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TECHNICAL REPORT

What Age of Acquisition Effects Reveal about the Nature of Phonological Processing

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What Age of Acquisition Effects Reveal about the Nature of Phonological Processing

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Abstract

Evidence that signers use phonological structure during sign recognition has been difficult to obtain. By carefully controlling age of acquisition of American Sign Language (ASL), we demonstrate here the psychological reality of phonological structure during sign recognition. Sixty-four signers, who were born deaf and varied in initial age of ASL acquisition from birth to 13 years, performed a primed lexical decision task in ASL. A small subset of prime-target pairs was phonologically related and another small subset was semantically related; the majority of stimulus pairs were unrelated linguistically. Reaction time for sign recognition increased as age of ASL acquisition increased and varied as a function of the linguistic structure of sign. Phonological overlap between the prime and target facilitated sign recognition for signers who learned to sign in early childhood but inhibited it for signers who learned ASL at older ages. By contrast, semantic overlap between the prime and target facilitated sign recognition for all signers independent of age of acquisition. These results show that sign recognition entails a stage of phonological processing that is sensitive to age of acquisition, as is the case for recognition of spoken words.

Mastering the phonological system of language is an easy task for babies but a more difficult one for adolescents and adults. Learners of new languages who are no longer young children typically speak the new language with an accent and misperceive words, even after years of practice (Flege, Yeni-Komshian, & Liu, 1999; Flege, 2003). Indeed, one of the strongest markers of being a non-native speaker is phonological accent (Scovel, 1989). The question arises as to whether such effects also characterize learning a new language when it has no sound, as in the case of American Sign Language (ASL). The answer illuminates the nature of linguistic structure and sensory-motor modality with respect to when and how the mind uses phonology. If mental manipulation of sublexical structure is unique to speech, then phonological effects associated with learning a language at older ages should not be apparent in sign languages. However, if the mental manipulation of sublexical structure is a universal feature of language processing, one that transcends sensory and motor modality, then phonological effects related to age of acquisition should be observed in sign languages.

We summarize here a study showing that age of acquisition (AoA) affects phonological processing and lexical access in ASL. These effects demonstrate an important principle of language comprehension, namely that phonological processing is an abstract and supra-modal stage of language processing, psychologically real for signers as well as speakers. Signers, like speakers, analyze phonological structure as part of lexical access and comprehension.

Among the design features for language, Hockett (1958) believed the most important one to be duality of patterning (Gair, 2003). The basic meaning units of all languages, words or morphemes, are created from combinations of smaller units that have no meaning, phonemes. Sublexical structure, or patterning, is a major distinguishing feature between words and gestures. Gestures, including those that accompany speech, do not have sublexical structure (McNeill, 1992). Unlike gestures, but like words, signs are constructed from a finite set of sublexical units (Stokoe, Casterine & Croneberg, 1965; Liddell & Johnson, 1989) despite having evolved from gesture (Senghas, Kita, & Özyürek, 2004). Every

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sign in ASL, for example, is constructed from a set of meaningless articulatory units including, a handshape and orientation, along with a movement, and locations on the body where the sign is articulated. Altering a single sublexical unit, such as closing the fingers, changes sign meaning because “finger closing” is a linguistically contrastive phonological unit in sign language (Sandler, 1993). The phenomenon is the same as changing one phoneme of a spoken word to another. Altering the phoneme /b/ in the English word [bɛt] to the phoneme /p/ changes the word meaning to [pɛt] for example. Altering the place of articulation of the ASL sign BIRD from the chin to the non-dominant hand changes the sign meaning to PRINT as another example.

Evidence that signers mentally manipulate the sublexical structure of signs comes almost entirely from language production tasks. Signers make mistakes during spontaneous expression known as “slips of the hand” which typically involve the re-arrangement of the sublexical units of adjacent signs (Klima & Bellugi, 1979). Signers’ errors on short-term memory tasks also entail a re-shuffling of phonological units (Bellugi, Klima & Siple, 1975). Babies exposed to sign language babble with elements of phonological structure (Petitto & Marentette, 1991), and young children make sign mistakes that involve errors in using the appropriate phonological units of signs (Cheek, Cormier, Repp, & Meier, 2001; Marentette & Mayberry, 2000). Even the paraphasic errors of aphasic signers of are faithful to the phonological structure of signs (Corina, 2000). Missing from this body of evidence that duality of patterning in ASL signs is psychologically real is evidence that signers use phonological structure during on-line sign recognition and comprehension.

One experimental approach the question is to investigate the nature of age of acquisition effects on sign language processing. Age of acquisition effects on phonological processing of spoken language have been well documented and are some of the most robust effects of AoA on language use (Flege, 2003). Previous ASL research has found AoA to affect syntactic comprehension and production of ASL, just as it does in spoken languages (Boudreault & Mayberry, 2005; Emmorey, Bellugi Friederici, & Horn, 1993; Newport, 1990). Hints that AoA affects recognition of individual signs come from this line of work as well. Increased AoA is associated with increased phonological error production on short-term memory and shadowing tasks of ASL sentences and narratives (Mayberry & Fischer, 1989). One striking example is a shadowing error of a late learner of ASL shown in Figure 1, where the sign SLEEP was substituted for the sign AND; the stimulus and error signs share all phonological features except place of articulation.

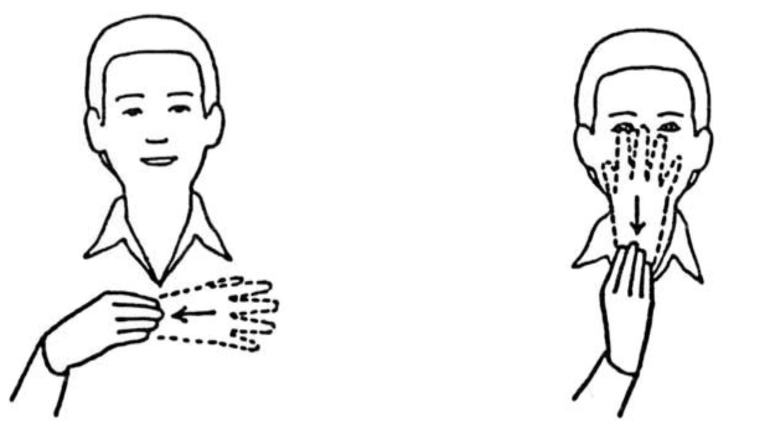

Figure 1. Example of a phonological substitution error produced when a signer was shadowing the ASL stimulus sentence meaning, “I ate too much turkey and potatoes.” The signer produced the sign SLEEP for the stimulus sign AND. The stimulus sign and error share all phonological features except for place of articulation. (Drawing by B. Raskin © R. I. Mayberry)

In a series of studies, we found that as age of ASL acquisition increases, phonological error production also increases across a variety of off-line, language tasks, including narrative and sentence shadowing and sentence recall, as Figure 2 shows. Importantly, phonological error production on these tasks correlates negatively with narrative comprehension. This suggests that these phonological errors are not mindless mistakes divorced from language comprehension, but rather reflect processing differences associated with AoA, specifically at the phonological level of the single word. Conversely, semantic error production is associated with early childhood AoA on the same tasks. Semantic errors correlate positively with ASL comprehension (Mayberry & Eichen, 1991; Mayberry 1994). We thus have evidence from off-line language tasks that AoA affects processing of the two levels of sign structure, phonology and meaning. The question remains as to whether AoA affects on-line phonological processing during sign recognition. We test this hypothesis in the present study.

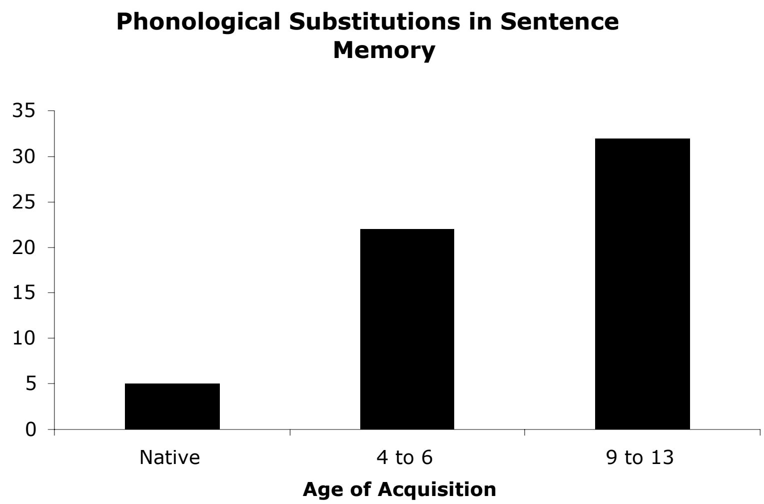

Figure 2. Mean phonological substitution errors produced by signers on an ASL sentence recall task as a function of the age at which they first began to learn ASL. Native signers began to acquire ASL from birth. (Data from Mayberry & Eichen, 1991)

Procedure

The stimuli were prime-target sign pairs consisting mostly of nouns and adjectives. No sign appeared more than once in any form in the experiment. Half the targets were signs, which had one of three linguistic relationships to the primes: (1) 17% of the targets formed a minimal phonological pair with the prime, sharing two of three formational parameters (handshape, place of articulation, and movement), e.g. BIRD and PRINT are phonologically identical in ASL except for place of articulation; (2) another 17% of the targets were semantically related to the prime in a superordinate category and exemplar fashion, e.g., FURNITURE and CHAR; and (3) 66% of the primes shared no linguistic relation to the target, i.e., no phonological, semantic or syntactic relations, and served as baseline. We specifically used a low incidence of phonological and semantic sign-target pairs to increase the likelihood of priming, especially phonological priming (Neeley, 1991). Mean subjective frequency of the stimulus signs did not differ across the prime types (Mayberry & Zvaigzne, in prep.). Half the targets were non-signs, which we created by altering one parameter of an ASL sign.

A native-ASL learner who is deaf signed the stimuli for video recording. Two native-ASL learners then located the recognition point of each sign on each video clip. Each video clip was subsequently edited so that an equal number of video frames preceded and followed the recognition point. The data we summarize here come from stimuli separated by a 300 msec interval.

A native-ASL learner who is deaf tested the participants individually. Participants began the experiment only after demonstrating that they understood the task with a practice trial of two dozen prime-target pairs not included in the experiment. They decided with a button press whether the target was an ASL sign or not. Stimuli were presented in a fixed-random order on a color-laptop screen controlled by PowerLab (Chute, 1996).

Sixty-four adults participated who were born deaf (> 80 dB pure-tone-average in the better ear as confirmed an audiogram) and had used ASL as their preferred language for 10 years or more. All participants scored within the normal range on a nonverbal IQ screening task. We grouped the participants as a function of the age when they first began to see ASL on a daily basis: 22 were native learners whose Deaf parents signed to them from birth; 21 were early learners who first used ASL in school between the ages of 4 and 8; and 21 were late learners who first used ASL in school between the ages of 9 and 13. The groups had approximately equal numbers of men and women; mean chronological age and length of ASL experience did not differ across the groups.

Findings

We analyzed reaction time (RT) for correct responses with ANOVAs for the between-subjects factor of AoA and the within subject-factor of prime type, phonological or semantic. We computed the priming effect for the phonologically and semantically related prime-target pairs using the sign pairs with no linguistic relationship as the baseline.

AoA affected time to recognize signs ($F[2,61] = 3.58$, $p<.03$). Specifically, as AoA increased, RT also increased. Importantly, however, the structure of the sign also affected RT in separate ways for phonology and semantics ($F[2, 61] = 4.15$, $p<.01$). Substantial phonological overlap between the prime and target facilitated sign recognition for the early learners, but inhibited it for the late learners, and had no effect for the native learners, as Figure 3 shows. By contrast, semantic overlap between the prime and target facilitated sign recognition for all the groups independent of AoA, as Figure 3 also shows. AoA effects on RT in relation to linguistic prime type were not due to a speed-accuracy tradeoff. Error rates were unaffected by age of acquisition. However, there was trend for phonological primes to elicit more errors from the late learners and semantic primes to elicit fewer errors for all the groups, independent of AoA.

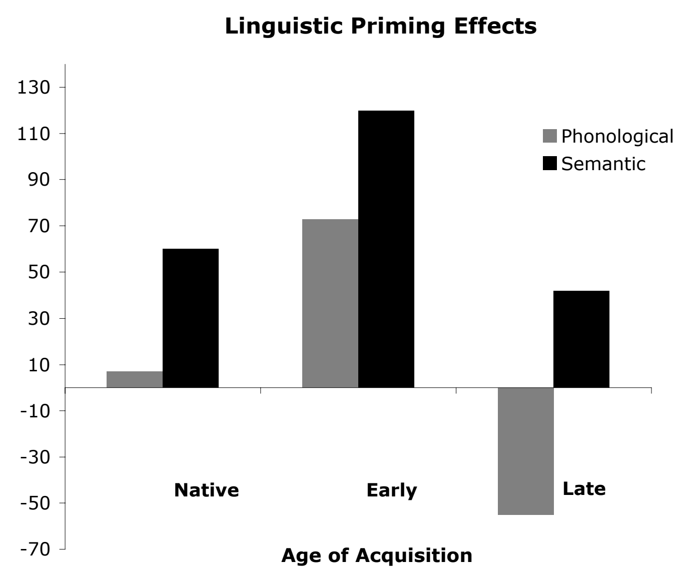

Figure 3. Mean phonological and semantic priming effects for ASL sign recognition as a function of age of ASL acquisition. Native signers began to acquire ASL from birth. Baseline sign recognition for stimulus pairs unrelated linguistically is set at zero. Sign recognition facilitation is expressed as milliseconds faster (positive) than baseline. Sign recognition inhibition is expressed as milliseconds slower (negative) than baseline

Discussion

These results provide several important findings. The first finding is that AoA affects sign language recognition at the level of the single word. As AoA increases, the time needed to recognize signs also increases. The second finding is that AoA exerts differential effects on sign recognition specific to the dual levels of sign structure, phonology and meaning. These effects are similar to the well-documented effects of AoA on spoken language processing. Significant phonological overlap between signs facilitates sign recognition for early learners, inhibits it for late learners, and shows no effects for native learners. Semantic overlap between signs facilitates recognition independent of AoA. The net consequence of these findings is a demonstration that the phonological structure of ASL signs is psychologically real, that signers analyze the phonological structure of signs during on-line comprehension.

In the absence of a linguistic relation between contiguous signs, native signers recognized signs more quickly than signers who first learned ASL at older ages, corroborating earlier findings (Emmorey & Corina, 1990).1 A semantic relation between signs facilitated the native signers' recognition. But unlike the sign recognition of the early and late learners, the native learners' sign recognition was uninfluenced by phonological relations between signs. This was likely due to the fact that the native signers' recognition was faster to begin with, suggesting that the lack of phonological priming effects for the native learners were due to floor effects. The sign recognition patterns of the two groups with older AoA were longer and, in turn, showed sensitivity to phonological relations between signs. Other work has found phonological priming for native learners of British Sign Language at a 50 msec inter-stimulus interval (Dye, in press). Together these findings suggest that phonological processing occurs early in sign recognition for native learners.

The early learners required more time to recognize signs than the native learners when there was no linguistic relation between signs. Phonological overlap boosted their sign RT to native-like levels. The facilitative, phonological priming effects shown by the early learners suggest that signs in the mental lexicon are organized according to phonological features. The phonological structure of an identified sign activates signs with similar phonological features so they are recognized more quickly. This was also true for the semantic priming effects shown by the early learners, demonstrating that the sign mental lexicon is additionally organized along semantic dimensions.

The signers who first learned to sign at the oldest ages showed the slowest sign recognition. Like signers who first learned to sign at younger ages, the late learners showed facilitative semantic priming, indicating a spreading activation of sign meaning during sign recognition. In addition, the late learners were sensitive to the phonological structure of signs, but rather than facilitating sign recognition, it was inhibitory. In previous work we hypothesized that increasing AoA may be associated with a "phonological bottleneck" during sign recognition requiring attention and making the process effortful (Mayberry & Fisher, 1989; Mayberry & Eichen, 1991; Mayberry, 1994). The present results support this hypothesis. Substantial phonological overlap between adjacent signs hinders rather than helps sign recognition for late learners.

There are at least two possible explanations for why phonological priming is inhibitory for the late learners. First, their phonological system may be less differentiated than that of early learners; their knowledge of ASL phonology may include fewer contrastive segments so that signs may be harder to distinguish given only phonological form. Hence, their lexical neighborhoods may be denser, thereby slowing sign recognition (Slowiaczek & Pisoni, 1986). Evidence for this interpretation comes from work finding that native ASL signers make phonological similarity judgments that are different from those of non-native signers (Hillebrandt & Corina, 2002). Native ASL signers also make similarity judgements that are different from people who are naïve to ASL (Poizner, 1981).

Additionally, AoA may affect the mapping of phonological segments onto the lexicon (Pallier, Colomé, & Sebastián-Gallés, 2001). Evidence for this explanation comes from work showing that non-native learners of British Sign Language show phonological priming for non-signs, but native signers do not, suggesting an extra-lexical basis for the effect (Dye, in press).1 Indeed, the contrastive phonological processing patterns we have uncovered here for AoA may explain why phonological priming effects have been difficult to isolate in sign language experiments (Corina & Hildebrandt, 2002). Heterogeneity in AoA for both first- and second-language acquisition is a unique feature of sign language communities (Mayberry & Lock, 2003), unlike the case for spoken language communities. This makes testing groups of participants with similar linguistic backgrounds an experimental challenge. Whether AoA effects on phonological processing during lexical access are similar in the cases of first- and second-language acquisition begun after early childhood remains to be investigated (Mayberry& Lock, 2003; Mayberry, Lock & Kazmi, 2002).

In sum, we find that AoA affects phonological knowledge and processing even when the language has no sound. This means that phonology is an abstract, mental construct not bound to the sensory-motor modality of language. Signers, like speakers, appear to organize their mental lexicon along both the phonological and semantic dimensions of words. Signers, like speakers, engage in phonological analyses during lexical access. How they do so, however, is greatly influenced by the developmental timing of their experience with sign language. Sign language acquisition, like spoken language acquisition, is sensitive to AoA with respect to how the mind treats the dual linguistic structure words.

Notes

1. "Non-native" or "late learner" was either undifferentiated by age or described as between ages 5 and 17.

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