What can we learn from monkeys about orthographic processing in humans?

A reply to Ziegler et al.

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Through two provocative papers (Grainger et al., *Science*, 2012; Ziegler et al., *Psychological Science,* in press), six baboons have recently become unexpected contributors to reading research. The baboons were trained using operant conditioning to differentiate between repeated four-letter "word" stimuli with high-frequency English bigrams, such as DONE, and four-letter "nonword" stimuli with low-frequency bigrams, such as VIRT. The papers report that the baboons learned to discriminate the words from the nonwords with relatively high-accuracy, and like humans they also showed transposed-letter effects (the baboons tended to confuse nonwords as belonging to the "word" category they had been trained on, if they involved letter transpositions (DNOE-DONE). The authors argue that since baboons do not have a linguistic system, but nevertheless perform like humans, the neural mechanisms underlying orthographic processing in the two species must be similar and therefore nonlinguistic.

We will argue that these conclusions are logically fallacious and do not withstand empirical scrutiny. If performance of baboons with printed material is at all similar to that of humans, it does not follow that the neural mechanisms underlying orthographic processing of humans is similar to that of baboons. Similarly, the presence of transposed-letter effects in the absence of a linguistic system does not imply the absence of linguistic modulation of transposed-letter effects. More importantly, however, close inspection reveals that the baboons' behavior as reported by Ziegler et al., is critically different from that of humans.

The issue at stake is the extent to which humans and baboons respond similarly to misspellings of words that contain transposed letters. Studies that have examined the

impact of manipulating letter-order on reading performance in humans have shown a small cost of letter-transpositions in terms of reading time, along with robust masked priming effects when primes and targets share all of their letters but in a different order (e.g., Perea & Lupker, 2003). In their recent paper, Ziegler et al. have shown that the six baboons classify both words (DONE) and their transposed letter version (DNOE) as "words". While at first glance, this finding may seem to be similar to that of humans, Ziegler et al. seem to forget that the transposed letter phenomenon presupposes a substantial ability to differentiate words from their transposed letter versions in the first place. Considering the baboons absolute level of accuracy, they seem to consistently perceive the transposed-letter versions as "words", making as many positive responses to trained words as they make false positive responses to transposed letter nonwords. This stands in sharp contrast to humans who correctly reject transposed letter nonwords in a lexical decision task (albeit more slowly and slightly less accurately than nonwords with substituted letters, e.g., Chambers, 1979). Thus, humans have *a genuine flexibility in coding letter position <u>in spite</u> of the explicit knowledge that letter-order matters in constructing words*. For now, the only thing that has been shown is that baboons have learned that the presence of certain shapes or symbols in a series has a relation to a particular response category, and that the order in which they are presented does not matter. This does not mean that they demonstrated "flexible" letter-coding. Moreover, as Ziegler et al. report, the baboons could not discriminate between "words" and nonwords that were one-letter different, again in sharp contrast to humans. This suggests that a critical proportion of mismatches is required for two series of shapes to be considered different for baboons, demonstrating severe limitations on how far "orthographic processing" can develop non-linguistically via the object recognition system. Ziegler et al., also seem

to forget that transposed-letter effects for humans are not always present, and are modulated by the linguistic properties of the stimuli (e.g., Dunabeitia et al., 2012, see Frost 2012a,b, for a review). Baboons by definition are blind to such linguistic factors.

Comparing abilities of humans and non-humans allows us to trace the demarcation line between processing mechanisms shared with other species and those that are specifically human. However, such investigations should also seek the point at which performance of species *diverges*, rather than halt at an apparent convergence. For example, finding that both humans and rats can segment a stream of continuous speech (e.g., Toro & Trobalon, 2005) does not imply that *the cues* that govern speech segmentation are identical for humans and rats. Indeed Toro and Trobalon demonstrate that rats are sensitive to simple frequency of co-occurrence, whereas humans rely on transitional probabilities. Returning to "reading" performance of baboons the results simply show that baboons can learn probabilistic conjunctions of 3-4 individual shapes, and that this learning does not extend to the order of the shapes. Whether this form of statistical learning should be labeled "orthographic processing" seems very doubtful. More important, the data regarding how letter transpositions affect baboons vs. how they affect humans, certainly does not suggest that the processing mechanisms for orthographic information are the same in the two species. The inevitable conclusion is, therefore, that the recent findings with baboons reveal something about their statistical learning abilities, but have no important implications for theories of human visual word recognition.

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