Letters Response

Response to Carreiras *et al*: The role of visual similarity, feedforward, feedback and lateral pathways in reading

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Carreiras *et al.* [1] envisage their priming experiment as a severe challenge to our model of local combination detectors (LCD) [2]. However, we feel that the results can easily be accommodated by the LCD model and, in fact, by essentially all current models of reading. Carreiras *et al*'s main finding is that a few letters of a masked prime word can be replaced by resembling digits or symbols, without affecting the amount of masked priming too much. This effect might simply indicate that the letter detectors, which are thought of as the front end of invariant word recognition, tolerate some shape distortion, thus enabling the letter detector for 'A' to react to 'Δ' or '4'. In our LCD model, we insisted that the postulated letter detector neurons rest on a robust pyramid of lower-level feature detectors with increasingly larger receptive fields and with a considerable redundancy. For instance, a neuron sensitive to letter 'A' would receive a convergence of inputs coding for two diagonal bars and a horizontal bar, with some tolerance on their exact placement and orientation. That such a receptive field would be capable of responding (perhaps slightly less well) to symbols Δ or 4 does not seem astonishing. It would be analogous to the finding that in monkey inferotemporal neurons sensitive to complex shapes, a simpler combination of visual features can often be found that makes the neuron discharge just as much [3,4]. Following this letter stage, processing would continue at bigram, morpheme and word levels with only a minor reduction in the amount of bottom-up information. Thus, it seems that a bottom-up model alone could account for the experimental findings.

There are, however, other possible interpretations of the findings. Research on bigram priming has demonstrated that a word (e.g. 'material') can be primed by the mere presentation of a subset of its letters (e.g. 'mtril'), provided that a sufficient number of open bigrams is preserved [5]. Given that Carreiras *et al.* only substituted a few letters of a long word with digits or symbols (e.g. 'M4T3R14L'), it seems possible that the remaining letters (M T R L) sufficed to cause priming. The 'control letters' stimulus used in Carreiras *et al.*'s experiment one (e.g. 'MOTURUOL') is inappropriate because it introduces additional bigrams not present in the target, which is known to kill the priming effect. The 'control leet' stimulus

(e.g. 'M6T2R76L') used in experiment two is better, but might still cause some activation of inadequate bigrams by the same letter similarity mechanisms discussed before. It would have been better to compare the amount of priming caused by 'M4T3R14L' with a prime with deleted letters ('M-T-R- - L', see Ref. [5]) to verify whether the effect is truly a facilitation owing to letter similarity.

Finally, we never intended our LCD model to be a purely feedforward model. Our paper explicitly mentions that 'feedback and lateral connections are numerous in the visual system, and probably contribute to shaping the neurons' receptive field, for instance by enforcing probabilistic relations amongst consecutive letters, or by disambiguating letters and bigrams within words (thus explaining the word superiority effect)'. Whether feedback contributes to Carreiras *et al.*'s experiment is unclear, however. Perhaps the context of the letters M and T helps to categorize stimulus 4 as a poor instance of letter A in 'M4T3R14L' – internalized statistics about the transitional probabilities of letters, which are known to be represented in the left occipitotemporal visual word form system [6,7], might provide mutual support among letter detectors by means of reciprocal lateral connections. However, there is nothing in Carreiras *et al.*'s experimental design that forces such an interpretation – visual similarity alone can explain the results. The bulk of the evidence, indeed, suggests that heavily masked and non-conscious stimuli do not engage recurrent connections [8]. We close by noting that this feedforward/feedback debate could be addressed by examining where and when in the brain the 'leet' priming effect first occurs, for instance using scalp or intracranial event-related potentials [9,10].

References

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