Introduction

Humans integrate multimodal information (e.g., vision, haptics) statistically optimal according to a maximum likelihood estimator (MLE) [1]. Signals from different sensory modalities are weighted according to their reliability. Does attention affect integration of sensory signals? We apply a dual-task paradigm to examine whether selectively detracting attention from one sensory channel does change the weight attributed to this channel.

MLE Integration Model

Statistically Optimal Integration:

\[ JND = \sqrt{\sum_{i=1}^{n} w_i^2} \]

The combined visual/haptic estimate is the weighted sum of the unimodal estimates. Its variance is lower than the variance of either estimate.

Effect of Attention:

Model 1: Early Noise

Model 2: Late Noise

Adding a 'distractor'-task affects the unimodal estimates at an early level, prior to the integration of the multiosensory information. Selective influence (=increased variance) of the distractor on one sensory modality should result in a loss of weight attributed to this channel. Weights and JNDs are expected to be in agreement with the predictions of the MLE model.

Setup and Stimuli

Subjects feel and/or see a raised bar. The haptic stimulus is presented with two PHANToM force-feedback devices. The visual stimulus is a random-dot stereogram displayed on a CRT.

Procedure

Primary task: H, V, VH: Subjects estimate the size of the bar, either visually alone (V) or haptically alone (H) or by using information from both sensory channels simultaneously (VH).

A: Selective Influence of 'distractor'-task:

JNDs are higher when subjects perform a 'distractor'-task concurrently.

The vision-based estimates are significantly more affected by a visual 'distractor'-task than the haptics-based estimates, i.e. the 'distractor' does selectively detract attention from the visual modality.

B: Discrimination Performance (JND)

Bimodal JNDs of individual subjects vs. predicted JNDs:

Results

The combined estimates have significantly lower JNDs than the unimodal estimates (with and without distractor).

C: Weighting

Visual weights of individual subjects vs. prediction:

In the condition without distractor the relative visual weight corresponds to the predicted weight, indicating that subjects integrate visual and haptic information statistically optimally.

Conclusion

We found that adding a 'distractor'-task results in a decrement in performance in the main-task. The vision-based estimates are more affected by a visual 'distractor' than the haptics-based estimates.

In accordance with the MLE rule, JNDs in the cross-modal conditions (with and without 'distractor'-task) are lower than visual-alone or haptic-alone JNDs. This indicates that observers integrate visual and haptic information.

Cue weighting is not affected by the 'distractor'-task, suggesting that integration occurs at a preattentive level of processing.

Literature