raise here, we value the program and are working hard to improve it (*1*).

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Reference

1. See http://ito.uc3m.es.

Are There Limits to Statistical Learning?

"DOES GRAMMAR START WHERE STATISTICS stop?", ask M. S. Seidenberg *et al.* in the title of their Perspective (18 Oct., p. 553). Arguing against a "reconcilist" position in which complex cognitive functions would depend on a mixture of statistical and algebraic (rule) mechanisms (*1*, *2*), Seidenberg *et al.* favor a position that they describe as "statistical learning," wherein languages are a product not of language-specific knowledge, but of limits on the statistical structures that "learners are able to track."

Unfortunately, nowhere do they spell out what exactly statistical learning consists of. Broadening the notion of statistics from things like transitional probabilities between particular elements (*3*) to relationships between any kind of information, concrete or abstract, trivializes the very term, rendering it broad enough to encompass any lawful relationship, including the very rules that Seidenberg and his colleagues have argued against (*4*). Without a notion of what would not count as statistical learning, it is hard to even see what the hypothesis is; as Karl Popper has noted, an unfalsifiable theory is no theory at all (*5*).

One way to render the question about statistical learning into something falsifiable is to pit it against an alternative hypothesis that makes specific predictions. One such hypothesis is that learners might be able to extract and generalize rules, where rules are defined as operations over variables. For example, a simple rule of reduplication might state that **X** goes to **XX**, where **X** is a variable that can stand for a large class of elements (e.g., *b*, *d*, *f*). Because such rules make reference to variables (e.g, **X**), it follows that speakers should be able to generalize them across the board, to any representable element that can be substituted into the variable, irrespective of the properties of specific elements, their similarity to trained items, and their previous history of statistical cooccurrence (*6*, *7*).

Empirical data suggest that people can indeed generalize in just this way. In addition to being able to learn to recognize statistical relations between particular sets of elements, listeners can also acquire formal patterns that hold for any element, irrespective of its statistical properties, just as the "rule" theory predicts. Hebrew speakers, for example, recognize that root morphemes that follow an **XYY** (e.g., *sll*, *bdd*) pattern are well formed, whereas roots that follow an **XXY** pattern (e.g., *ssl*, *bbd*) are not, and they extend this generalization to novel word forms (*8*), even for those that contain phonetic contrasts that do not appear in Hebrew (*9*). Similarly, human infants that have been exposed to sentences like *la ta la* and *ga na ga* appear to recognize the differences between novel items like *wo fe wo* (which follows the same pattern) and *wo fe fe* (which does not) (*10*). Such generalizations are naturally handled by computational systems that come equipped with operations over variables but cannot be captured by systems that are only capable of counting transitional probabilities between known elements, nor, we suspect, by any system that could be reasonably construed as purely statistical (*11*), unless the notion of "statistical" were broadened to the point of being unfalsifiable.

Seidenberg *et al.* may be confusing a plausible notion of statistics as an important component of cognition with an overly general view in which statistics would be wholly responsible for cognition. Such a perspective leads them to take seriously the proposition that the difference between linguistically proficient humans and less linguistically adept species such as chimpanzees would lie primarily with "the statistics of natural language," the idea being that such statistics would be "too complex for other species to learn." But there is no evidence that humans can learn particularly complex statistics (*12*) or that they are uniquely gifted statistical learners—cotton-top tamarins, for example, are just as capable as humans in learning transitional probabilities (*13*). There is little doubt that people can detect correlations and transitional probabilities, but such tools are unlikely to be the only elements in the cognitive equation.

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Response

THE MARCUS AND BERENT LETTER IS A misreading of our Perspective, which was not an argument against a "reconcilist" position or for an exclusively statistical approach to language learning. This is evident from the title, which posed a question rather than making an assertion, and from the text, which pointed out unknowns concerning both grammar-based and statistically based approaches. Marcus and Berent repeat the very issues we raised about statistical learning, e.g., the fact that the limits of statistical learning are not known. Unlike Marcus and Berent, however, we also addressed some of the unknowns about grammar learning. Marcus and Berent complain that there is no definition of statistical learning in our Perspective, but our point was that there are ambiguities on both sides that made it difficult to sustain M. Peña *et al.*'s claim to have discovered evidence for two distinct mechanisms, one statistical and one rule-based ("Signal-driven computations in speech processing," Reports, 18 Oct., p. 604).

The bulk of the Letter restates Marcus and Berent's arguments that learners must extract and generalize rules to acquire language. As we noted in our Perspective, claims of this sort are entirely negative: In each case, evidence is provided that observed behavior cannot be explained by a specific statistical analysis; it is then inferred that no statistical analysis is viable and that a rule-learning mechanism must therefore exist. Of course, these conclusions are valid only if the behavior does not afford other statistical analyses. In the case of the Peña *et al.* Report, we noted that their artificial language stimuli provided numerous other statistical regularities that could contribute to performance. With respect to the evidence cited by Marcus and Berent, at issue is their assumption that if the generalization that humans extract from the data is abstract (e.g., referring to word position rather than adjacent elements), then the behavior reflects rule learning rather than statistics. Our Perspective cited a number of critiques of this general approach and of their work in particular. Marcus and Berent's letter is another illustration of a point we have already made, that the definition of what constitutes language-relevant "statistics" is not yet clear, mitigating attempts to prove their limitations. Waving the banner of falsifiability here does nothing to bolster Marcus and Berent's claims in this complex area. Indeed, as Chomsky (*1*) has emphasized in his own work, the danger of the Popperian strategy that Marcus and Berent invoke is that one might prematurely reject a theory based on "falsification" data that are themselves poorly understood.

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TECHNICAL COMMENT ABSTRACTS

COMMENT ON "Parasites as a Viability Cost of Sexual Selection in Natural Populations of Mammals"

Brandon Brei and Durland Fish

Sexual difference in mammalian home range is a proximate mechanistic basis for sex-biased parasitism that Moore and Wilson (Research Articles, 20 September 2002, p. 2015) did not consider. Neither that study nor the accompanying analysis of human mortality data by Owens (Perspectives, 20 September 2002, p. 2008) support male immuno-inferiority, as Owens suggested.

Full text at www.sciencemag.org/cgi/content/full/300/5616/55a.

RESPONSE TO COMMENT ON "Parasites as a Viability Cost of Sexual Selection in Natural Populations of Mammals"

Kenneth Wilson, Sarah L. Moore, Ian P. F. Owens

Sex differences in home range size do not provide a mechanistic basis for sex-biased parasitism in wild mammals. Further new analyses show that in contemporary human populations, men are more than twice as likely to die from parasitic diseases as women, which suggests that parasites contribute to male-biased mortality both in wild mammal and human populations.

Full text at www.sciencemag.org/cgi/content/full/300/5616/55b.