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Maximizing decision rate in multisensory integration

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Summary

Effective decision-making in an uncertain world requires making use of all available information, even if distributed across several modalities, as well as trading off the speed of a decision with its accuracy. Animal and human subjects have previously been shown in tasks with fixed stimulation presentation time to combine information from several modalities in a statistically optimal manner. Furthermore, for highly salient stimuli and under the assumption that reaction times result from a race-to-threshold mechanism, subjects feature multimodal reaction times faster than predicted from unimodal conditions when assuming independent (parallel) races for each modality. However, due to lack of adequate ideal observer models, it remained unclear if subjects maintain optimal cue combination as soon as they are allowed to choose their response times freely.

Based on data collected from human subjects performing a visual/vestibular cue integration heading discrimination task, we show that the subjects appear to feature worse discrimination performance in the multimodal condition than predicted by standard cue combination criteria from their behavior in the unimodal conditions. Furthermore, their multimodal reaction times are slower than those predicted by a parallel race model, opposite to what is commonly observed for highly salient stimuli.

Despite violating the standard tests of optimal cue combination, we show that subjects still accumulate evidence optimally across time and cue, even when the strength of the evidence varies over time. Additionally, they adjust their decision bounds, controlling the trade-off between speed and accuracy of a decision, such that they feature correct decision rates close to the maximum achievable value.

Further Details

We tested human multisensory integration in a reaction-time version of a fine heading discrimination task, with subjects being seated on a motion platform. They experienced motion with a Gaussian velocity profile in the vestibular condition, and a 3D random-dot optic flow stimulus in the visual condition. The subjects' task was to report at any time after stimulus onset if their perceived motion direction was left or right from straight ahead. As a standard test of optimal cue combination we check if the inverse variance in the combined condition, recovered from a cumulative Gaussian fit to the psychometric function, is the sum of the inverse variances of the two unimodal conditions. We investigate how multimodal reaction times relate to predictions of parallel race models by comparing their cumulative distributions to Miller's and Grice's bound, corresponding to the fastest and slowest reactions achievable by a parallel model, respectively. We show that optimal behavior is achieved by utilizing one diffusion model per condition, each weighting incoming information temporally by its reliability. These models are combined in the multimodal condition, weighted by the reliability of their corresponding stimulus. We compute the maximum achievable correct decision rate by these models by adjusting the model decision bounds while leaving all other parameters fixed to those resulting from previous fits to observed behavior.