Attention Does Not Affect Multisensory Cue Weighting

MAX-PLANCK-GESELLSCHAFT

MPI FOR BIOLOGICAL CYBERNETICS

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Introduction

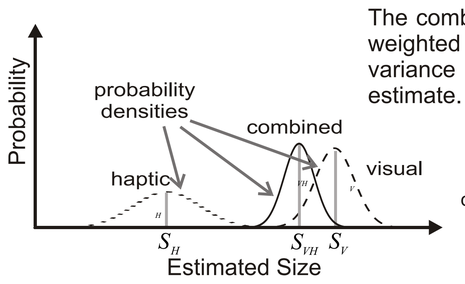
Humans integrate multimodal information (e.g., vision, haptics) statistically optimal according to a maximum likelihood estimator (MLE) [1]. Signals from different sensory modalities are weighted according to their reliability.

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:



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

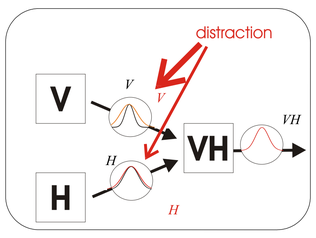
combined estimate: $S_{VH} \quad w_H S_H \quad w_V S_V$

variance of combined estimate: $\sigma_{VH}^2 \quad \frac{\sigma_H^2 \sigma_V^2}{\sigma_H^2 \sigma_V^2}$

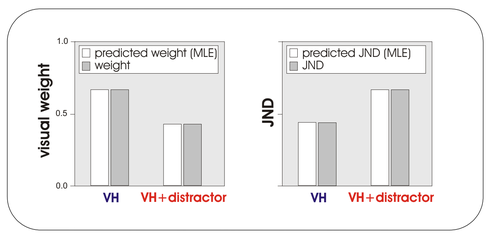
Effect of Attention:

Model 1: Early Noise

Assumption



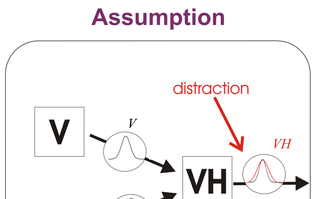
Predictions of Model1



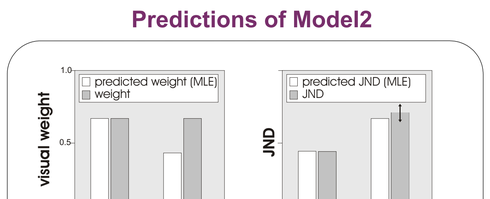
Adding a 'distractor'-task affects the unimodal estimates at an early level, prior to the integration of the multisensory information. Selective influence (->increased variance) of the distractor on one sensory modality should result in a loss of weight attributed to this channel. Weights and JNDs are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

Model 2: Late Noise

Assumption

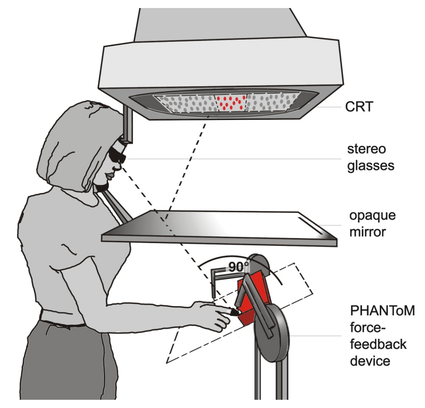


Predictions of Model2



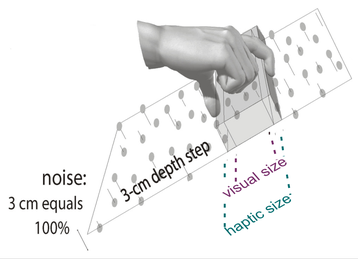
Adding a 'distractor'-task affects the combined estimate, integration occurs at a preattentive level. The weighting of information from different sensory modalities is not affected.

Setup and Stimuli

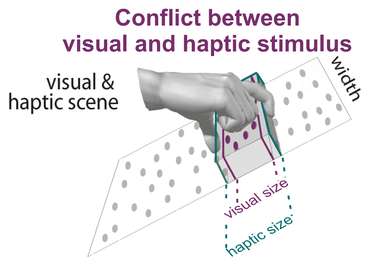


Subjects feel and/or see a raised bar. The haptic stimulus is presented with two PHANToM force-feedback devices. The visual stimulus is a random-dot stereogram displayed on a CRT.

Noise level



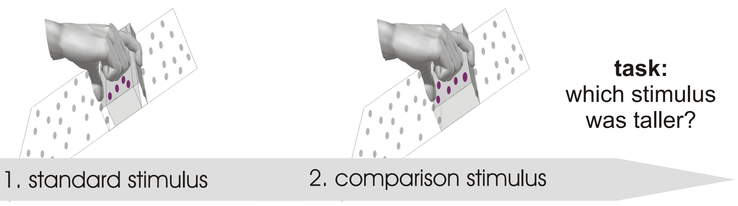
Conflict between visual and haptic stimulus



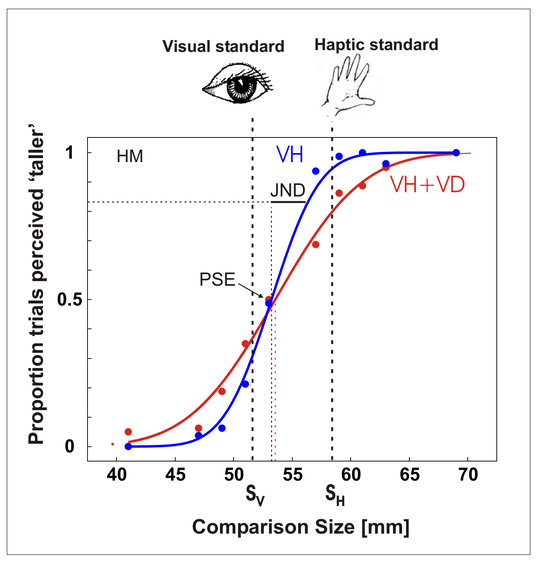
Procedure

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**).

2-IFC discrimination task



task: which stimulus was taller?



From the psychometric functions the just-noticeable differences (JNDs) and the points of subjective equality (PSE) were determined.

$JND \quad \sqrt{2}$

Visual 'distractor'-task: VD
The secondary task consists of discriminating two sequences of letters. The letters are presented on the upper surface of the bar, one sequence in each interval.

H K S Y = ≠ H K S L **task:** same/different?

Conditions:

	without 'distractor'	with 'distractor' VD
haptic alone:	H	H+VD
visual alone:	V	V+VD
visual-haptic:	VH	VH+VD

2 noise levels: 0%, 100%

Predictions of the MLE-model:

The predicted weights for optimal integration are calculated from the unimodal JNDs (JND_H, JND_V):

$$w_V \quad \frac{JND_H^2}{JND_H^2 \quad JND_V^2}$$

According the MLE rule, the combined estimates should have lower JNDs (JND_{VH}):

$$JND_{VH}^2 \quad \frac{JND_H^2 \quad JND_V^2}{JND_H^2 \quad JND_V^2}$$

In the cross-modal condition we introduce a conflict between the visual and haptic size stimulus. The shift of the PSE towards the haptic/visual input is a measure of the haptic/visual weight:

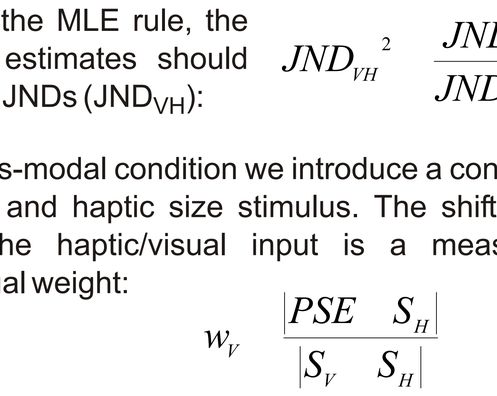
$$w_V \quad \frac{|PSE \quad S_H|}{|S_V \quad S_H|}$$

Results

A: Selective Influence of 'distractor'-task:

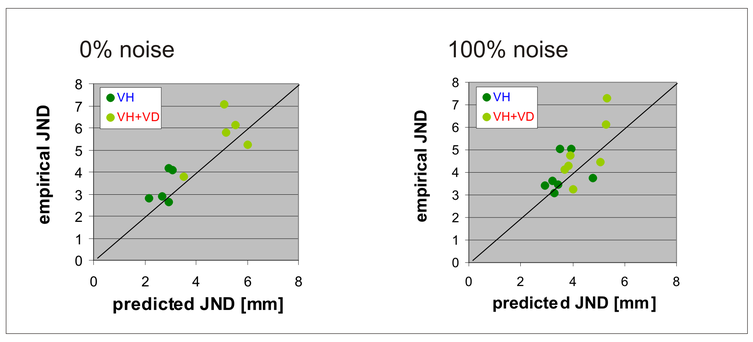
JNDs are higher when subjects perform a 'distractor'-task concurrently.

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.

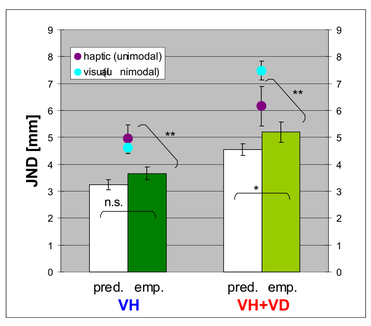


B: Discrimination Performance (JND)

Bimodal JNDs of individual subjects vs. predicted JNDs:



Bimodal JNDs collapsed across subjects & noise levels:



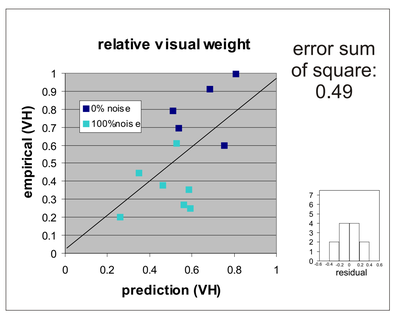
The combined estimates have significantly lower JNDs than the unimodal estimates (with and without distractor).

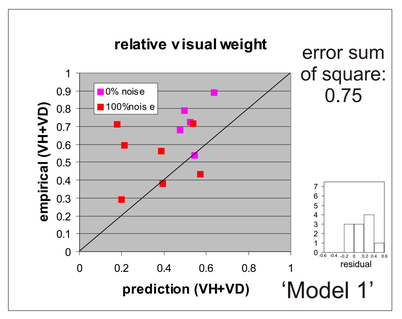
'With-distractor-performance' is indistinguishable from prediction.

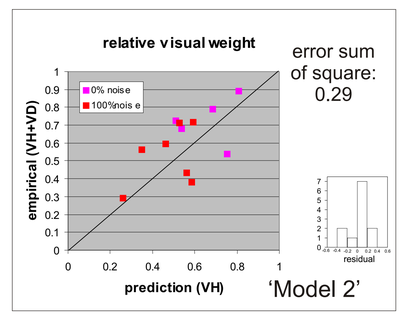
This indicates that observers integrate visual and haptic information, regardless of whether the 'distractor'-task is performed concurrently or not.

C: Weighting

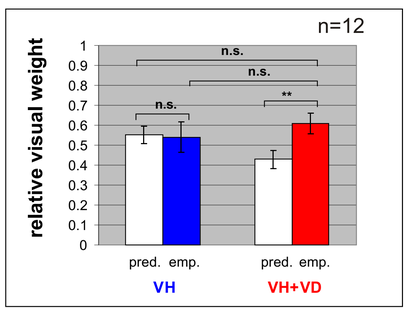
Visual weights of individual subjects vs. prediction:







Visual weights collapsed across subjects & noise levels:



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

Contrary to the 'Early Noise' model the visual weights are not affected by the distractor task but correspond to the weights without distractor. This argues for a 'Late Noise' Model.

Conclusion

Model1: Early Noise

Model 2: Late Noise

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

[1] Ernst, M.O. and Banks, M.: Humans integrate visual and haptic information in a statistically optimal fashion. Nature, 415, 429-433 (2002)

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