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Early developing syntactic knowledge influences sequential statistical learning in infancy

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ABSTRACT

Adults' linguistic background influences their sequential statistical learning of an artificial language characterized by conflicting forward-going and backward-going transitional probabilities. English-speaking adults favor backward-going transitional probabilities, consistent with the head-initial structure of English. Korean-speaking adults favor forward-going transitional probabilities, consistent with the head-final structure of Korean. These experiments assess when infants develop this directional bias. In the experiments, 7-month-old infants showed no bias for forward-going or backward-going regularities. By 13 months, however, English-learning infants favored backward-going transitional probabilities over forward-going transitional probabilities, consistent with English-speaking adults. This indicates that statistical learning rapidly adapts to the predominant syntactic structure of the native language. Such adaptation may facilitate subsequent learning by highlighting statistical structures that are likely to be informative in the native linguistic environment.

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Introduction

Statistical information has been argued to play an important role in language development (e.g., Romberg & Saffran, 2010; Saffran, Aslin, & Newport, 1996; Thiessen & Erickson, 2014). One aspect

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of statistical learning has been studied especially closely in this regard: the use of conditional statistical information to group linguistic elements into units (Perruchet & Vinter, 1998; Thiessen, Kronstein, & Hufnagle, 2013). For example, sounds within words predict each other better than sounds across word boundaries, and both infants and adults can use this information to group sounds together into words (e.g., Aslin, Saffran, & Newport, 1998; Graf-Estes, Evans, Alibali, & Saffran, 2007). Similarly, learners are sensitive to the likelihood of words occurring together and can use this information to identify phrasal clusters in a string of words (Saffran, 2001; Thompson & Newport, 2007). Sensitivity to the predictable relation among elements of the input may play an especially important role early in language acquisition because, unlike many acoustic cues to linguistic structure, it does not require infants to have language-specific biases or expectations (e.g., Thiessen & Saffran, 2003).

However, accounts of language development and processing that rely on statistical information are often critiqued as relying on knowledge that is local and strongly lexically based (e.g., Tomasello, 2000). Detractors of these statistical approaches claim that many crucial linguistic properties, such as word order, are abstract and represented independently of individual words (e.g., Gervain, Nespor, Mazuka, Horie, & Mehler, 2008). This perspective emphasizes the generativity of linguistic structures; once infants have identified an abstract property of linguistic structure, they can generalize the property to novel input and produce novel constructions. This perspective often describes language learning in terms of discovering abstract symbolic rules. For example, once infants have learned that the past tense of the English verb involves adding *ed* (e.g., *kick* transforms to *kicked*), they can apply this rule to any verb (Pinker & Ullman, 2002).

We have proposed an alternative to this perspective, which is that statistical learning itself adapts to the structure of linguistic input in ways that lead learners to have expectations about novel subsequent input (Onnis & Thiessen, 2013). From this perspective, what infants are learning as they acquire a language is not a set of symbolic rules. Rather, they are absorbing examples from the input and generalizing on the basis of the statistical structure of those examples (e.g., Thiessen & Saffran, 2003). This allows statistical learning to "specialize" to the structure of the input, for example, by focusing attention on cues that have been informative in past experience. That is, although statistical learning is an early developing and potentially universal cue to linguistic structure, different languages are characterized by different statistical regularities. Statistical learning may adapt to these regularities in ways that make learners better prepared for subsequent learning in that language. Note that this contrasts with the view that statistical learning (and perhaps implicit learning more generally) is a stable trait that does not show substantial change over time (e.g., Arciuli & Simpson, 2012).

The claim that statistical learning adapts to the structure of the input suggests that it should be possible—even likely—to observe differences in statistical learning as a function of the kinds of regularities that are informative across different languages. One difference in the statistical regularities across languages occurs as a consequence of the predominant directionality of phrase structure in the input. Languages contain both predictive (forward-going) and retrodictive (backward-going) relations among elements of the input. These relations are not necessarily identical; for example, whereas *the* does not strongly predict *dog* (because many words can follow *the*), *dog* strongly retrodicts *the.* Recent experimental work using artificial input has demonstrated that learners are sensitive to informative relations in both directions. For instance, Jones and Pashler (2007) showed participants sequences of shapes governed by probabilistic relations and found that participants were able to recall which shapes reliably occurred both after a probe shape in the input (prediction test) and before a probe shape (retrodiction test). Similarly, both infants and adults are able to segment fluent speech into words on the basis of either forward-going relations among syllables or backward-going relations (Pelucchi, Hay, & Saffran, 2009; Perruchet & Desaulty, 2008).

In natural languages, the predominant directionality of relations among elements of the input can differ. One example of this is described in linguistic terms as the "headedness" of a language. The head of a phrase is the word that defines the syntactic function of the phrase (i.e., the verb in a verb phrase). Some languages (e.g., English) are classified linguistically as head initial, meaning that the head of the phrase tends to occur before complement items (e.g., *going* in *going home*), whereas other languages