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Sign Languages: Contribution to Neurolinguistics from Cross-Modal Research

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Abstract

Using sign language research as an example, we argue that both the cross-linguistic descriptive approach to data, advocated by Evans and Levinson (2009), as well as abstract ('formal') analyses are necessary steps towards the development of "neurolinguistic primitives" for investigating how human languages are instantiated in the brain.

Keywords

American Sign Language; neurolinguistics; experimental; analysis

1. What Do Linguistic Universals Look Like in Sign Language?

Evans and Levinson (2009) (further referred to as E&L) appropriately mention sign languages (SLs) as a proving ground for linguistic theories, as SLs reflect both modality-independent and modality-specific properties of human linguistic ability. While E&L are to be commended for including SLs in the discussion, there are reasons for caution in interpreting the arguments that use sign language examples.

For example, the statement in Box 1, that "Sign languages like ASL (American Sign Language) also lack pronouns, using pointing instead", is an incomplete linguistic description of spatial indexing in SLs, with the false implication that 'pointing' in SLs is the same as non-signers' pointing gestures. There are very clear structural limits to the uses of pointing in sign language discourse. Pointing to an object present in the context in ASL, for example, a lamp, can be used to mean 'a lamp like that but not that one', whereas such a pointing in a non-signing context means 'that lamp' (Petitto 1984; Hoffmeister 1977). Thus, from a descriptive perspective, observable deictic uses of 'pointing' are not the same between signing and non-signing populations. On a more abstract level of analysis, it has been shown that Subject Copying in ASL, whereby pointing back to the location established for the Subject of the sentence is licensed at the end of the sentence, can be used grammatically to refer to the Subject of the main clause, but not that of any embedded clause (Padden 1983). Finally, psycholinguistic investigation (Emmorey and Falgier 2004) has demonstrated that despite the spatial

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(‘pointing’) nature of reference in ASL, the processing mechanism underlying on-line interpretation of it is the same as that of spoken language pronouns: spatial indices activate only referent nouns, but not spatial location nouns associated with the referent.

Further, if systematicity in linguistic data is not looked for, it is safe to predict that systematicity will not be found. For nearly 20 years, Coulter's (1978) descriptive statement that eyebrow raise marked ‘unasserted’ information in American Sign Language (ASL) was accepted uncritically. It took a data-driven demonstration that brow raise did not always occur on unasserted information, and that it *did* occur on asserted, even focused information, to make a transition from descriptive investigation to formal analysis (Wilbur 1999; Wilbur and Patschke 1999), which showed that brow raise marks the restriction information of dyadic semantic operators. As unexpected as this solution was, it was the only one which predicted all, and none but, the observed occurrences of brow raise in ASL across a large variety of signers and structures (topics, relative clauses, conditionals, the focus associates of ‘only’ and ‘even’, etc.).

2. From Cross-modal Data to Neuroscience of Language

The main difficulty in translating the wealth of linguistic research into experimental investigation of the brain basis of language lies in the disparity between minimal constituent units of inquiry in linguistics and cognitive neuroscience. Sign language research owes its beginning as a field to rigorous descriptive work (Stokoe 1960; Klima and Bellugi 1979; Padden 1983; Liddell 1977, 1978, 1980; Coulter 1979), which formed a foundation for subsequent abstract analyses within several linguistic frameworks, including Transformational generative grammar (Fischer 1974; Fischer 1975); Government and Binding (Petronio and Lillo-Martin 1997; Lillo-Martin 1986, 1991; Petronio 1993; Neidle et al. 2000); Minimalism (Churng 2009); Optimality Theory (Brentari 1998), and Event Structure (Wilbur, 2003). These ‘formal’ analyses are united by a common approach: they use abstract constructs to generalize over observable linguistic phenomena, and to produce further testable hypotheses. An abstract construct, which possesses explanatory adequacy over available cross-linguistic data, can be used for investigating neurobiological correlates of linguistic ability using experimental methods, including those of perceptual psychology and cognitive neuroscience.

One example of an abstract construct amenable to investigation across the fields of linguistics, perceptual psychology, and cognitive neuroscience comes from the research on verbal event structure in sign languages. In the process of trying to analyze various gaps in the behavior of ASL verbs with respect to the types of aspectual reduplication (Wilbur, Klima, and Bellugi 1983; Klima and Bellugi 1979), Wilbur (2003, 2005, 2009) made the observation that some ASL lexical verbs appear to have a sharper ending movement to a stop. This marking corresponded to the well-described concept of ‘change-of-state’ at the syntax-semantics interface (Vendler 1967; Pustejovsky 1991), already shown to be cross-linguistically valid in spoken languages and important during on-line sentence processing (Sanz 2000; O'Bryan 2003; Folli and Harley 2006). Quantitative analysis of ASL motion capture data has subsequently demonstrated that kinematic variables marking the ‘change-of-state’ in the predicates include peak velocity of dominant hand motion within the sign, and its subsequent deceleration (Malaia, Borneman, and Wilbur 2008). ASL acquisition data has further shown that these perceptual-kinematic features are relevant for infants acquiring sign language (Brentari et al. in press). Finally, an fMRI study of ASL verb processing showed increased neuronal activity in superior temporal gyrus, precuneus, and cerebellum during the processing of visually presented predicate signs containing a rapid deceleration at the end of the sign, as compared to predicates without such kinematic properties (Malaia, Ranaweera, Tamer, Wilbur, and Talavage 2009). Given that some of these findings are strikingly similar to neural activations found during visual scene segmentation in hearing populations (Zacks et al. 2001), such results indicate that visuo-kinematic perceptual features of events might undergo

grammaticalization in SLs, and are subsequently processed as linguistic distinctions by Deaf signers. These findings, of course, produce multiple further hypotheses, which might eventually lead to re-formulation of 'formal' phonological, semantic, and syntactic theory in terms of neural system behavior.

4. Conclusion

The fact that descriptions of cross-linguistic data in various modalities yield abstract analyses of specific phenomena should be viewed as a part of a normal scientific cycle. We support E&L's claim that in order to produce robust testable hypotheses, linguistic analyses need to be descriptively rigorous, both cross-linguistically and cross-modally. However, linguistic descriptions do lead to cross-linguistic generalizations and development of models, which will only be more 'abstract' and neurobiology-based as linguistics advances toward understanding of the neural substrate of human linguistic ability.

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