event. Sandler (2009) uses the same type of variability across signers to distinguish gestural from linguistic facial expressions in Israeli Sign Language (ISL). Different signers produced different iconic mouth gestures to describe the cat climbing up the inside of the narrow drainpipe. One signer indicated the bulge of the cat seen from outside with puffed cheeks; another indicated the cat's tight fit with narrowed eyes and a pursed mouth gesture. Importantly, the facial expressions used in grammatical constructions in ISL (e.g., wh-questions and conditionals) do not display this type of variation.

It is worth pointing out that this type of variability is, once again, not a surefire marker of gesture. Variability has been found to characterize manual movements that are not used along with a codified linguistic system (and thus are not co-language gesture), but are instead used *in place of* such a system. For example, Goldin-Meadow et al. (2015) examined variability in the handshapes used to refer to a particular object in adult homesigners in Nicaragua whose hearing losses prevented them from acquiring Spanish and who had not been exposed to Nicaraguan Sign Language (NSL). The homesigners displayed more variability in the handshapes they used for an object than did NSL signers, even signers who were members of the earliest cohort of the newly emerging language. This result is not surprising given that each homesigner was inventing his or her own homesign system and was not part of a linguistic community. More surprising is the fact that the homesigners also displayed more variability within themselves; that is, an individual homesigner was less likely than was an individual NSL signer to use the same handshape every time she referred to an object. By not repeatedly tapping into a single form (an invariant form-meaning mapping suggestive of *langue*) homesign lacks one central feature of a linguistic system. Importantly, however, homesign contains the essential feature of discreteness, as well as many other linguistic properties (e.g., morphological marking on the verb, Goldin-Meadow 2003a; Goldin-Meadow et al. 2015b), and thus is not gestural in the way we use the term.

Having chosen a target form, there may be variability, both within and across speakers, in how that form is produced, and this is the second type of variability that may help us distinguish gesture from sign. This type of variability can be based on many factors (speaker, gender, age, speech register, etc.). For example, in the production of English /r/, the properties of being "bunched" or "retroflexed" vary both by speaker and by the surrounding segmental context (Archangeli et al. 2011). This type of variability is also found in fingerspelled letters of the ASL manual alphabet. The letters N, R, U, and V all have selected index and middle fingers, and closed (i.e., flexed) unselected ring and pinky fingers; the degree of flexion of the ring and pinky fingers varies by signer and by the surrounding segmental context (Keane 2014). In terms of distinguishing between gesture and language, one interesting question is whether there is more of this type of (phonetic) variation in the handshapes produced in gesture than in the handshapes produced in sign language. To address this question, we would, of course, need to control for the number of gestures in the sequence, which can be difficult because co-speech gestures often come only one to a clause (McNeill 1992).

R2.3. How to treat properties that gesture and sign have in common

In our target article, we highlighted differences between language and gesture. However, we recognize that there are also commonalities between the two. **Barca & Pezzulo** point to an embodied framework for language that unites gesture and sign. We did not focus on embodiment in our target article simply because it does not highlight the difference between gesture and sign, as it applies to both. The fact that gesture (like sign) is an act of the body may be critical in determining some of its effects. But it is important to recognize that the impact that gesture has on thinking does not stem entirely from its being an act of the body. For example, Novack et al. (2014) explored the impact of instruction in which learners acted on a math problem during a lesson and compared it to instruction in which learners gestured about the problem. They found that children who acted on the problems learned how to solve the problem just as well as children who gestured about the problem. But gesturing was much more effective than acting when it came time to generalize what they had learned to new problem types. Gesture and action both involve the body; the different impact they have on learning cannot be explained by embodiment. Similarly, gesture and sign both involve the body. They may, or may not, have the same effects on cognition, an empirical question that takes us beyond the fact that the body is representing information and forces us to consider the format by which that information is represented.

What is more pressing in terms of commonalities, however, is that we need to ask whether a form that elicits the same response in signers and speakers is necessarily a gesture. This question arises with respect to the study of telicity mentioned in **Strickland et al.** Strickland et al. (2015) conducted a perception study on American English speakers without sign language experience, using signs from Italian Sign Language (LIS). They found that speakers reliably paired LIS signs for events with and without an endpoint with videos of events that did and did not have endpoints (telic vs. atelic events); the telic/atelic distinction is found in many sign languages (Wilbur 2010).

On the basis of these findings, we might be tempted to argue that these forms are gestural not only for non-signers, but also for signers. But the fact that a form is transparently related to its meaning does not make it gestural. Iconicity runs throughout linguistic systems, particularly sign systems, but that iconicity is constrained. For example, the temporal affixes for telic (punctate movement, with an endpoint) and atelic (continuous movement, with no endpoint) cannot be applied to all verbs, and the particular set of signs to which the affixes apply varies from sign language to sign language. Knowledge of the lexical semantics of the verbs and their syntactic frames is not explored in Strickland et al.'s (2015) fixed, binary-choice task. As a result, the findings show only that both groups use iconicity to interpret the meaning of a form, not whether the form has other grammatical or lexical constraints. We suggest that these restrictions will be present in signers but not non-signers. Strickland et al.'s lovely results make it clear that signs for telicity have iconic roots, but the findings should not be used to argue that this aspect of sign is gestural.

To push the point even further, imagine two handshapes – a straight index finger versus a straight index+middle finger – presented with the picture of a pen. Hypothetically, if non-signers and signers both preferentially associate the single index finger handshape with the pen, we would not want to conclude that non-signers have a phonological contrast for the number of fingers, nor would we want to conclude that signers lack a phonological system for handshape. Participants would simply be using iconicity to make the best of a fixed-choice scenario, with no information provided about the way the form fits into a phonological system. Sign languages work *with* iconicity most of the time, not against it, and so it is not surprising that there are some situations where signers and non-signers behave in precisely the same way.

R2.4. When gesture and sign differ

There are many ways in which gesture and sign are similar as semiotic systems, a point made in the target article and emphasized by **Kendon**. But we argue that the differences are too fundamental to ignore. Both contribute different kinds of information that are largely complementary (when gesture adds or reinforces information found in sign or speech), but sometimes gesture conveys information that is different from the information conveyed in sign or speech (a so-called *mismatch*), and, when it does, it offers a window onto cognition. **Pouw et al.** suggest that we can't have it both ways: that gesture can't mismatch speech and, at the same time, be part of an integrated system. But mismatches in morphology and syntax (Sadock 1991) and in phonology and morphology (see Fig. 3 in the target article for mismatches in number of syllables, a phonological unit, and number of morphemes, a morphological unit) happen relatively frequently, yet all of these components function as a unified system. Along the same lines, the allosemantic enrichment examples that **Schlenker** describes fit the definition of a mismatch. In allosemantic enrichment, gesture provides information that is not conveyed within the linguistic unit that it accompanies, the classic definition of gesture-speech mismatch: for example, producing a hit gesture while talking (or signing) about punishment without explicitly mentioning how the punishment was administered. In autosemantic enrichment, by contrast, gesture provides information that is expressed within the linguistic unit: for example, producing the hit gesture while talking (or signing) about hitting. As Schlenker makes clear, these examples are not anomalies but rather work within the constraints of the semantic system and can be helpful in revealing the properties of that system.

There are two points that we need to stress about gesture-speech mismatches. First, the information conveyed in gesture is different from, but not contradictory to, the information conveyed in speech, as **Pouw et al.** suggest. In fact, in all instances of true mismatches, the information conveyed in the two modalities has the potential to be integrated; it just hasn't been integrated by the speaker or signer. Importantly, the brain treats speech and gesture as if they belong together when the two convey different but potentially integrable information, but not when the two modalities convey contradictory information. For example, in a study of the brain's electrophysiological response (ERPs, event-related potentials) to different types of stimuli, Kelly et al. (2004) found that gestures conveying information that is truly incongruent with the information conveyed in speech (gesturing *short* while saying "tall") produce a large negativity at 400 ms (the N400 is known to be sensitive to incongruent semantic information; Kutas & Hillyard 1984).

Importantly, gestures conveying information that is different from, but integrable with, information conveyed in speech (gesturing *thin* while saying "tall" to describe a tall, thin container, a true gesture-speech mismatch) are processed no differently at this stage from gestures that convey the same information as speech (gesturing *tall* while saying "tall"; Kelly et al. 2004). Neither one produces a large negativity at 400 ms; that is, neither one is recognized as a semantic anomaly. It is important to note, however, that at early stages of sensory/phonological processing (P1-N1 and P2), speech accompanied by gestures conveying different but potentially integrable information (e.g., gesturing *thin* while saying "tall") is processed differently from speech accompanied by gestures conveying overlapping information (gesturing *tall* while saying "tall"). Thus, potentially integrable differences between gesture and speech are noted at early stages of processing but not at later, higher-level stages.

The second point about mismatches is that, although detecting gesture-speech mismatch in an experimental situation requires elaborate controls, as **Koschmann** points out, mismatches are noticed and, in fact, acted on by ordinary communication partners. For example, Goldin-Meadow and Singer (2003) videotaped teachers using whatever techniques they wanted to instruct children in mathematical equivalence. The one-on-one tutorials were videotaped and the children later classified according to whether or not each child produced gesture-speech mismatches; the teacher's instruction to each child was then analyzed. The teachers were found to instruct children who produced mismatches differently from children who did not (they taught mismatchers more different types of problem-solving strategies in speech and in gesture). Teachers seem to know when learners produce gesture-speech mismatches (albeit not consciously; see Alibali et al. 1997), and they alter their instruction accordingly. Along the same lines, mothers interacting with their toddlers at home, responded to the child's gesture+speech utterance with longer utterances of their own when gesture and speech conveyed different information (and thus mismatched: e.g., "mommy"+point at hat, to indicate that the hat belonged to mom) than when they conveyed overlapping information (e.g., "hat"+point at hat; Goldin-Meadow et al. 2007a). The procedures developed to ensure methodological rigor in identifying gesture-speech mismatch in the lab do not render the concept useless in the real world, as both teachers and parents seem to know (and act on) a mismatch when they see one.

But **Pouw et al.** are not questioning whether mismatch can be identified; they are asking about the mechanism by which gesture introduces new ideas into a learner's repertoire. Cook et al. (under review) have hypothesized that gesture's power to change thought stems from its ability to introduce nondeclarative knowledge into a learner's repertoire, knowledge that is often different from, but produced at the same time as, declarative knowledge expressed in speech. Co-speech gesture and, we would argue, co-sign gesture resemble nondeclarative knowledge in that both are implicit and (as Pouw et al. suggest) based in action. Co-language gesture is thus ideal for integrating declarative and nondeclarative knowledge not only because it is itself a vehicle for conveying nondeclarative knowledge, but also because it is seamlessly integrated with speech or sign, the gold-standard vehicle for conveying declarative knowledge.

R2.5. Multiple levels of representation in sign, but not gesture

The idea that linguistic forms are subjected to multiple levels of representation during processing has been addressed directly for spoken (Levelt 1989) and signed (Pfau et al. 2012) languages. If a form is linguistic, it will tap into multiple levels of representation. **Coppola & Senghas** suggest that, in addition to categorizing a form as gradient or discrete (categorical in their terms), it should be identified by whether or not it combines with other forms (which they refer to as "systematic" vs. "noncombining"). Being systematic may capture some (but not all) aspects of the fact that some forms are part of a linguistic system; however, we are not convinced that the four cells fully capture distinctions between gesture and sign. Combination per se isn't the issue; the combinations need to reflect a system that engages phonological, morphological, syntactic, semantic, and pragmatic levels. Hearing speakers frequently string pointing gestures together, and the particular combinations of gestures they produce are meaningful (e.g., strings of pointing gestures that convey different problem-solving strategies for solving mathematical equivalence problems, Alibali & Goldin-Meadow 1993). But these gestures are not part of a hierarchical system of multiple levels.

Supalla (1982), Benedicto and Brentari (2004), Brentari et al. (2012), and Brentari et al. (in press) illustrate the notion of multiple levels at work in sign language phonology, morphology, and syntax for two types of handshapes in classifier constructions. These constructions are polymorphemic, iconic, motion, and location predicates that may lie at the boundary between language and gesture. The two types are (1) *handling classifiers,* expressed via handling handshapes, which have "hand-as-hand" iconicity because they represent how hands handle objects; and (2) *entity/semantic (object) classifiers,* expressed via object handshapes, which have "hand-as object" iconicity because they represent properties of the object on the hand.

These constructions are, first of all, motor schemas, the first level of representation. The second level at which the constructions can be analyzed is conceptual. The iconic relation between form and meaning in the two types of handshape forms is clear. However, there is a difference in how these forms are used by signers and non-signers. Non-signers, when asked to gesture without speech (i.e., to produce silent gesture), have a strong bias toward one of the two types of iconicity: hand-as-hand iconicity. Padden et al. (2013) have shown this effect in a naming task, where they find that silent gesturers display a bias toward using handling handshapes (as opposed to object handshapes) to represent instrument-like objects. Non-signers understand the idea that the hand can represent the hand, but when the hand is called upon to represent something else (in this case, an object), they are more likely than signers to use a neutral handshape not displaying any properties of the object, or to trace the shape of the object with an index finger. Signers, in contrast, will represent properties of the object in the handshape itself.

The third level is morphological. Both object and handling forms combine with a wide range of movements in classifier predicates to achieve agentive (handling handshapes) and non-agentive (object handshapes) meanings, so the handshapes are meaningful and productive. Indeed, even homesigners, who are inventing their gestures without benefit of a linguistic model, use handling and object handshapes systematically for agentive and non-agentive meanings (e.g., Rissman & Goldin-Meadow, in press); importantly, the same structures are typically *not* found in silent gesture (Brentari et al. 2015a), nor in the co-speech gestures that the homesigners' hearing parents use with them (Goldin-Meadow et al. 1995; 2007a).

The fourth level is phonological. There are differences between signers and silent gesturers with respect to the internal structure of handshape (Brentari et al. 2016). Signers balance the complexity of their handshapes between joint complexity and finger complexity, showing a double dissociation between handling handshapes (high joint complexity–low selected finger complexity) and object handshapes (low joint complexity–high finger complexity). Silent gesturers also use more joint complexity in their handling handshapes (almost veridically representing how the hand holds the object) than in their object handshapes. But, unlike signers, they show the same pattern with respect to finger complexity: more finger complexity in handling handshapes than in object handshapes (Brentari et al. 2012). Building this kind of division of labor in a system is the work of a phonological level of representation; signers have it and non-signers do not.

The final level of representation is syntactic. Diagnostic tests have been applied to these forms in several sign languages (ASL, Hong Kong Sign Language, LIS, British Sign Language) to show that handling handshapes are sensitive to both the grammatical subject and object arguments in a sentence, whereas object handshapes are sensitive only to the grammatical object argument. To date, grammaticality judgments of this type have not been obtained from non-signers (nor from homesigners).

The fact that an iconic form is part of a system for signers but not for non-signers suggests that iconic forms may be processed differently in signers and in non-signers. **Davidson** notes that when bimodal bilinguals (individuals equally fluent in a signed and spoken language) are speaking English, they often produce classifier constructions comparable to those found in sign language alongside speech; in this context, the classifier constructions are serving the function of co-speech gesture. In other words, their status changes from sign to gesture when spoken language shoulders the linguistic burden of communication.

The converse – that is, gesture (albeit in this case, silent gesture) is treated as sign – has been shown in recent work by Newman et al. (2015), who collected manual event descriptions of objects moving in space from signers and from non-signers. The signers produced classifier constructions, which (as noted earlier) are transparently related to their meanings and thus have the potential to be gestural rather than linguistic. The non-signers' descriptions were produced without speech and thus were silent gestures transparently related to their meanings. These productions were then used as stimuli in a functional magnetic resonance imaging (fMRI) study and shown to signers and non-signers. Once low-level stimulus features were taken into account, signers were found to process the classifier signs within the left-lateralized frontal-temporal network used for spoken languages. But they also processed the silent gestures within the same network, demonstrating an influence of lifelong experience with sign on the perception of silent gesture. In contrast, non-signers processed both the classifier signs and the silent gestures within regions involved in human action perception, not within linguistic areas. In other words, both types of forms were processed linguistically in signers, and non-linguistically in non-signers. This work highlights the fact that the iconicity of a form is not sufficient to make the form gestural. When silent gestures (which are iconic) are processed by signers, they activate language areas; not so when they are processed by non-signers. The interesting question from the point of the framework we have proposed here is – Will signers process *co-speech gesture* within language areas? We suspect that they will not. Although silent gesture has enough of the discreteness found in sign language to activate language areas in individuals who have had lifelong experience with sign, co-speech gesture does not. We therefore hypothesize that co-speech gesture will activate regions involved in human action perception not only in non-signers, but also in signers.

R3. Gesture types and their relevance to our model

We began our target article by situating what we call gesture within Ekman and Friesen's scheme (1969) for classifying non-verbal behavior (interpret "verbal" in this case as "linguistic"): (a) *affect displays,* whose primary site is the face, convey the speaker's emotions, or at least those emotions that the speaker does not wish to mask; (b) *regulators,* which typically involve head movements or slight changes in body position, maintain the give-and-take between speaker and listener and help pace the exchange; (c) *adaptors* are fragments or reductions of previously learned adaptive hand movements that are maintained by habit; (d) *emblems* are hand movements that have conventional forms and meanings; and (e) *illustrators* are hand movements that are part of an intentional speech act, although speakers are typically unaware of these movements. We focused initially on illustrators, called *gesticulation* by Kendon (1980b) and *gesture* by McNeill (1992), for two reasons: (1) these behaviors have been extensively studied with regard to their relation to spoken language, and (2) the behaviors have been argued to be an integral part of language (e.g., McNeill 1992). But over the course of our tour through research on gesture, sign, and speech, we enlarged our window to include facial movements in sign and prosody in speech, both of which have the potential to be linguistic *and* gestural.

Several commentaries address what they perceived in our target article as an overly narrow definition of gesture: that we might have been bending categories and, in the process, distorting them for our purposes. **Liebal** asks why we limit ourselves to manual gestures, especially when, from her perspective as a psychologist working with nonhuman primates, gesture data run the whole gamut from affect displays to illustrators. She points out that there is currently no shared definition of gesture that serves communities working on gesture data in human and nonhuman primates. This point is well taken, and we could learn much from comparative work on human and nonhuman primates' communicative use of gesture, if there were a commonly accepted terminology. **Tversky** calls us to task on gestures using points and lines. She describes these manual gestures not only as gestures but also as abstractions (a point with which we agree), and suggests that they are not necessarily analog, or at least not completely analog; for example, line-like gestures fall into approximate categories parallel to the ways language coarsely categorizes quantitative concepts like *some, few, many*. Whether co-speech (and co-sign) gestures are better described as approximate categories or as continuous representations is an empirical question. But it is clear that gesture often adds precision to language, as **Kästner & Newen** suggest when they argue that gestures fit into language as a type of modifier: for example, using a *big* gesture along with the word *big* to show how big (an autosemantic enrichment in **Schlenker**'s terms). We agree with Tversky that points and lines can be abstractions, but we stress that they also vary in a gradient manner. They vary from one utterance to another, one context to another, and in ways that linguistic material does not. The meanings of words such as *this*, *that*, *here,* and *there* can be made more precise by gesture, but the precision of the gesture is analogic. The points or lines can be closer or farther apart from one another in a gradient fashion; they can differ only along one planar dimension or all three; or, as **Emmorey** notes, they can be omitted entirely.

A few commentators thought we made category errors, ascribing some phenomena to the realm of gesture that should not be. For example, **Giezen et al.** and **Rosselló et al.** suggest that we were too quick to say that location might be gestural in sign language simply because location is clearly categorical in lexical signs. To be clear, we were suggesting that location might be both gestural and categorical. When we described location as a potentially gestural component of signs, we were limiting the discussion to agreeing verbs in sign language. We agree that location, and movement as well, are both linguistic in frozen lexical items; these parameters have minimal pairs and fit into a phonological system. We did not provide in the target article text the often-cited minimal pair for location in ASL in which APPLE (Fig. 1, center, in the target article, which is produced at the cheek) contrasts with ONION (in which the same handshape is produced at eye level).

Examples of this sort make it clear that location is a phonological parameter in sign and, in this sense, linguistic. Verb agreement makes use of a different kind of location: "neutral" space in front of the signer, which is where classifiers are produced. Perhaps the best way to think about location in sign is in terms of a continuum, with categorical uses of location on one end (e.g., location as a phonological parameter on which lexical distinctions in frozen forms are based) and more imagistic uses of location on the other end (e.g., location in classifiers, which has the potential to be analog, although see Supalla 1982, for evidence that it too may be categorical and morphemic). In between, there are many structures with both types of properties and without a clear boundary between them (e.g., referential locations in verb agreement). It is an open question as to whether this boundary is necessarily fuzzy, or whether additional research and new techniques can add precision to the line. As an example, **Giezen et al.** point out that categorical perception is only one way to establish a property as linguistic, and they cite studies showing that the density of location (i.e., neighborhood density) can affect lexical decision tasks and, in this sense, is functioning linguistically. Categorical perception and neighborhood density are independent pieces of evidence contributing to the status of a property as linguistic: One interesting question is what we should conclude about linguistic status if the two pieces of evidence end up disagreeing.

Prosody is another gray zone between gesture and language. Prosody not only signals constituent breaks, but also it can carry meaning in a gradient way, as intonational tunes or contours. We appreciated **Tversky**'s reference to the hypothetical "*50 Shades of* No." Beckman and colleagues (Beckman & Ayers 1997 Beckman & Hirschberg 1994; Silverman et al. 1992) have, with the development of the tones and break indices (ToBI) system, been able to extract categorical meaning from prosody and intonation, particularly with regard to tone. But a great deal of prosodic structure remains in the realm of gesture, as pointed out by several commentators, including Tversky, **Strickland et al.,** and **Cornejo & Musa**. This point holds for both spoken language prosody in the voice and sign language prosody on the hands, face, and body.

With regard to prosody's role in marking constituent breaks, two commentaries suggest that we expand the data we consider to include laughter (**Provine**) and emoticons (**Feldman**). Both of these communicative objects can be inserted into discourse at constituent boundaries but not elsewhere. The point is that these forms of expression, which fit within the gestural realm (although on the periphery), provide further evidence that gesture and language form an integrated system. Laughter and emoticons behave like speech interjections and expressives (Potts 2007), which also have well-formed constraints on where they can be inserted.

With regard to prosody's role in establishing sentence meaning, scalarity presents a set of cases that are particularly gray because they are gestural and linguistic at the same time. The prosodic intensity of words like *yeah*, *okay*, *right*, and *really* can co-vary with the speaker's degree of belief (Kennedy & McNally 2005; Lai 2009), sometimes with a positive bias (i.e., the more intense the *really*, the more certain the speaker is, e.g., John *really* likes apples!) and sometimes with a negative bias when the lexical item is used as a cue question (e.g., John likes apples. *Really?*). There is thus an alignment between gradability of prosodic form and gradability of speaker belief (just as there is an alignment between gradability of prosodic form and speaker perception of how long an event is taking in the "*It took s-o-o-o l-o-o-o-ng*" example from Okrent 2002, cited in our target article).

Prosody can also take over a role that is marked linguistically. For example, words or signs can mark a sentence as imperative: in ASL, POINT-2SG = **MUST** READ THAT PAPER!; in English, *You **must** read that paper!* But imperative meanings can also be differentiated from neutral sentences by prosody alone: READ THAT PAPER! (command conveyed by visual prosody on the face in ASL and intonational contour in English), compared to [I want to..] READ THAT PAPER (neutral in ASL and in English; Brentari et al. 2015b). Imperatives can be expressed prosodically by atypical populations and young children, and potentially also by higher order nonhuman primates. As a result, this type of form could serve as an excellent arena for the comparative analyses that **Liebal** advocates, assuming, of course, that we can establish consistent definitions and frames of reference across the populations.

These gray areas underscore the point made in our target article and by many commentaries: Forms in spoken languages and in signed languages are not necessarily gestural *or* linguistic; some forms can be gestural *and* linguistic.

R4. New types of data, methods, and populations

In speech+gesture, it is relatively easy to detect the divide between language and gesture. However, in sign languages, we need to find theoretically motivated ways of distinguishing linguistic from gestural elements. In our target article, we described easy cases where the entire form is either a gesture or a sign; for example, a signer enacted the cat's climb up the outside of the drainpipe (looking just like a hearing gesturer) and interspersed this gesture with the sign in Taiwanese Sign Language for *climb-up* (Duncan 2005). We also described handshape forms that were clearly linguistic but were modified in ways that were gestural, illustrating how a handshape could be linguistic and gestural at the same time. It has proven more difficult to find clear evidence for the linguistic nature of location and movement in signs (but see **Rosselló et al.** for neighborhood density effects that are suggestive). We suggested that the correct instrument for analyzing movement or location has not yet been found, and that motion capture might be one of the many relatively new technologies that could provide insight; for example, it may be easier to impose a categorical analysis on a signer's motions and locations than on a gesturer's motions and locations.

Malaia also suggests eyetracking and neuroimaging, which focus on perception rather than production, as possible technologies; both are excellent suggestions. For our purposes, any new technology is useful insofar as it provides a way to distinguish linguistic from gestural elements. In fact, **Emmorey** and **Coppola & Senghas** articulated our own general position when they suggested that minuscule differences in form, no matter how nuanced the detail provided, will be unlikely to provide clear answers about what is gesture and what is language. Emmorey suggests that looking at form differences in properties of elements that vary in sign languages, as well as their optionality/obligatoriness, will be more informative. For example, when locations in horizontal or vertical space are used as reference tracking points in sign language agreement, how often are they used and how often are they omitted? And does this pattern differ for gestures (both co-language and silent gesture)? We agree that these criteria are essential no matter what type of instrument is measuring the output.

Campbell & Woll suggest that neuroimaging can be used to distinguish brain activation in signers watching the manual gesture system "tic-tac" used by bookies in the United Kingdom, compared to signers watching signed utterances. The superior temporal and inferior frontal sites implicating the perisylvian regions associated with language processing were activated only for signed utterances. They also highlight the importance of data from individuals with brain damage. They suggest that because aphasics with right hemisphere damage, who had no difficulty processing manual (linguistic) markers, had difficulty comprehending sentences that contained only a non-manual headshake marker of negation, the headshake might be more prosodic than linguistic in nature (but see earlier comments noting that prosody is in the realm of both gesture and language). Unfortunately, it will be a challenge to use imaging techniques to distinguish gesture from sign for forms that can be both linguistic and gestural.

Except for very young children, we know relatively little about the time course of gestural acquisition, either in typical or atypical development. As we said in the target article, we know that language+gesture combinations are a precursor to the acquisition of two-word combinations in clauses (i.e., subject verb clauses; Capirci et al. 1996; Goldin-Meadow & Butcher 2003) and in noun phrases (Cartmill et al. 2014), and we know that the use of iconicity has its own time course of acquisition (Namy et al. 2004). However, we do not have a foundation for the acquisition of gesture that is as extensive as what we know about the acquisition of spoken or signed language. **Marschik et al.** and **Eigsti & de Marchena** note that there are evaluative measures for atypical populations that take gesture into account, but there is much more that can be done along these lines to compare the acquisition of gesture in typically and atypically developing children. **Lakshmanan & Pilot** offer the theater and sequential bilingualism as other possible populations in which to explore the relation between language and gesture.

Homesign systems and emerging sign languages are also important populations that we hint at, and that **Motamedi et al.** and **Hall** point to explicitly in their commentaries. In certain ways, our own research on these populations has led us to the conclusion that we drew in our target article. We have both been deeply engaged in research on homesign and emerging sign languages, and we find is that it is not a smooth continuum from gesture to, in this case, sign language. The biggest break is between co-speech gesture, which is continuous and imagistic in form, and homesign (or silent gesture), which is discrete (see Goldin-Meadow et al. 1996).

But there are also a number of factors that may be needed to catalyze a homesign system to move toward becoming a full-fledged sign language (Brentari & Coppola 2013; Goldin-Meadow 2010): (1) being the primary means of communication, (2) having a linguistic community, and (3) having a language model to transmit to the next generation. First, the system may need to be used as the primary means of communication and thus bear the full burden of communication in order to take on linguistic structure (Goldin-Meadow et al. 1996). A lingua franca, such as Plains Indian Sign Language (Davis 2006) or co-speech gesture, will not suffice. Second, a linguistic community may be crucial so that individual users not only experience the system as conveyers of information, but also as receivers of information (Goldin-Meadow et al. 2015b). This situation typically involves a group of people who use the same system and interact on a regular basis. Third, a language model may be essential; namely, a system that is already in use by the linguistic community may be modified by newly entering members as they acquire and use the system (Coppola & Senghas 2010; Senghas 2003; Senghas & Coppola 2001). Populations with each of these factors have now been extensively studied and compared, providing evidence for a range of linguistic phenomena that do (and sometimes do not) depend on regular exposure to a language.

But it is only with a solid description of how gesture and language differ that we can come to understand how one type of communication system changes into another. The distinction between gesture and language that we call for in our target article is crucial for understanding how gesture becomes language.

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[The letters "a" and "r" before author's initials stand for target article and response references, respectively]

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