Role of task difficulty in modulation of neural activity

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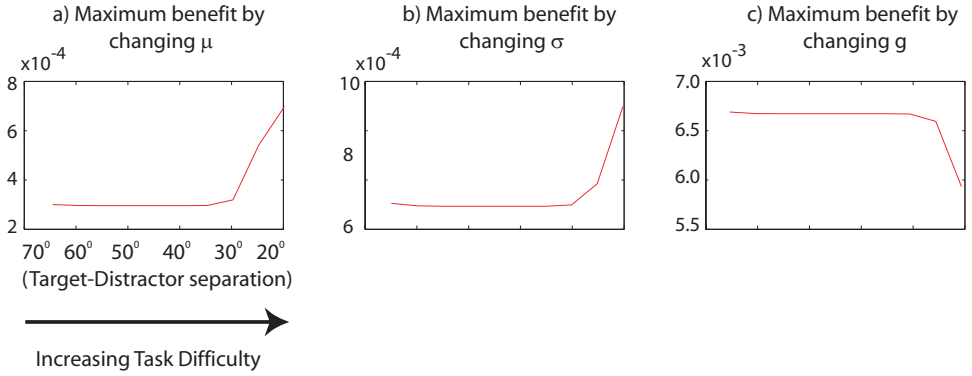
How does attentional modulation of a neuron's preferred feature (μ), or changing its tuning width (σ), or its response gain (g) benefit behavioral performance? We investigate this in the context of a visual search task, e.g., search for a vertical bar among horizontal bars (which becomes more difficult as the target orientation approaches horizontal). We consider $\mathcal{SNR}$ (ratio of expected population response to the target over the distractor) as the performance metric [1]. We compute the benefit in performance per unit change in μ, σ and g. Our simulation results show that changing σ can be beneficial or not, depending on the task difficulty due to target-distractor discriminability (measured here as separation in degrees between target and distractor orientation). We find that a unit change in σ is more beneficial in difficult than easy tasks (fig 1b). A similar trend is observed for changing μ (fig 1a). However, the opposite trend is observed for gain modulation – a unit change in g is more beneficial in easy tasks than difficult tasks (fig 1c).

These results suggest that gain modulation is more likely to be observed in easy tasks, while tuning width modulation is more likely to occur in difficult tasks. We suggest that the differences in task difficulty may resolve existing conflicts in the field on whether attention modulates gains or tuning width. Indeed, previous studies reporting gain modulation have used easy tasks (target-distractor separation around 45-90° [2], or target only without any distractor [3]), while studies reporting tuning width modulation have used difficult tasks (22.5°, [4]). We conclude that task difficulty plays a critical role in determining attentional modulation.



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