Neural coding and the anticipation of complex visual stimuli

Mike W. Oram, Dengke Xiao, Nick E. Barraclough and David I. Perrett
School of Psychology, University of St. Andrews, KY16 9JU, UK.
Email mwo@st-andrews.ac.uk

Using a simple model of visual encoding and decoding we have investigated the implications of forward masking of visual responses by one stimulus on the presentation of a second stimulus for the recognition of target stimuli when presented in ordered sequences (e.g. the detection of a face in a sequence of images depicting a rotating head). The results of the neuronal modelling, based on observed neuronal activity in the superior temporal sulcus of the macaque, provide a mechanistic account of human behavioural data related to speed and accuracy of recognition of target stimuli when presented in sequence compared to performance of the same images presented in isolation.

We have recently found that the neuronal encoding of visual stimuli in the superior temporal sulcus of the macaque monkey depends on the previous stimulus and the delay between stimuli (Xiao et al, in submission). Specifically, if a visually presented stimulus elicits a high neuronal response, the response of the neurone to a subsequent visual stimulus will be reduced. The reduction in response magnitude to the second stimulus decreases monotonically with the interval between stimuli but is still observed at delays of over 450 ms. The forward masking found pairs of stimuli is dependent on the mean neuronal response to the first stimulus rather than the trial-by-trial activity of the neurone, suggesting forward masking is a function of the network rather than attributable to simple cellular mechanisms (e.g. fatigue).

Observed neuronal responses to sequences of stimuli can be accurately modelled using the “masking function” of neurones. The accuracy of the model depends on assuming (1) that the masking effect is due to the mean response of the neurone to the stimulus presented alone rather than the ongoing activity of the neurone (as we see in the empirical data), (2) the time-course of the masking is approximately that seen in the single unit data and (3) the masking is cumulative (i.e. masking from successive images is additive). These results suggest that the model used is consistent with observed neuronal coding of visual stimuli.

Decoding of the modelled neuronal activity was based on the activity of simulated populations of neurones with the same masking functions as observed empirically (Xiao et al. in submission). A population vector decoding approach was used, although it is noted that optimal Bayesian decoding would, given the nature of the modelled population, yield similar results. The decoding indicates that, when presented in the appropriate sequence of images, the neuronal activity would “anticipate” the appearance of a target. This anticipation would lead to faster recognition reaction times and, if the target stimulus did not appear, an increase in the number of “false positive” decisions.

The behavioural predictions based on observed neuronal encoding and modelled decoding were tested using human subjects. The results were consistent with the predictions, adding further evidence that behavioural phenomena, traditionally viewed as requiring “cognitive” processes, can be explained in terms of neuronal encoding of the input stimuli (Oram, under revision)

References

Xiao D-K, Barraclough N.E., Keysers C., Oram, M.W., Perrett, D.I. Forward masking shown by neurons in temporal cortex. (In submission).

Oram, M.W. Integrating neuronal coding into cognitive models: Predicting reaction time distributions. (Under revision, Network – Computation in Neural Systems)