Lexical access in sign perception: A computational model

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Psycholinguistic theories have predominantly been built upon data from spoken language, which leaves open the question: How many of the conclusions truly reflect language-general principles as opposed to modality-specific ones? We take a step toward answering this question in the domain of lexical access in recognition by asking whether a single cognitive architecture might explain diverse behavioral patterns in signed and spoken language.

Within the psycholinguistic framework, the comprehension of a single word ultimately involves mapping a physical signal onto its meaning and the production of a single word involves mapping meaning to a physical signal. Multiple stages of processing have been posited to take place in between these two endpoints, most generally the identification (or in production, the preparation) of sub-lexical and lexical units (e.g., McClelland & Ellman, 1986; Dell, 1986). According to a number of accounts, signed and spoken languages, like all languages, might have similarly organized semantic systems (e.g., Jackendoff, 2012). At the same time, their most peripheral elements clearly differ: signed languages utilize manual and facial articulators and are perceived through the visual system while spoken languages are produced with the oral articulators and are perceived through the auditory system. We ask whether the core mechanisms of sub-lexical and lexical processing might be the same despite differences in the most peripheral aspects of sign/word recognition.

Research on lexical access has revealed both parallels and discrepancies between sign and spoken word perception. In spoken word recognition, one of the most well-documented findings is that the number of words that are phonologically related to a target (its neighborhood density) inhibits recognition of the target word (Dufour & Peereman, 2003; Goldinger, Luce & Pisoni, 1989). Phonological neighborhood density also plays a role in sign processing. However, in a study of Spanish Sign Language (LSE), Carreiras et al. (2008) found that signs with many handshape neighbors ('dense handshape neighborhoods') are easier to identify in a lexical decision task than signs with few handshape neighbors. Meanwhile, signs with dense location neighborhoods are harder to identify than signs with sparse location neighborhoods.

How might we account for the apparent unique role of neighborhood type in sign language? One possibility is to assume that there are different computational principles at work in signed and spoken language, leading to fundamental differences in the way words and signs are activated during language processing (e.g., Baus et al., 2008). The fact that it matters in sign language whether a neighbor shares its location or its handshape with the target suggests that there are sign language-specific retrieval mechanisms since there is no exact corollary of these parameters in spoken language. However, another possibility is that spoken and signed languages make use of the same core mechanisms to access the mental lexicon and it is a handful of relatively peripheral differences between modalities that accounts for the differences in the way neighbors affect processing.

Looking deeper into the effects of neighborhood density, there is a pattern of reversals in spoken and written language is not unlike the pattern of reversals in sign perception. In spoken production neighborhood density is facilitatory (Mirman, Kittredge, & Dell, 2010; Vitevitch, 1997, 2002), while in spoken perception neighborhood density is inhibitory (Dufour & Peereman, 2003; Goldinger et al., 1989). In visual word recognition neighborhood density is facilitatory (Andrews, 1992), except for high frequency words in which case neighborhood density is inhibitory (e.g., Grainger, O'Regan, Jacobs & Segui, 1989; Davis, Perea, & Acha, 2009). The effect of neighborhood density depends on modality even in spoken and written word processing.

Chen and Mirman (2012) presented a computational model of word processing that unified opposite effects of neighborhood density in speech production, perception, and written word recognition. They posit that lexical neighbors thus send both facilitatory *and* inhibitory activation to other lexical items. It is a balance of facilitation and inhibition that determines the net contribution of neighbors, and the balance can be tipped depending on how strongly the neighbors are activated. Strongly activated neighbors exert net inhibition on the target, and weakly activated neighbors exert net facilitation on the target. Chen and Mirman's theory of lexical access accounts for the pattern of reversals observed in spoken (and written) language with a single core lexical access mechanism, varying only the most peripheral elements across modality (e.g., the sequence of activation of sub-lexical units in speech perception and word recognition).

We present a computational simulation of neighborhood effects in sign perception that imports principles from Chen and Mirman's model. We test three reasons that location neighbors might be strongly activated (and thus exert net inhibition on targets) and handshape neighbors might be weakly activated (and thus exert net facilitation on targets). Location is identified earlier in perception than handshape (Emmorey & Corina, 1990; Grosjean, 1981), in the behavioral data on average locations were more frequent in the language than handshape, and on average there were more location neighbors than handshape neighbors (Carreiras et al., 2008). We show that if a model containing these core principles is elaborated to incorporate relatively minor facts about either 1) the time course of sign perception or 2) the frequency of sub-lexical units, it produces data that match the experimental findings from sign languages. Interestingly, we were not able obtain the observed pattern of results when the number of lexical neighbors was similarly varied.

Our success in modeling the effects of location and handshape provides evidence that there may be universal principles governing the way the mental lexicon is accessed. Even though location and handshape are elements that are unique to sign languages, it appears that their influence on recognition can be modeled using the same principles that have been used to explain lexical access across tasks in spoken and written language. We wish to note that our results do not rule out the possibility that there are sign language-specific factors that influence lexical processing. They do, however, indicate that such factors are not necessary to account for the empirical data on neighborhood effects.

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