The influence of stimulus contrast on response latency and response strength of neurones in the superior temporal sulcus of the macaque monkey

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Abstract

We examined responses of single neurones in the superior temporal sulcus and inferotemporal cortex to stimuli varying in internal contrast. We found the response latency increased with decreasing contrast for all recorded neurones. The increase in response latency is not due to changes in response magnitude although response magnitude decreased with decreasing stimulus contrast. Additionally, response latency decreased when the presentation rate was increased. We conclude stimulus dependent changes in response latency are mostly determined by stimulus contrast, with both response magnitude and presentation rate having a small influence.

Introduction

Response latency increases as stimulus contrast decreases in early visual areas (retina, LGN, V1). Studies examining the responses of neurones in the inferior temporal lobe and superior temporal sulcus to changing stimulus contrast report changes in response magnitude, but not response latency. We re-examined the responses of such neurones to stimuli of different contrasts.

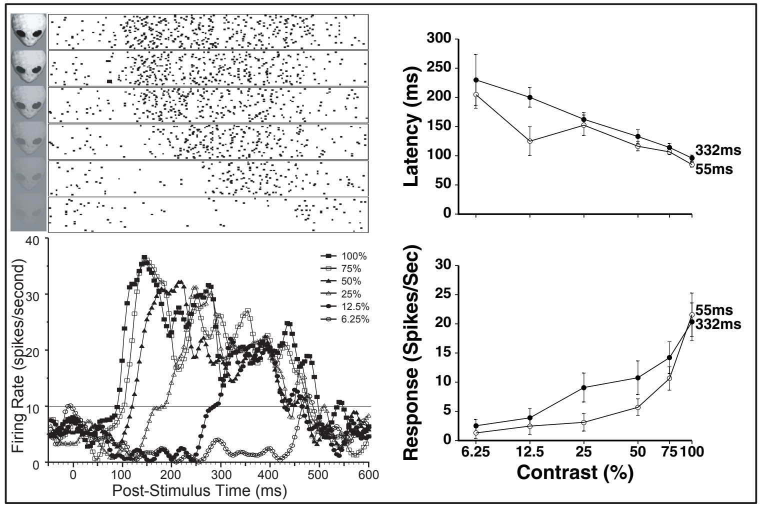
Methods

Extra-cellular single-unit recordings were made using standard techniques from the upper and lower banks of the anterior part of the superior temporal sulcus (STSa) and inferotemporal cortex (ITC) of a monkey (*Macaca mulatta*) performing fixation task.

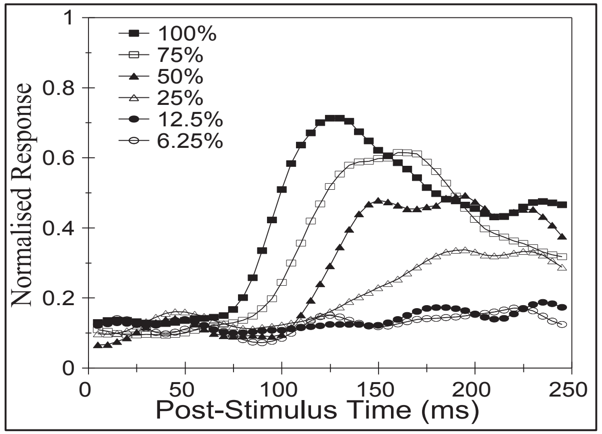
During initial screening 38 images of different perspective views of monkey and human head, animals, fractal patterns, natural scenes, and everyday objects were presented (110ms, 0ms ISI). The various contrast versions of a cell's preferred, non-preferred and at least one intermediate stimulus were presented in random order either at fast (55ms per stimulus) or slow (332ms per stimulus) rates.

The 100% contrast $(L_{max}-L_{min})/(L_{max}+L_{min})$ version of an image was prepared by normalising the foreground pixel values such that they occupied the monitor's full luminance range. Other contrasts (75-6.25%) were achieved by varying the width of the distribution of the foreground pixel values while maintaining the average luminance. [All manipulations were performed using the measured gamma function of the display monitor].

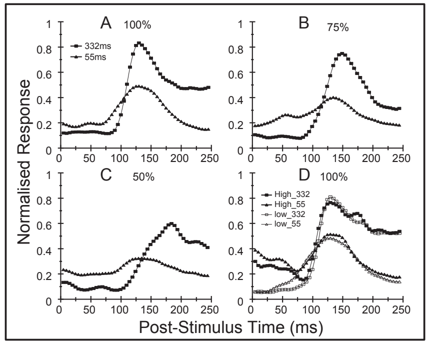
Results



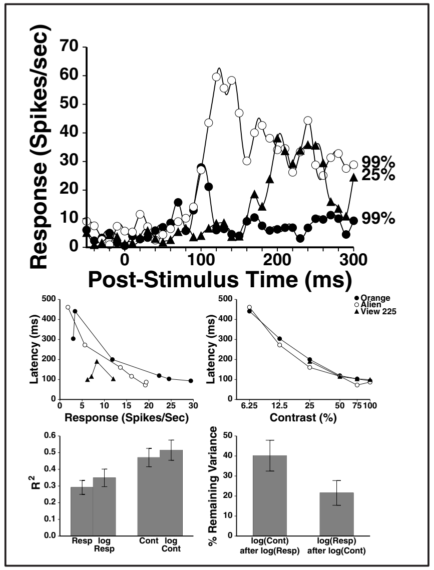
Left: Example responses from a single neurone. The response onset latencies (93, 103, 119, 185, 292, 468 ms) increased as the stimulus contrast decreased (100%, 75%, 50%, 25%, 12.5%, 6.25%). Despite different onset latencies, the response end at the same time (486?18ms). **Right: Average response latency depends on contrast and presentation rate**. The average latency is shorter to high contrast stimuli and when stimuli were presented faster (ANOVA: Contrast: $F_{[5,116]}=17.1$, $p < 0.0005$; Presentation rate: $F_{[1,116]}=7.2$, $p < 0.01$; Interaction $F_{[5,116]}=1.1$, $p>0.3$). **Response strength varies with contrast and presentation rate.** Response strength drops 50% ~every quartering (332ms) and every halving (55ms) of contrast Contrast: $F_{[5,192]}=20.9$ $p < 0.0005$, Rate: $F_{[1,192]}=4.0$, $p<0.05$).



Population response. The spike density function of 21 neurone (332ms presentation) was normalised to the peak response to the 100% contrast stimuli and averaged. Similar effects are seen at the faster rate.



Change in latency with presentation rate. A-C: Average responses are shown for 100, 75 and 50% contrasts. D: Responses to 100% contrast stimuli split into those with high and low pre-stimulus activity. Note the pre-stimulus activity level does not influence the response latency.



Changes in response strength do not explain latency changes. **Upper**: Spike density functions from one neurone to one low contrast and two high contrast stimuli. The response latency to high contrast stimuli are equivalent while the latency to the low contrast stimulus has a long latency despite a larger response than one of the high contrast stimuli. **Lower panels**: Example plots of latency against response strength and latency against contrast. Bottom Left: The R^2 is higher for latency~contrast than for latency~response strength. Bottom Right: Addition of contrast into the regression after response strength explains ~40% of the remaining variance. Response strength explains ~20% of the variance above that explained by contrast.

Conclusions

1. Stimulus contrast affects response strength
2. Stimulus contrast has a powerful effect on response latency
3. Response magnitude has a small but significant effect on response latency
4. Changes in response latency cannot be explained as a consequence of response strength
5. Presentation rate has a small but significant effect on response latency