Visual-haptic integration: Evidence for dynamic rescaling of visual and haptic signals during tool use

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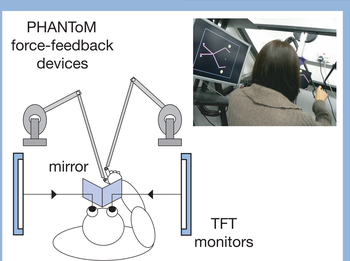
Background

For visual-haptic integration to be effective, the brain should only combine information referring to the same object. This could be achieved by considering the similarity of signals in the two sensory modalities. For example, if there is a large conflict between two size estimates it is unlikely that they originate from the same object (Ernst, 2007; Körding et al., 2007).

Humans are adept at using tools such as pliers, however, which systematically change the spatial relationship between the hand and object (*Takahashi et al., Journal of Vision, in press*), including the gain between (seen) object size and the opening of the hand.

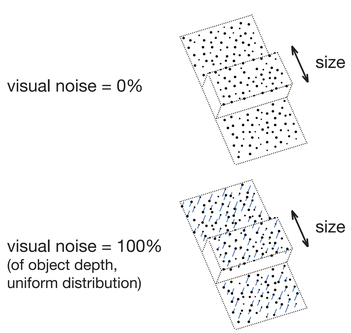
Here we investigate whether the brain takes into account the geometry of tools, and appropriately integrates "conflicting" visual and haptic signals.

Apparatus & Stimuli

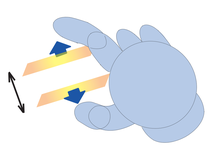


Visual Stimulus
(Random-dot stereogram)

- We manpulated visual reliability by adding a random displacement in depth to each dot (c.f. Ernst & Banks, 2002).

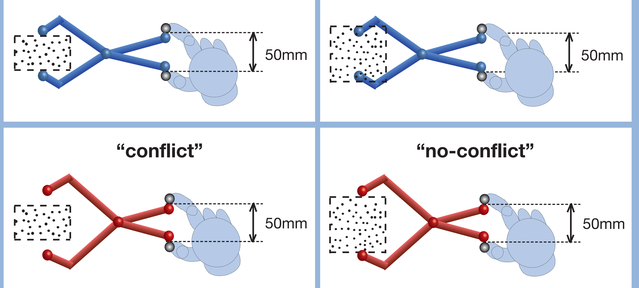


Haptic Stimulus
(Two force planes)



Tool use conditions

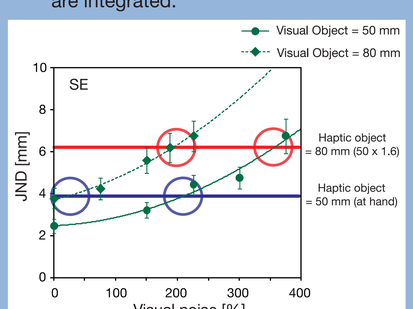
	Visual object size = 50 mm	Visual object size = 80 mm
Haptic object size = 50 mm **tool gain = 1 : 1**	**no-conflict**	**conflict**
Haptic object size = 80 mm **tool gain = 1.6 : 1**	**"conflict"**	**"no-conflict"**



- **The haptic stimulus at the hand was 50 mm in all conditions.**
- The visual stimulus was controlled by contact with the haptic object.
- The tool was extinguished *before* visual and haptic stimulus presentation.
- The four conditions, above, were randomly assigned trial-by-trial.

Single-cue conditions

- We measured size discrimination thresholds (JNDs), using a 2-AFC task, in vision-alone and haptic-alone conditions, in order to predict performance if the two signals are integrated.

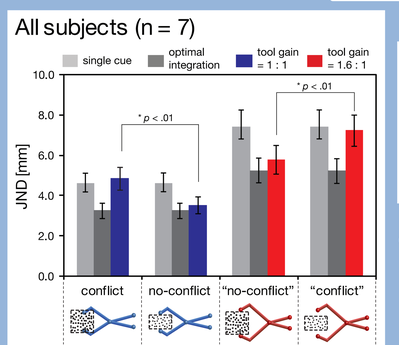


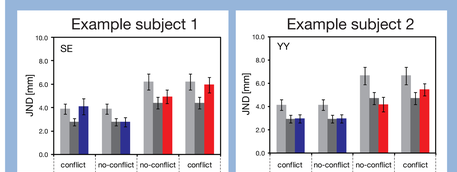
- A reduction in JNDs when both cues are available suggests visual-haptic integration.
- "Optimal cue integration" predicts maximum reduction in JNDs when cue reliabilities are equal:

$$\sigma^2_{VH} = \frac{\sigma^2_V \sigma^2_H}{\sigma^2_V + \sigma^2_H}$$

- **We matched the reliability of the visual and haptic signals in each condition, above, by adding visual noise.**

Results

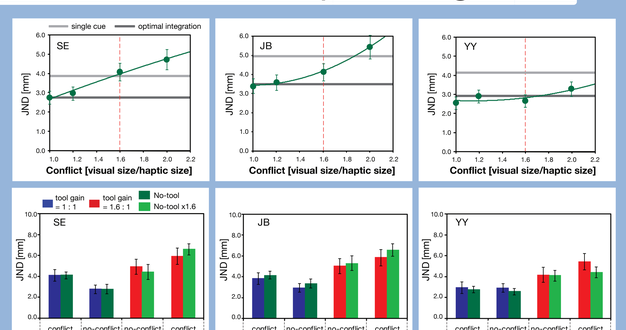




- Visual-haptic integration was based not on the similarity between the visual size and the opening of the hand, **but on the similarity between visual and haptic objects.**

Effect of conflict on visual-haptic integration

- We measured the effect of conflict between visual and haptic signals on cue integration **with no tool.**
- Individual differences in integration during tool use can generally be predicted from the effects of conflict with no tool.



Conclusion

- The brain takes into account changes in the relative scaling of haptic and visual signals introduced by tools (on a trial-by-trial basis).
- Visual and haptic signals are combined when they are caused by the same object, independent of conflicts between the visual size and the haptic stimulus at the hand.