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SENSITIVITY TO VISUAL PROSODIC CUES IN SIGNERS AND NONSIGNERS

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Running Head: Prosodic Cues in Signers and Nonsigners

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ABSTRACT

Three studies are presented in this paper that address how nonsigners perceive the visual prosodic cues in a sign language. In Study 1, adult American nonsigners and users of American Sign Language (ASL) were compared on their sensitivity to the visual cues in ASL Intonational Phrases. In Study 2, hearing, nonsigning American infants were tested using the same stimuli used in Study 1 to see whether maturity, exposure to gesture, or exposure to sign language is necessary to demonstrate this type of sensitivity. Study 3 addresses nonsigners' and signers' strategies for segmenting Prosodic Words in a sign language. Adult participants from six language groups (3 spoken languages and 3 sign languages) were tested. The results of these three studies indicate that nonsigners have a high degree of sensitivity to sign language prosodic cues at the Intonational Phase level and the Prosodic Word level; these are attributed to modality or 'channel' effects of the visual signal. There are also some differences between signers' and nonsigners' sensitivity; these differences are attributed to language experience or language-particular constraints. This work is useful in understanding the gestural competence of nonsigners and the ways in which this type of competence may contribute to the grammaticalization of these properties in a sign language.

KEY WORDS: gesture, sign language, prosody, Intonational Phrase, Prosodic Word

INTRODUCTION

The studies presented in this paper address the ways in which nonsigners interpret visual prosody relative to their gestural system as well as the ways in which signers interpret the same visual prosody. By 'visual prosody' we mean the facial expressions and movements of the body, which serve a function in the co-speech gesture systems of hearing people, and which also serve both a prosodic and grammatical purpose in sign languages. This work may illuminate not only the cues relevant to the gestural system for nonsigners, but also the ways in which these may or may not overlap with cues in a linguistic system. There is growing evidence that hearing, nonsigners possess what might be called gestural competence, and gestures have been found to be integral to the interpretation of the spoken message on many levels in both adults and children. McNeill (1992) has argued that gestures are a part of linguistic representation, and in fact, speakers often perform gestures while on the phone when they have no overt value to the listener. McNeill describes various gestures types, one of which, beat gestures, serves a prosodic function in that they coincide with the rhythm of language (rhythm being influenced by all three aspects of prosody – pitch, length and loudness). In addition, beat gestures help a speaker to convey (and a listener to understand) shifts in various communicative functions. Other research has determined that gesture plays an important role in signaling utterance boundaries (Cassell, Nakano, Bickmore, Sidner & Rich, 2001) as well as informational content (Cassell & Thorisson, 1999; Kendon, 2004). Skilled lecturers even produce gestures which are correlated with the pitch accents in their phrases (Yasinnik, Renwick & Shattuck-Hufnagel, 2004), and McClave (1998) has suggested that there is often a coordination of direction for gesture and pitch, with rising pitch associated with upward gestures and the opposite for falling. In addition, with respect to facial gestures, nonsigners have been found to show a sensitivity to the use of facial expressions in perceiving the prominence of pitch accents (Krahmer & Swerts, 2007). In sum, gesture serves a prosodic function whose interweaving with spoken language prosody has only recently begun to be explored, but is clearly influential for both processing and production of speech.

Furthermore, gesture often proves useful in language learning contexts. For example, mothers often move objects in synchrony with their speech and move objects in an exaggerated way with their infants and toddlers (Brand, Baldwin, & Ashburn, 2002; Gogate, Bahrick, & Watson, 2000). This movement has implications for learning since toddlers learn words better when objects are moved in synchrony with the accompanying speech (Gogate & Bahrick, 2001). Lastly, the communicative intentions (pre-cursors to speech acts) of one-year old, nonsigning, toddlers at the one-word stage of language acquisition are better understood by caregivers when their gestures and speech cues coincide with one another in timing and content (Balog & Brentari, 2008). All of this work would then suggest that speakers also have a great deal of experience producing and perceiving gestures, and that spoken language users have a sense of how gestures function—with (and possibly without) speech.

One would not, however, expect sensitivity to production or perception of co-speech gesture to approach the scale of gestural competence found in users of a sign language. Given that sign languages use the visual/gestural modality to express every aspect of the grammar, signers show sensitivity to a wide range of cues marking prosodic constituents at every level in a way that would not likely be found in nonsigners (Allen, Wilbur & Schick, 1991; Boyes Braem, 1999; Brentari & Crossley, 2002; Malaia & Wilbur, 2009; Nespor & Sandler, 1999; Sandler & Lillo-Martin, 2006; Wilbur, 1994; Wilbur & Patschke, 1998). Evidence also points to clear differences between the two populations in the processing of gestures. Specifically, Pettito, Zatorre, Gauna, Nikelski, Doste & Evans (2000) demonstrate that for native signers (Deaf signers whose parents are also Deaf signers) the area of the brain associated with the processing of sound is activated by nonsense signs both in ASL and in Langue des Signes Quebecoise (LSQ). More specific to our work, neuroimaging studies of grammatical facial expressions show that they are left-lateralized in signers but not in nonsigners (McCullough, Emmorey & Sereno, 2005). Left-lateralization (as opposed to right-lateralization) would suggest that some non-manual cues expressed on the face are processed in a discrete fashion in signers but not in nonsigners, particularly those facial behaviors that express adverbial or morphosyntactic meaning. Non-manuals on the face have also been shown to be acquired in stages by signing children, contrasting with affective facial expressions (Reilly & Anderson, 2002). There is, however, individual variation in the production and perception of these cues in native signers that is less well understood; hence in any study in which nonsigners' performance is being compared with that of signers', signers must also be tested on the same task so that signers' variability in performance is clear.

There are several methodological advantages to using sign language stimuli, rather than other types of gestural stimuli, to accomplish our goal of exploring the processing of visual prosody. First, we know *a priori* that the sign language cues under study are a part of a grammatical (as opposed to a gestural) system. In a sign language there are clear phonotactic constraints and prosodic cues that can be identified, and this grammar can be seen as an 'end-state'—that is, if gesture is allowed to become a primary communication system over many generations (ASL is about 200 years old) this is what happens. Given that there are many populations that use gesture in many different ways and in many different contexts—in co-speech gesture (gestures used by hearing people while speaking), in home sign (the gesture systems of isolated deaf individuals who have little or no access to a signed or spoken language), and in young sign languages[1]—there is much to be learned by tracing these various populations' performance on tasks that involve such well-formedness constraints. It is unlikely that there would be an 'all-or-nothing' difference among these groups, so how does sensitivity to a grammar manifest itself in these different communicative contexts? Adding the intermediate populations would help map the landscape between nonsigners and signers more clearly, but the first step is to establish the endpoints for the signing and nonsigning groups for adults, move to infants, and then begin to understand the cross-linguistic and cross-cultural factors that might be also be involved. Second, by using sign language stimuli to test nonsigners we can tap into the specific nature of gestural competence. How skilled are nonsigners with gesture when asked to focus their energies on communicating via this medium alone with respect to specific properties of sign languages?[2] Our perceptual tasks do not involve the spoken language at all, so the speakers' (gesturers') attention in our studies is not divided between speech and gesture; therefore, we can tap into gestural competence unencumbered by speech. Third, by testing nonsigners using sign language stimuli we are given a glimpse into some of the phonetic pressures that might shape a sign language grammar; specifically what perceptual pressures might shape a sign language phonology. We assume that nonsigners do not possess a phonology for gestures; therefore, we

[1] One example of a young sign language is Nicaraguan Sign Language, which is between 30-40 years old (Kegl et al., 1999; Senghas & Coppola, 2001).

[2] Research on sign languages has begun to provide suggestions for greater in-depth analysis of gestures than those conducted to date (Wilbur & Malaia, 2008).

can expect that visual pressures related to the ease of perception will be the primary factors that govern nonsigners' responses.

The Intonational Phrase and Prosodic Word were chosen for our studies because the role of specific cues at these levels of prosodic structure are better understood in sign languages than other levels of prosodic structure. For example, blinks, pauses and lengthening are robust cues for Intonational Phrases crosslinguistically (Malaia & Wilbur, 2009; Nespor & Sandler, 1999; Wilbur, 1994, 2009; Tang et al., in press). Regarding the Prosodic Word, Brentari (1998) has shown that polymorphemic words, such as lexical compounds, conform diachronically to a constraint requiring one contrastive value for each major manual parameter—handshape, movement, and location.

One study has shown that adult nonsigners are able to perceive the presence of Intonational Phrase boundaries in British Sign Language (BSL) and Swedish Sign Language (SSL) in a reliable fashion (Fenlon, Denmark, Campbell & Woll, 2007). In this study, BSL signers and English speakers were asked to indicate the sentence boundaries in narrations of Aesop's fables in BSL and SSL. There was a significant correlation between the level of performance in deaf and hearing participants in SSL, the language that was unfamiliar to both the BSL signers and the nonsigners. In BSL there was only a one-way correlation; that is, sentence boundaries identified by signers in BSL were also identified by nonsigners, but not vice-versa. The authors conclude that nonsigners are using only superficial, visual cues to make their judgments, while signers use both phonetic cues and linguistic knowledge when available.

With regard to the cues marking Prosodic Word boundaries, there have been three studies to date, one of which is directly relevant to the work we will present here. Brentari (2006) is a precursor to the third experiment presented in this paper. In this study, Brentari found that when asked whether disyllabic nonsense strings were one or two signs, signers and nonsigners performed similarly across forms that were attested (possible) and unattested (impossible) forms in ASL. The one difference between the two groups occurred in the handshape parameter: the signers utilized this parameter much more to make word segmentation judgments than did the nonsigners. Brentari suggests that there is a difference in word segmentation strategies in signed and spoken languages due to nature of the signal and the resulting Prosodic Word-level phonotactics. In other words, modality effects are present because the structure of sign language is more simultaneous, while speech is more sequential.

Two other studies of word segmentation in a sign language (Orfanidou, in press a; in press b) used a 'word spotting' paradigm (Cutler & Norris, 1988; McQueen, 1996). In Orfanidou (in press a) the "possible word constraint" (PWC) was tested. The PWC is an algorithm that predicts that speakers (and signers) would try their best not to leave unparsed residue when segmenting strings into words (signs). Signers were tested with BSL stimuli and speakers were tested with comparable Dutch stimuli. For example, the PWC predicts that, regardless of modality, participants will parse the following phrase "Is sign like speech?" with 'sign' as the possible word in target position rather than 'sigh', leaving 'n' as a bit of unparsed residue. Studies showed that in the English nonsense forms, such as 'fapple', the real word 'apple' takes longer to recognize because 'f' is left as unparsable residue than when it is preceded by a possible word, such as in 'vuffapple' (Norris, McQueen, Cutler & Butterfield, 1997). Equivalent BSL 2-sign forms were constructed in which the first form was either a possible or impossible form and sometimes the second form was an attested sign. Signers and speakers show similar patterns of performance, hence the PWC produces no 'modality effect'. Orfanidou (in press b) analyzed the 'false alarms' from the study just mentioned; that is, an analysis of the nonsense fillers perceived as a word but which were, in fact, nonsense. There was an age of acquisition effect in the false alarms for the Movement parameter. This parameter created the most misperceptions for native signers and those that learned BSL in early childhood, while handshape was the most affected parameter in BSL signers that learned the language in adolescence.

These studies leave open many questions, not only with respect to when in development a sensitivity to these units occurs, but also with respect to the particular cues that speakers (gesturers) might use in finding both Intonational Phrase- and Prosodic Word-like units. Thus, the following questions motivate the studies discussed below: How do nonsigners interpret sign language prosodic cues at the Intonational Phrase and the Prosodic Word Level? How does the performance of nonsigners compare with that of signers? How much of this sensitivity is due to modality (factors of the 'channel'), experience with sign language or gesture, or language-particular factors?

EXPERIMENT 1: INTONATIONAL PHRASE CUES IN ADULTS

Following the rationale outlined in the Introduction, this first study addresses the following 2 questions: (1) Are nonsigners sensitive to visual-gestural prosodic cues marking ASL Intonational Phrases, and how are these cues weighted? (2) How does nonsigners' performance compare with that of adult, native signers' in terms of sensitivity and weighting?

Participants

Sixteen adults participated in this experiment. Eight were fluent Deaf signers with at least 20 years of ASL experience, and eight were hearing nonsigners. The Deaf participants were from the greater Chicago area (age 22-55). All considered ASL to be their primary language, were culturally Deaf (they were well-integrated into the Deaf Community) and had learned ASL before age 10. The eight nonsigners were undergraduate students at Purdue University (age 20-21) with no experience with ASL or any other sign language.

Stimuli

The stimuli were constructed so that both signers and nonsigners would be forced to rely primarily on visual prosodic cues to locate the prosodic unit edges. Each of the cues studied was carefully measured and controlled. Although prosodic units are often isomorphic with syntactic units, both in signed and spoken languages, this is not always the case; therefore, we adopt Pierrehumbert's (1980) approach to coding prosodic units and use prosodic cues to define prosodic units, independently of syntax (in contrast with a more syntactically-based strategy e.g., Selkirk, 1984).

In order to construct these stimuli, two female signers who are instructors of ASL and had learned ASL before age 7 were taped signing pairs of passages, such as the example pair in (1).

(1) Adult Familiarization and Test Clips[3]

a. ANIMAL TEND THEIR STRANGE. **SNAKE BIG STILL MOVE FAST CAN. ALWAYS** HAVE PLENTY EAT.

'Animals have strange characteristics. Big snakes still can move fast. [They] always have plenty to eat.'

b. YESTERDAY MORNING MY GARAGE I SAW **SNAKE BIG. STILL MOVE FAST CAN ALWAYS.** CHASED (X3) IT.

'Yesterday morning I saw a big snake in my garage.' [It] can still always move fast! [I] chased it all over.'

The signers were instructed to employ Infant Directed Signing (IDS) and their interlocutor was a hearing toddler of 16 months of age who had been exposed to baby signs for 6 months. We used IDS so that the same passages could be used in the infant study that follows. This is relevant since we know that in commensurate tasks in spoken language, words are learned better in infant directed rather than adult directed speech (e.g., Golinkoff & Alioto, 1995). In work comparing IDS and adult directed signing (ADS), it was found that infants attend better to IDS than ADS (Masataka, 2000). We also hoped that the signers would exaggerate their prosody thus making the task easier for signers and nonsigners alike. Although we expected the task to be easier with IDS than ADS, it was, nonetheless, assumed that adults would attend equally well to ADS or IDS.

[3] See http://www.cla.purdue.edu/slhs/research/labs/Brentari_Publication.html for video clips of these examples.

Each passage was signed by both signers; ten passages were used for this study. The longer passages were used in the Familiarization phase of the experiment. From these longer passages the shorter stimulus pairs were clipped, each having identical signs and identical syllable count, but with different Intonational Phrase constituency. An example stimulus pair is shown in bold in (1). These were the stimulus clips shown to participants during the Test phase of the experiment. For the pair in (1), for example, SNAKE BIG STILL MOVE FAST CAN ALWAYS was clipped from both passages. The participants were asked to attend to a pair of target signs from each stimulus passage. From each stimulus clip, two pairs of signs in each stimulus passage were targeted—one with an Intonational Phrase break and one without a break. These are underlined in (1). For example, from the pair of passages in (1), BIG STILL and CAN ALWAYS were the target pairs. Between BIG and STILL there is no break in (1a), but there is in (1b). Between CAN and ALWAYS there is a break in (1a), but none in (1b).

Each passage had two target sign pairs, and each pair was shown three times (10 passages x 2 signers x 2 target sign pairs x 3 repetitions of each pair = 120 items). Of the 120 items, 60 had breaks and 60 had no break. Prior to employing these passages in the experiment they were transcribed using ELAN. ELAN (EUDICO Linguistic Annotator) is a tool developed at the Max Planck Institute for Psycholinguistics, Nijmegen, specifically designed for the analysis of language, sign language, and gesture. ELAN allows you to create, edit, visualize and search annotations for video and audio data using time-aligned tier structures that allow the researcher to indicate the location and duration of each annotation. We transcribed the following five cues in the experimental stimuli since each one has been shown to be consistent, robust, and related to prosodic units in ASL. Our stimuli gave us an excellent opportunity to carefully examine the same signs in phrase-internal (Prosodic Word-final) and Intonational Phrase-final positions since we had tokens of the same signs in both positions. The following cues were measured.

Blinks Short blinks (inhibited, voluntary eye blinks) have been shown to correlate with the end of an Intonational Phrase (Wilbur, 1994 for ASL; Boyes Braem, 1999 for Swiss German Sign Language; Nespor & Sandler, 1999 for Israeli Sign Language). The coordination of blinks with the end of eyebrow raise is an additional indicator of the end of an Intonational Phrase (Wilbur, 1994; 2009). This cue was measured as either present or absent.

Lengthening Liddell (1978) noted that utterance final signs are marked by increased duration, known as pre-boundary lengthening. Perlmutter (1992) and Brentari (1998) proposed lengthening rules implemented by the signer as additional timing units (moras or segments, respectively) to account for this lengthening. Wilbur (1999) analyzed acceleration, velocity and duration, and was able to disambiguate the role that each plays in the prosody of ASL. She also determined that, from among these three movement cues, duration was the marker of phrase-final position. These findings have been confirmed experimentally (Wilbur, 2009) and with the technical assistance of motion capture equipment (Malaia & Wilbur, 2009). The duration of signs was measured in our stimuli from the complete formation of the initial handshape of the sign to the time when the final handshape begins to deteriorate. Signs at Intonational Phrase boundaries were consistently at least 1.5 times their counterparts in the non-boundary position.

Holds Hold time refers to the period of time when the hand is kept in its particular shape and position, in this case, at the end of a sign. The behavior of hold-time and pause-time in Intonational Phrases can be traced back to the lexical (underlying) representation of signs. For our purposes, lexical signs were best divided into those that exhibit phrase-internal holds for phonological reasons, such as contact with body, and those that do not. Signs with a non-boundary hold, which can be as brief at 66 ms (2 frames; Liddell, 1984), lengthened at an Intonational Phrase break to at least 5 frames (or 165 ms).[4]

Pauses A pause is a composite cue that includes the hold at the end of the sign as well as the transition movement between one sign and the next. Grosjean & Lane (1977) analyzed the pauses present in ASL by measuring pause durations, and then averaging them by subject. The pause data were used to divide the passage into sentences and the sentences into clusters. They observed that the distribution of pauses was not random. Pauses appeared to group signs together in a hierarchical manner: longest pauses were placed between two sentences, whereas shorter pauses occurred within those sentences. Their results provided evidence for the internal structure of sentences in ASL. Brentari, Poizner, & Kegl (1995) also found that normal signers have a hierarchy of pauses. In their study, this systematic pause variation in control signers was contrasted with that of signers who had Parkinson's Disease; the latter group displayed a flattening of differences in pause duration among prosodic constituents. This measure was important for the signs that did not exhibit phrase-internal holds, since such signs have a much shorter hold or no hold at all at Intonational Phrase boundaries. Instead, the transitional movement from one sign to the next was lengthened. In our stimuli, this composite cue was at least 5 frames in duration (165 ms). This is consistent with those found in Grosjean (1977),

[4] Perlmutter (1992) and Brentari (1998) discuss the predictable nature of holds in Prosodic Words and Phonological Phrases, but their analysis involves abstract timing units (either segments or moras), which do not translate directly into absolute time.

Brentari et al. (1995), and Wilbur (2009)—150-300 ms. The mean pause length in our corpus, shown in Table 1, is 770 ms., which may be due to the exaggerated cues of IDS.

Dropping the hands This occurs when the signer deviates from the direct trajectory between the end of the preceding sign and the beginning of the next sign during the transitional movement. When a signer is seated, as our signers were, sometimes the hands drop to the lap or to neutral position, but sometimes the dropping of the hands is less obvious. This is an Intonational Phrase boundary cue recently found in interpreter signing (Nicodemus & Smith, 2005). This cue was measured as either present or absent.

The distribution of the five cues listed above is summarized in Table 1. We expected they would be exaggerated since IDS tends to exaggerate prosodic cues. The only difference found between our stimuli and traditional ADS stimuli was with respect to eye blinks. In phrase-final position we found either an eye blink or eye widening, instead of the cue of blinks alone; hence our percentage of items with blinks is less than might be expected in ADS. We suggest that widening of the eyes may be an IDS-specific marker whose purpose seems to be to continue to engage the infant's attention during the phrase break.

[TABLE 1 HERE]

Procedure

The task included a Familiarization Phase and a Test Phase. The experiment instructions, as well as the Familiarization and Test phases were presented on a Macintosh computer with a 19-inch screen. In the Familiarization Phase subjects watched all 10 of the full (longer) passages once. In this phase, both groups were familiarized to the signing style of the models. In addition, for the nonsigning participants, this phase helped to familiarize them with the nature of signing, and for the signing participants, it helped to familiarize them with the specific nature of the stimuli, since items that contained pieces of two Intonational Phrases might look somewhat unnatural to signers. In the Test Phase short passages (excerpted from the longer passages) appeared on the screen one at a time. For each item, there was a pencil and paper response form on which a still frame for each of the target signs along with labels for their meanings was shown, and two questions: "Is there a sentence break between these two signs (yes/no)?", and "How confident are you in your response (0-10)?" Participants were instructed to look at the page on the response form corresponding to the stimulus video clip. Once they knew which were the target signs for that item, participants watched the stimulus item; they then responded to the two questions. They were given unlimited time for the task. A sample page from the response form is given in Figure 1.

[FIGURE 1 HERE]

Results

There were four possible outcomes: hit (a break was present and it was correctly identified), correct rejection (no break present and it was correctly identified), false alarm (no break present but it was incorrectly identified as a break), and miss (a break present but it was incorrectly identified as a non-break).

Accuracy On hits, signers were more accurate (signers 86% correct; Standard Deviation (SD) = 9) than nonsigners (76% correct; SD = 4). On correct rejections, nonsigners were more accurate (signers: 76.5% correct; SD = 15; nonsigners: 85% correct; SD = 10). However, when a d-prime statistical test for revealing bias was applied to the results, there was no main effect of group for accuracy.[5]

Cue Weighting/Stimuli with Breaks The logistic regression model was implemented. This procedure yielded a series of results, including the Wald Chi-square test, which is the most relevant for this research. The Wald Chi-square tests the statistical significance of each independent variable. Pauses were significant in predicting where both signers and nonsigners would identify a break. However for nonsigners, Drop-hands and Hold were also significant in predicting breaks (see Table 2).

[TABLE 2 HERE]

Stimuli without Breaks The same cue—namely, Holds—was most predictive on the stimuli without breaks for both signers and nonsigners (see Table 3).

[TABLE 3 HERE]

Discussion

Signers and nonsigners were equally accurate in their responses; both groups had a high degree of accuracy in identifying breaks and non-breaks. One might wonder if the fixed-choice nature of the task influenced the outcome; however given the results of Fenlon et al. (2007), which also showed that nonsigners are capable of identifying the location of sentence breaks in signed

[5] See Keating (2005) for background on the use of the d-prime test for this purpose.

narratives, we can conclude that the high performance of nonsigners is not due solely to the nature of the task. With regard to cue weighting we can see that signers focus more closely on a single cue (i.e., pause) in order to make their judgments for stimuli with breaks, while nonsigners used a broader range of cues to make these judgments. For stimuli without breaks both groups behaved similarly, using a hold (or lack thereof) to make these judgments. It is possible that nonsigners responded in a similar way to signers because the nonsigners already have a phonology in place (albeit in a spoken language), or because they have a lifetime of experience with gesture. In order to further explore this question we turn to a population who have likely not yet become fully attuned to their language-specific phonology or to gesture, namely infants.

EXPERIMENT 2: INTONATIONAL PHRASE CUES IN INFANTS

A natural follow-up question concerning the type of sensitivity to visual prosodic cues just described in Experiment 1 is whether this sensitivity comes with the experience of using and perceiving gesture throughout life or whether infants possess this ability prior to extensive gestural experience. In this experiment, two groups of 9-month-old hearing infants from English speaking homes were tested using a visual fixation procedure. Launer (1982), Meier (1982), Masataka (2000), and Meier, Pizer & Shaw (2008) have discussed IDS, but as yet no research has been carried out concerning the prosodic bootstrapping of sign languages. Yet, we know that hearing infants are sensitive to and discriminate among movements in ASL (e.g., Baker, Golinkoff, & Petitto, 2006; Carroll & Gibson, 1986; Schley, 1991). One key aim of this paper is to test the hypothesis that spoken and signed language share a common linguistic mechanism. The question of interest is: Is there a language general prosodic foundation for bootstrapping? Or rather: Is there a language acquisition device for bootstrapping syntactic units from prosodic units and if so, does this device traverse all languages from different families and even from different modalities? Preliminary evidence suggests that it may: The movements of IDS signs are larger and show increased lengthening over adult-directed signs (Meier et al., 2008) and hearing infants have been shown to pay more attention to IDS than ADS (Masataka, 2000). This indicates a sensitivity to suprasegmental cues in signs suggesting a similar time course for tuning suprasegmental cues in both speech and sign.

Some recent work has explored young infants' sensitivity to segmental cues in ASL. In this work, Baker et al. (2006) used a visual fixation procedure and found that hearing 4-month-old infants are sensitive to and can detect subtle differences in the segmental cue of Handshape (although they lose this ability by 14 months). In our study we seek to discover whether this ability present in young infants extends to suprasegmental/prosodic cues as well.

Participants

Twenty-four infants were included in the study. Infants were recruited from monolingual English-speaking households in the Midwest. Although infants at 9 months of age have been shown to have a declining sensitivity to non-native prosodic units in spoken language (e.g., Johnson & Seidl, 2008b; Jusczyk, 2003), it is likely that 9-month-olds are still within a modality-neutral window of development. This is because their segmental inventory is not yet fully formed (e.g., Werker & Tees, 1984) and because these babies easily learn signs from their caregivers and seem to be sensitive to a correspondence between action sequences and prosody (Brand & Tapscott, 2007).

We chose this age because we inferred from previous work that infants would be able to perceive the more subtle cues present in our videotaped sign language stimuli by 9 months of age. Vision is relatively poor in newborns and improves substantially by 9 months. Both the ability to interpret 3-D objects (e.g., Kellman & Spelke, 1983 and the ability to detect subtle actions in gestural stimuli (Saylor, Baldwin, Baird, & LaBounty, 2007) have been demonstrated to be present at 9 months of age. Although others have found that infants at 4 months are able to perceive large differences in signs (Carroll & Gibson, 1986), we felt that we needed evidence of the two specific requisite skills just mentioned in order to insure that visual skill would not be a confounding factor in our study.

Stimuli

One pair of passages from the set recorded for Experiment 1 was used here. As in Experiment 1 each passage contained two shorter passages consisting of identical signs with different prosodic properties; one passage contained a break and one passage did not. As in the previous experiment, there was a Familiarization phase and a Test phase, but with the infants the shorter passages comprised the Familiarization phase (2) and Test phase consisted of the longer passages (3). (The reasons for this will be explained in the Procedures.)

(2) Familiarization passages[6]

a. GROUP A — expected to watch passage (3b) for a longer time

    i. GREEN VEGETABLES RABBITS EAT THEM

[6] See http://www.cla.purdue.edu/slhs/research/labs/Brentari_Publication.html for video clips of these examples.

ii. GREEN VEGETABLES] [RABBITS EAT THEM

b. GROUP B — expected to watch passage (3a) for a longer time

i. RABBITS EAT THEM TASTE SO GOOD

ii. RABBITS EAT THEM] [TASTE SO GOOD

(3) Test Passages

a. FATHER'S GARDEN HAS MANY **GREEN VEGETABLES. RABBITS EAT THEM TASTE-SO-GOOD**. WOW! 'Father's garden has many green vegetables. When rabbits eat them, [they] taste so good. Wow!'

b. FOOD WITH COLOR MANY ANIMALS PREFER. **GREEN VEGETABLES RABBITS EAT THEM. TASTE-SO-GOOD**.WOW 'Many animals prefer food with color. As for green vegetables, rabbits eat them. [They]taste so good. Wow!

Procedure

The design was based on Nazzi, et al. (2000) and Seidl (2007), but, instead of using the Headturn Preference procedure, we used a visual fixation procedure. The infants were randomly assigned to one of two different familiarization groups—Group A and Group B. In commensurate tasks with speech, infants at 9 months have been shown to prefer, or look longer at, material with which they have been familiarized, and in particular, to look longer at phrases to which they are already familiar (Soderstrom, Seidl, Kemler Nelson, & Jusczyk, 2003). In this experiment each group was familiarized with two different versions of one sequence of signs—one version without a break (an Intonational Phrase) and one with a break. Group A was familiarized on (2a);

Group B was familiarized on (2b). There were 4 familiarization trials in which the structures without a break (an entire Intonational Phrase) or with a break (pieces of two Intonational Phrases) were repeated 16 times with a maximum of 40 seconds looking time to each stimulus. In between each repetition there was a blank lavender screen, which appeared for .5 seconds. In between each of these trials there was yellow screen with a flashing light and a beeping sound synchronized to the light in order to get the infant's attention before the next trial began.

After familiarization for a minimum of 26 s to the break and non-break sequence of signs (viewing each sequence around 10 times), the infants were tested with 4 blocks of exposure to the 2 longer passages that contained the familiarized units (both of the passages in (3)). The Test phase consisted of 8 trials of the longer signed passages presented in one of 2 pseudo-randomized orders with a maximum looking time of 30 seconds for each trial. On each trial the passage could appear a maximum of 3 times. Once again a .5 second lavender screen separated repetitions of the passages and in between trials the attention getter was shown. If infants are sensitive to the visual cues of a sign language each group should prefer, or look longer at, the passage that contained the familiarized, intact prosodic unit (the form without a break) and not the one with a break, as has been found in commensurate studies with spoken language (Nazzi et al., 2000). Thus, Group A was expected to watch passage (3b) longer, and Group B was expected to watch passage (3a) longer.

The Habit 2000 program (a computer program produced by Leslie Cohen's laboratory at the University of Texas at Austin) was used to order stimuli presentation. The program was run on a Macintosh G4 computer and projected on a large 56-inch video screen from an LCD projector.

The video presented did not utilize the whole screen but instead filled an area of approximately 20 x 14 inches.

Upon arrival at the lab, parents and their infants were escorted to a playroom. There, the experimenter explained the study and gave the parent a consent form to sign. The infant and the parent were then led to a testing room where the infant was seated in the center of her parent's lap approximately 2 feet away from the large video screen. The caregiver wore blackened sunglasses. The presentation of the trials was controlled by an experimenter hidden behind a black curtain in the same room as the parent and infant. Looking times during each trial were video taped by a camera out of the infant's sight. For each subject, durations of looking time to the test stimuli were coded offline, frame-by-frame. During coding, the coder was blind to the order of the test trials and the group assignment (Group A or Group B).

Results

Looking time was measured in frames and then converted to seconds. Looking times were compared on test passages that were intact Intonational Phrases and those that were not. Eighteen of 24 infants looked longer at the familiarized intact Intonational Phrase (the passage without the break) than at the familiarized passage that was not an Intonational Phrase. The average looking time to the stimuli that were intact Intonational Phrases was 14.7 seconds (Standard Error (SE) = 1.22 seconds). For stimuli that were not intact Intonational Phrases, the average looking time was 12 seconds (SE = 1.24 seconds). In Group A average looking time to the Intonational Phrase stimuli was 15.02 seconds (SE = 1.92 seconds) and 13.9 seconds (SE = 1.64 seconds) to those that were not. In Group B average looking time to Intonational Phrase stimuli was 13.9 seconds (SE = 1.59 seconds) and 9.77 seconds (SE = 1.72 seconds) to those that were not. An ANOVA with Group (A and B) x Looking time (IP and Non-IP) revealed a main effect for Looking time ($F(1, 22) = 4.39$, $p < .048$), but no main effect for Group ($F(1, 22) = 1.59$). Thus, infants looked significantly longer at the Intonational Phrase versions in both groups. A Cohen's *d* revealed a medium/moderate effect size of $d = .62$.

Discussion

These results suggest that young infants may be sensitive to prosodic cues in an unfamiliar language and modality. Previous work for spoken languages shows that at 6 months infants are sensitive to pitch, volume and duration as cues marking Intonational Phrases, and that by 9 months infants are beginning to lose sensitivity to cues that are not important for their native language (Johnson & Seidl, 2008b). The work in this experiment, however, suggests that a sensitivity to the cues relevant to sign languages that is not language-specific may persist until infants are 9 months old when infants are not in a signing environment. We do not know why this would be, but it may be that that lack of a competing grammatical system in this modality keeps language specialization open for this modality at a time at which it closes in the other modality. This hypothesis, of course, leads to many interesting and testable alternatives.

Ideally, however, we would like to know whether the ability to segment these units in ASL, or any other sign language for that matter, is something unique to language or whether it is a general cognitive ability. Recent work by Baldwin and colleagues (e.g., Baldwin et al., 2001) suggests a similar parsing ability to units and non-units in the domain of actions. In these studies infants viewed actions segmented by pauses in the middle of an action or at the end of an action. Their findings indicate that 10-11-month-old infants are able to differentiate between actions with pauses in the middle of the action and actions with pauses at the completion point of an action. It may seem at first glance that our findings for segmentation of the linguistic units in ASL are very similar to these non-linguistic findings; however, it may be that actions, gestures and signs operate along a continuum such that at some point real linguistic units (signs) will not share commonalities of parsing with these other kinds of sequences. Only through examining and comparing processing of all three of these sequence types can we eventually answer this question. These data only provide a humble beginning to such an inquiry. To summarize the results of both experiments, adults with gesture experience, as well as infants prior to extensive experience with gesture, are sensitive to cues used in sign languages marking Intonational Phrases.

EXPERIMENT 3: WORD SEGMENTATION

We have just provided evidence that hearing individuals are sensitive to the prosodic cues used to mark Intonational Phrase cues in sign languages. What about smaller units such as the Prosodic Word? We address this question using a word segmentation task. Cutler & Norris (1988), Cutler & Butterfield (1992), Johnson & Jusczyk (2001), Johnson & Seidl (2008a), Jusczyk, Cutler & Redanz (1993), Jusczyk, Hohne & Bauman (1999) and Suomi, McQueen & Cutler (1997) all provide seminal work on word segmentation for spoken language in adults and infants. Suomi et al. (1997), Johnson and Jusczyk (2001), Johnson and Seidl (2008a), and Jusczyk et al. (1999) are particularly relevant because they employ cue conflict, pitting segmental cues (e.g., allophonic distributional cues [nait^{ʔ}reit] 'night rate' vs. [nait^{h}reit] 'nitrate'), against prosodic cues (foot structure 'con.**flict**' vs. '**con**.flict'), as well as domain cues, such as vowel or nasal harmony. They show that when put in conflict, speakers depend more on prosodic cues than either segmental or domain cues.

In this final experiment, our experimental design is based on cue conflict to test word segmentation strategies in signers and nonsigners for segmenting signed strings into one or two words. In this experiment we ask: To what extent are the word segmentation strategies used by signers and nonsigners the same when segmenting signs? What aspects of performance are due to modality effects, experience with a sign language, and/or language-specific constraints?

Participants

Six groups of adult subjects from the USA, Croatia and Austria participated in this study; three were Deaf and three were hearing, sign-naïve groups (Table 4). The signers were all culturally Deaf (they were well-integrated into the Deaf Community) and had all been signing for at least 20 years. The nonsigners were from the same urban areas as the signers in each country and in the same age group (between 20-55 years of age).

[TABLE 4 HERE]

Stimuli

The stimuli consisted of 168 nonsense signs—48 included combinations of parameters attested in real ASL signs (possible monomorphemic forms and lexical compounds) and 120 were combinations unattested in ASL monomorphemic forms or lexical compounds ('impossible'). The stimuli were composed of counterbalanced sequential combinations of movement (M), handshape (HS), and place of articulation (POA) in order to create cue conflict. There are 5 HS conditions, 2 POA conditions, and 6 M conditions. This resulted in 28 cells (two are impossible to construct), in which HS, POA, and M cues are placed in conflict with each other to test which parameters are the most predictive in making word segmentation decisions in each group of participants. Our design allows us to determine the relative strength of each type of cue with respect to each other as well as the relative effects of different forms within each of these cue types.

Handshapes are separated into unmarked (HSu) and marked (HSm) groups: HSu includes 'B', 'A', 'S', '1', and '5', based on Battison (1978) and Eccarius & Brentari (2007); and HSm includes all other HSs. There are five HS conditions in the stimuli, four of which are attested in ASL monomorphemic signs and lexical compounds ('possible') and one condition that is unattested in this context ('impossible'). The possible conditions are (1) just one HS or (2) a sequence of two HS which share the same set of selected fingers and are related by an aperture change ([open] <=> [closed]). Attested lexical compounds in ASL also allow sequences of (3) two HSu (i.e. the index or all fingers) and (4) one HSu and one HSm. There are no attested monomorphemic signs or lexical compounds with (5) two HSm. It is predicted that possible handshape sequences will elicit responses of 1 (meaning, one acceptable sign) and those with impossible sequences will elicit responses of 2 (meaning, the stimulus cannot be one acceptable sign). The conditions, the markedness of their HSs, a description of the HS sequence, and the predicted response (number of signs) are given in Table 5.

[TABLE 5 HERE]

There are two POA conditions: sequences with one POA or sequences of two different POAs (Table 6). The forms with two POAs do not occur in monomorphemic ASL signs but may occur in lexical compounds. The choices of POA came from the set of major body regions (head, torso, H2, arm), and the three-dimensional planes (horizontal, vertical, and midsagital).

[TABLE 6 HERE]

There were six M conditions, divided again into those sequences that are attested in monomorphemic signs and lexical compounds ('possible') and those that are not attested in this context ('impossible'); see Table 7. The sequences in two of the conditions are permissible in monomorphemic signs: (1) those with one movement and (2) those with two movements when the second is a repetition of the first movement. The remaining four M conditions contained 108 items containing sequences that are not attested in either monomorphemic signs or lexical compounds. These conditions include sequences of: (3) non-permissible *local movements* (e.g., combinations of HS changes and orientation changes); (4) two *path movements* (e.g. straight+arc or circle+circle with the second circle going in the opposing direction); (5) a path movement and a handshape change; and (6) a path movement and an orientation change.[7]

[TABLE 7 HERE]

[7] Let us emphasize that these are sequential combinations of parameter values. Simultaneous combinations of handshape+orientation change, path+handshape change, and path+orientation change do occur.

The overall organization of the stimuli is depicted in Table 8. By putting cues in conflict in this way, we can directly evaluate the word segmentation factors employed by the groups.[8]

[TABLE 8 HERE]

Procedure

Participants were asked to watch video clips of signs and to click one of two boxes to answer the question: '1 sign' or '2 signs' (Figure 2).

[FIGURE 2 HERE]

The stimuli were presented to the participants on a computer screen in four blocks with rest breaks between blocks. Presentation blocks were rotated such that the first subject started with block 1, the second started with block 2, and so on, returning to block 1 for the fifth subject and repeating the rotation as needed until all subjects were run.

Results

Because our data are non-continuous (viewers respond ‘1’ or ‘2’), we used binary logistic regression instead of traditional ANOVAs. Regression tells us which factors are important and gives us chi-square results, for which we report the Wald statistic and its significance level. We

[8]See http://www.cla.purdue.edu/slhs/research/labs/Brentari_Publication.html for a sample video stimulus items.

will report the results for Phonological Parameters (HS, POA, and M), Modality (signer, nonsigner), and Language Group (German, ÖGS, Croatian, HZJ, ASL, and English). The interactions will then be reported, concentrating on the details of one condition in particular, HS Condition 1 (HSu), which provides further insight into the strategies used to decide word segmentation.

Phonological Parameters Table 9 shows that HS and M are main effects, and that all two-way interactions are significant; that is, relative strengths of each cue, HS, POA, or M, are affected by what other cues might be in the sign with it.

[TABLE 9 HERE]

Modality There was no significant main effect of Language Modality (df = 1, Wald = .074, p = .786). Both groups, Signers and Nonsigners, used the same overall strategies: 1 value = 1 word. Brentari (2006) reported no difference between signers (ASL) and nonsigners (English speakers). In this study, we extend those results to two additional groups of signers (HZJ and ÖGS) and two additional groups of nonsigners (Croatian and Austrian Groups).

Language Group The data were also analyzed using language group as a factor (ASL, English, HZJ, Croatian, ÖGS, Austrian German), and this factor had a significant effect (df = 5, Wald = 76.143, $p < .0001$). Post-hoc analysis revealed that (1) the responses of the ASL group differed more from those of the European spoken language groups (Croatian, Austrian German) than the responses from the spoken English group, and they did not differ from HZJ or ÖGS groups; (2)

the responses of the English group diverged from all the European groups (HZJ, ÖGS, Croatian, Austrian German); and (3) there were no significant differences among the European groups.

Interactions Modality x M revealed no interaction. There was, however, an interaction of Modality x HS, indicating that signers made significantly greater use of HS information than did the nonsigners (df = 4, Wald = 13.480, p = .009). We will return to the HS and POA in the Section below specifically on HS condition 1.

Using Language Group instead of Modality, we continue to find no interaction with M (df = 25, Wald = 22.887, p = 0.584), and we continue to find an interaction with HS; that is, sensitivity to HS, but not M, is dependent on the Language Group among sign languages too, not just between signers and nonsigners (df = 20, Wald = 42.636, p = .002). POA also becomes important in the HS condition 1, discussed below.

To confirm this sensitivity, we employed the measure of d-prime (d'), which is a statistical test that allowed us to recognize and control for irrelevant response patterns, such as always saying '1 sign' regardless of the stimuli (Keating, 2005). It is calculated from the mean difference of the Z-scores of the Hits (e.g. the predicted value of the response was '1 sign', and the actual response was '1 sign') minus the False Alarms (the predicted value of the response was '2 signs' and the response was '1 sign') (Table 10). A value of 1.0 for d' includes about 69% of all cases.

[TABLE 10 HERE]

Looking first at the sensitivity differences between the Signing and Spoken Modality group, we can see that (1) overall sensitivity for the nonsigners was substantially below that of signers, and (2) HS was most important for the signers and least important for the nonsigners (Figure 3). Comparing the three signing groups (Languages 1, 3, and 5), the HSs used in the stimuli, which were taken from ASL, were most relevant to the ASL signers and less relevant to the other two signing groups, although more relevant to the ÖGS signers than to the HZJ signers. This suggests that the HS inventories and constraints in these two sign languages vary to differing extents from that of ASL. In those cases where HS might be the only available cue on which to base a decision, the HSs were not as useful to non-ASL signers as they were to ASL signers. The POA and M sensitivities indicate that the Prosodic Word level constraints of HZJ and ÖGS also differ from those of ASL.

[FIGURE 3 HERE]

Figure 4 shows the mean percentage of responses of '1 sign' vs. '2 signs'; the largest difference between signers and nonsigners is in HS condition 1 (circled). For these items, on the basis of HS alone, subjects should respond ‘1 sign’ to the question of whether the stimulus is one sign or two; however, each stimulus also contains at least one POA and at least one M. The difference between this condition and all others is significant (df = 1, Wald = 9.312, $p = 0.002$). Thus we will discuss HS condition 1 in greater detail than the others.

[FIGURE 4 HERE]

HS Condition 1 Exploring this condition further reveals interesting patterns of interaction between phonological parameters and subject groups. In HS condition 1, the stimuli contain a single HS from the inventory of ASL. As before, signers and nonsigners alike were sensitive to Movement in this condition, as elsewhere. The second observation is that decisions in HS condition 1 are affected differently by POA for signers and nonsigners, and interestingly, also among the signer groups. ASL signers were sensitive to HS regardless of whether the stimuli contained one POA or two. HZJ signers were not sensitive to HS when the stimuli had only one POA, but were sensitive when the stimuli had two POAs. In contrast, ÖGS signers were sensitive to HS when the stimuli had only one POA, but not when it had two POAs. For nonsigners, if the stimuli contained only one POA, their responses were sensitive to HS; that is, they paid attention to whether there was more than one HS. However, when the stimuli contained two POA, nonsigners were not sensitive to HS (see Table 11).

[TABLE 11 HERE]

Discussion

With regard to the similarity of word segmentation strategies used by signers and nonsigners, our results indicate no differences between signers and nonsigners overall, resulting from the same treatment of Movement by both groups. We would therefore conclude that this is due to a modality effect for Movement; that is, something about the visual nature of Movement within the signed signal make nonsigners and signers respond in the same way. Our results indicate that signers are more sensitive than nonsigners to simultaneous information in the signal overall. We would argue that this is due to language experience with a sign language. With regard to language group, there is a clear difference among the six language groups in the use of POA and

HS. The use of POA varied among signed and spoken language groups. English and Austrian German speakers showed almost no sensitivity to POA while Croatian speakers had more, perhaps this difference is due to a cultural difference in the use of gesture, but until the gesture systems of these cultures are better understood this is only conjecture.

There was also a difference between HZJ and ÖGS signing groups with respect to how POA values affected their decisions in the HS conditions. With regard to language-specific differences, signers will use the rules of their sign language for the segmentation task, even in an unknown sign language, much in the same way that speakers do when listening to an unfamiliar spoken language. The ASL signers were essentially dealing with the phonemic inventory of their own language while making decisions about Prosodic Word level constraints on the sequential combinations present in our stimuli. In contrast, the HZJ and ÖGS signers were dealing with unfamiliar phonemic inventories and Prosodic Word level constraints. The stimuli may have contained HS, POA and M that are not phonemic in either HZJ or ÖGS, and the Prosodic Word level constraints for these three sign languages may be different. For example, some of the stimuli that would clearly be two separate signs in HZJ or ÖGS might be allowable single signs in ASL, or vice versa. The use of language-particular constraints is also revealed by the different decision patterns for HZJ and ÖGS, i.e., their differential sensitivity to HS in the two POA conditions. HZJ signers were not sensitive to HS when the stimuli had only one POA, but were sensitive when there were two POAs. In contrast, ÖGS signers were sensitive to HS when the stimuli had only one POA, but not when it had two POAs. If it were merely a matter of experience with a sign language, we would expect the HZJ signers and the ÖGS signers to behave in a similar pattern rather than the contrasting pattern that was observed here.

It is surprising that the ASL signers did not use the language-particular constraints of ASL compounding to judge HS conditions 3 and 4 as '1 sign' and condition 5 as '2 signs.' HS conditions 3 and 4 are sequences attested in lexical compounds and those in HS condition 5 are not. Perhaps word segmentation judgments are more conservative in a controlled task or in a task of nonsense forms, where meanings cannot be inferred. It is unknown whether HZJ and ÖGS have lexical compounding, and if so, what the rules of compounding might be. This might be pursued in future work by changing the task to elicit relative judgments to members of sign pairs, or to include a question in the task explicitly related to compounds.

GENERAL DISCUSSION AND CONCLUSIONS

These results, taken together, support an explanation of sign language phonology that allows for the possibility that there some elements which display a continuity between gesture and sign languages, while other elements, not used in the same way in the two systems, show a discontinuity. In large prosodic units, pauses and holds show continuity of use identifying the breaks and nonbreaks, and in smaller, word-sized units, movements are used similarly in sign and gesture. Handshape and Place of Articulation, in contrast, have a different degree of sensitivity for signers and gesturers in making word segmentation judgments, and these parameters may even be employed in language-specific ways among sign languages. By recognizing which properties show continuity and discontinuity between sign and gesture, we are able to formulate more precise hypotheses as we proceed to study such properties in homesigners and users of young sign languages. We would expect that pauses and holds would be important in homesign and young sign languages as well, and we also might expect a sensitivity to handshape to signify an important shift from a gesture system to a sign language.

By studying the common behavior patterns of signers and nonsigners, the results of the experiments here have also provided specific properties, grounded in perception, that help to shape the phonological system in sign languages. In Intonational Phrase units, both groups depend primarily on pauses to perceive breaks and lack of holds at the end of signs to perceive non-breaks. With respect to Prosodic Words, the constraint utilized by sign languages which changes compounds over time to a form with 1 contrastive value in each parameter of HS, M and POA (Brentari 1998) appears to be motivated, at least in part, by ease of perception. Both groups are sensitive to changes within a parameter from one value to another in making word segmentation judgments (1 value = 1 word), particularly in the case of Movement. These processes may also be influenced by cognitive, and ultimately cultural (in nonsigners) or language-specific factors, as the results from Experiment 3 demonstrate. Finally, this work also taps into what we are calling gestural competence. What we see in gesturers is that there is selective sensitivity to some cues over others. Hence, even if gesturers do not componentialize gesture in production, as McNeill (1992) argues, in perception gesturers show selective sensitivity to specific properties of the signal that may be grounded in visual salience. While speaking, nonsigners are occupied by vocal communication, but if asked to concentrate on the gestural medium, they can tap into some skills that form a basis of those that are built upon, expanded, and ultimately grammaticalized in sign languages.

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Table 1.

Distribution of cues in the stimuli used in the experiment

	Between clause	Within clause
Eye blinks	70%	0%
Duration	mean 1100 ms	mean 730 ms
hold	mean 400 ms	mean 66 ms
pause	mean 780 ms	mean 90 ms
Drop hands	70%	0%

Table 2. Signers and Nonsigners Cue Weighting on Stimuli with Breaks

Effect	Signers		Non-signers	
	Wald Chi-Square	P	Wald Chi-Square	P
Pause	6.446	*0.011	25.035	*<.0001
Blink	2.334	0.127	2.425	0.119
Length	0.966	0.326	0.613	0.434
Drop-hands	0.617	0.432	4.779	*0.029
Hold	0.199	0.656	5.917	*0.015

Table 3. Signers and Nonsigners Cue Weighting on Stimuli without Breaks

Effect	Signers		Non-signers	
	Wald Chi-Square	P	Wald Chi-Square	P
Hold	28.903	*<.0001	12.727	*< 0.0004
blink	2.808	0.094	2.654	0.103
Drop-hands	2.657	0.103	0.856	0.355
Pause	2.261	0.133	0.606	0.872
Length	0.413	0.520	0.026	0.437

Table 4. Participating Groups

Groups & Language	USA	(N)	Croatia	(N)	Austria	(N)
Deaf signers	ASL	13	HZJ	10	ÖGS	10
Sign-naïve hearing speakers	English	13	Croatian	10	Austrian German	10

Table 5. Handshape Conditions

Condition	HS Markedness	HS in stimulus	Predicted response
1	U	1 HS (no aperture change)	1; stem
2	U	1 HS (+aperture change)	1; stem
3	U + U	2 HSu	1; lexical compound
4	U + M	1 HSu+1 HSm	1; lexical compound
5	M + M	2 HSm	2; phrasal forms

Table 6. Place of Articulation conditions

Condition	POA in stimulus	Predicted Response
1	1 POA	1; stem
2	2 POAs	1; compound

Table 7. Movement Conditions

Condition	M Permissibility	M in stimulus	Predicted Response
1	1 grammatical M	M	1
2	2 grammatical Ms	M + M	1
3	Ungrammatical local Ms	Local M1 + local M2	2
4	Ungrammatical path Ms	Path M1 + path M2	2
5	Ungrammatical path+HS change	Path + HS change	2
6	Ungrammatical path+orientation change	Path + Orientation change	2

Table 8. Distribution of items in stimulus set Movement Conditions are. Grey cells indicate physically impossible forms. ('Δ'= 'change')

			MOVEMENT					
			1	repetition	1or+1hsΔ	2path	1path+1hsΔ	1path+1orΔ
HANDSHAPE	1	POA(1)	3	3	0	3	0	3
		POA(2)	3	3	0	3	0	3
	2-apΔ	POA(1)	3	3	3	3	3	3
		POA(2)	3	3	3	3	3	3
	1u+1u	POA(1)	3	3	3	3	3	3
		POA(2)	3	3	3	3	3	3
	1u+1m	POA(1)	3	3	3	3	3	3
		POA(2)	3	3	3	3	3	3
	1u+1m	POA(1)	3	3	3	3	3	3
		POA(2)	3	3	3	3	3	3

Table 9. Effects of HS, M, and POA and 2-parameter combinations

	DF	Wald Chi Square	P
HS	4	280.021	<.0001
POA	1	755.873	
M	5	904.758	<.0001
HS*POA	4	112.138	<.0001
HS*M	18	238.059	<.0001
POA*M	5	42.939	<.0001

Table 10. Sensitivity to each parameter after applying d’

Modality	Language	d’-HS	d’-POA	d’-M
Sign	1 ASL	1.65	.78	.79
Spoken	2 English	.21	.04	.86
Sign	3 HZJ	.33	.38	.23
Spoken	4 Croatian	.01	.56	.04
Sign	5 ÖGS	.86	.54	.60
Spoken	6 Austrian German	.25	.02	.25

Table 11. The Effect of Language x POA on Handshape Condition 1

Language	POA = 1	POA = 2
ASL	Wald= 16.668, *p*=.002	Wald = 35.715, *p*<.0001
HZJ	Wald=3.857, NS	Wald = 11.586, *p*=.021
ÖGS	Wald=24.770, *p*<.0001	Wald = 3.500, NS
English	Wald = 29.178, *p*<.0001	Wald = 5.367, NS
Croatian	Wald = 48.365, *p*<.0001	Wald = 6.968, NS
Austrian German	Wald = 13.464, *p*=.009	Wald = 7.352, NS

Figure Captions

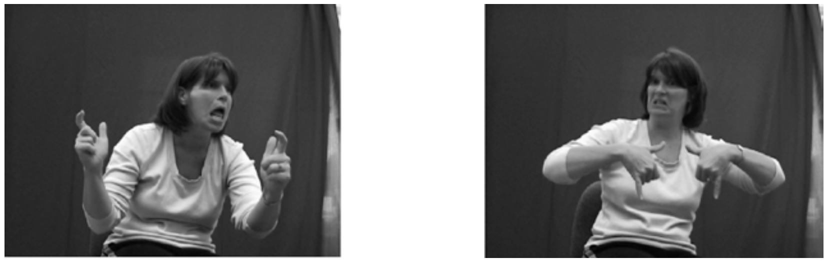
Figure 1. Sample page from the response form for Experiment 1.

Figure 2. Example of the display of task items on the computer screen

Figure 3. d’ for HS, POA, and M by Language

Figure 4. Subject responses for HS conditions 1-5 for Signers (1) and Nonsigners (2), (courtesy of J. Bourneman)

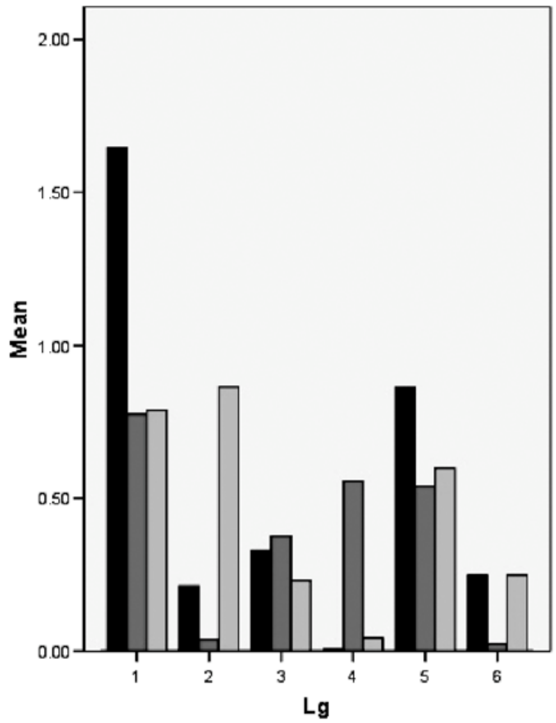
Figure 1



Between the two signs shown is there a sentence break? yes ___no ___
How confident are you in your answer? 10 9 8 7 6 5 4 3 2 1 0
very not at all

Figure 2

Figure3



d'-HS black
d'-POA dark gray
d'-M light grey

Languages

1	ASL
2	English
3	HZJ
4	Croatian
5	ÖGS
6	Austrian German

Figure 4

signer: 1
nonsigners: 2