1. Overview

We previously presented a simple computational model which appeared to account for the attentional modulation of human psychophysical thresholds. In that previous study we used a top-down attentional signal to modulate the gain of visual filters in a manner that corresponded to what we called a "hypercolumn," and reported a good account for the observed effects, in which attention strengthens competition among visual neurons. Here we explore whether more specific attentional mechanisms, underlying task-dependent filter populations is also plausible.

2. Motivation

Several groups have reported enhanced neural activity in visual neurons responding to the visual field which the animals attend to. Similarly, using psychophysics, we have measured significantly better pattern discrimination performance when attention was fully available for the pattern discrimination task compared to when we single-tasked by a concurrent language task.

Assuming a simple unified model for all psychophysical tasks and inattention paradigms, at all times in our model equally, the attentional signal can modulate the responses of different types of the visual filters. Thus, the attention strengthens competition among visual filters. Shifting attention paradigms increase the gain of the filters. Three factors, as well as a sharpening of filter tuning for orientation and spatial period, by up to 50% (Bai et al., 1995; Kishida et al., 1999).

Here we investigate whether a number of selective manipulations (involving only gain in inattention paradigms) but affecting specific subpopulations of filters rather than all filters, may also predict the observations. Additionally, we analyze whether attention could affect the gain of specific filters in a more specific manner (can be performed in a selective, gain-only, filter-and-task independent manipulation).

Specifically, we investigate whether:
- Attention could affect the gain of only the filter responding most vigorously (loudest)
- Attention could affect the gain of the filter best-tuned to the target stimulus
- Attention could affect the filter most informative about the target
- Attention could affect the gain of all filters equally, but by different amounts depending on the task.

3. Psychophysics of Lee et al.

Split in attention paradigm: attentional focus of the peripheral visual field, along with a selective attention task of fixation. In the "Peripheral" condition, observers only report on the peripheral pattern discrimination, while maintaining central fixation. With equally intense input, the "Peripheral" condition, observers report on the central target. Filter selectivity in the peripheral task depends on the spatial period discrimination.

4. Model

4.1. Model Architecture

Linear filter based on the input (Spa. freq. / Orientation)

Non-linear filters (sp. period / Orientation)

4.2. Excitatory and Inhibitory Pooling

Self-excitation and inhibition

\[ R_i = \sum_j W_{ij} R_j + R_i \]

Filter selectivity as weighted sum of the input:

\[ R_i = \sum_j W_{ij} R_j \]

4.3. Noise Model

Noise is noise given by:

\[ v_i = \hat{v}_i(P_{R_i} + \epsilon) \]

B: Light noise
C: Dark noise
E: x + \epsilon (average noise across x)
E: \epsilon (average noise across x)

4.4. Statistically Efficient Decision

Mean (T) = \frac{\text{signal}}{\text{variance}}

\[ \text{var}(T) = \hat{v}_i \]

\[ \lambda_i = \frac{\hat{v}_i}{\sqrt{\text{var}(T)}} \]

Filter selection (with or without attention)

\[ \lambda_i = \frac{\hat{v}_i}{\sqrt{\text{var}(T)}} \]

Reinforcement learning and selective attention

\[ \lambda_i = \frac{\hat{v}_i}{\sqrt{\text{var}(T)}} \]

4.5. Discussion & Conclusion

We found that none of the simpler gain-only attentional manipulations could explain the experimental findings as well as our presented manipulation: masking task - filter and independent intensified competition among visual filters.