Contrast, stimulus selectivity and neuronal responses

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ABSTRACT

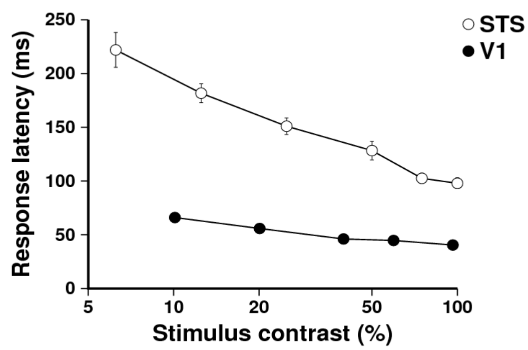

Figure 1. Stimulus contrast influences response latency more in late visual areas (STS) than in early areas (V1).

Neurones in visual cortex are known to show increasing response latency with decreasing stimulus contrast [1-5,7,9]. Neurophysiological recordings from neurones in inferior temporal cortex (IT) and the superior temporal sulcus (STS), show that the increment in response latency with decreasing stimulus contrast is considerably greater in higher visual areas than that seen in primary visual cortex (33±3ms versus 8±0.8ms for each halving of stimulus contrast, $F_{[1,7]}=56.8$, $p<0.0005$; Figure 1 and [6]). This suggests that the majority of the latency change is not retinal or V1 in origin, instead each cortical processing area adds latency at low contrast.

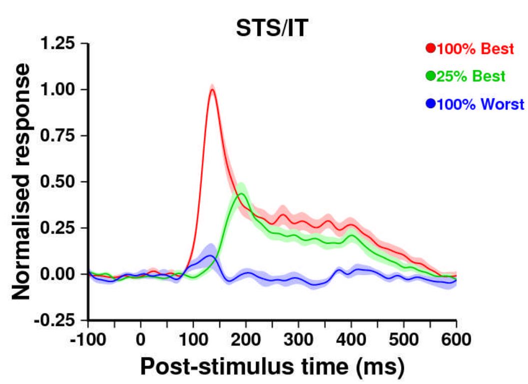

Figure 2. Stimulus contrast influences response latency more than response magnitude.

Figure 2 shows the average spike density function of STS neurones to effective (red) stimuli when presented at high (100%) contrast (red line). When effective stimuli are presented at low (25%) contrast there is a noticeable increase in response latency (green). Note, however, that despite the very small response, responses to ineffective stimuli have the same latency as the most effective stimuli.

Following [4], the extent to which response amplitude and latency varied with stimulus identity and stimulus contrast was examined. For recorded cells tested with stimuli that elicited significantly different mean spike counts (ANOVA, $p < 0.05$), stimulus contrast accounted for 67±7% of the variability of response latency and only 33±3% of the variability in spike count. Conversely, stimuli identity accounted for 69±6% of the variability in spike count and only 20±5% of the variability on response latency. Thus, in areas STSa and IT stimulus contrast is encoded mostly by response latency whereas stimulus identity is encoded mostly by response magnitude, the same reversal as observed in V1[4,8].

The neurophysiological recordings from some neurones in higher visual areas can show increases in response latency of up to 300ms when stimulus contrast is reduced to 6%. Other neurones, however,

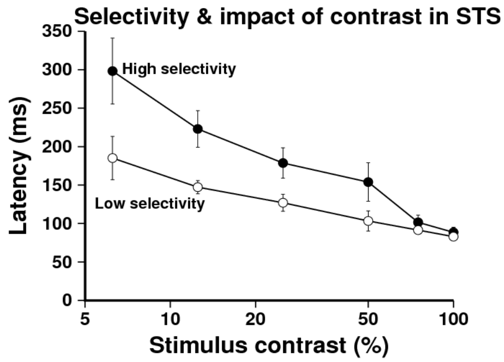

Figure 3. Sensitivity of response latency to stimulus contrast varies with selectivity.

show barely detectable increases of less than 5 ms over the same range of stimulus contrasts. Thus, neurones in IT and STS that respond to the same visual stimulus become increasingly asynchronous as stimulus contrast is reduced. While increasing asynchrony of visual responses at low contrast could reflect heterogeneity of neurones it is also possible that such asynchrony reflects functional aspects of visual processing. A median split according to the number of stimuli that elicit a response gives rise to a group of neurones that respond to many stimuli and a group that respond to a small number of stimuli. The sensitivity of response latency with stimulus contrast differs between these two groups (Figure 3). Specifically, the response latency of neurones that respond to many stimuli is less sensitive to stimulus contrast than those neurones which respond to only a small number of stimuli.

The relationship between the level of selectivity and contrast sensitivity raises the possibility that the increase in latency with decreasing stimulus contrast is an adaptive mechanism. As a simple example, consider that when a linear computation is performed, errors caused by the stochastic nature of spikes can be compensated by subsequent integration of the output. However, for non-linear computations noise-induced errors cannot necessarily be corrected by integration of the output. In other words, non-linear computations with signals of limited quality require signal integration *before* the computation otherwise errors may not be correctable. Thus it is reasonable to hypothesize that simple relatively linear computations require a smaller increase in latency at low contrast than complex, non-linear computations. It is of course possible that neurones which respond to only a small number of stimuli are responding to particular features that require no more complex computation to detect than the computation required to respond to many images. While it is by no means clear – at least to this author – whether the extent the number and range of stimuli to which a neurone responds relates to differences in the computational complexity, it is intuitively appealing and worthy of further investigation.

Keywords: Response correlation, Inferior temporal cortex, stimulus contrast.

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