Visual & Proprioceptive Integration in Reaching Movements

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Mirror illusion

A mirror can be used to present conflicting sensory information regarding the position of body parts. For instance, a mirror can present an apparent visual location of an arm which is in conflict with the real position perceived proprioceptively (& via touch).[5] This conflict can be used to study the integration of vision & proprioception.[3,4]

Visual bias

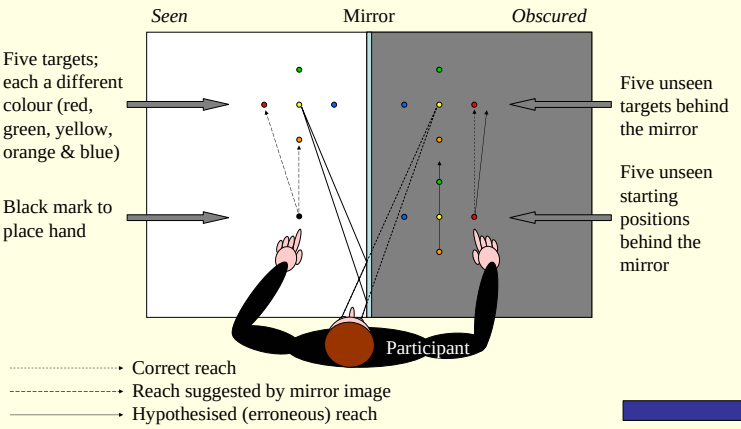
When presented with the mirror illusion, people are influenced in their reaching by the conflicting sensory information regarding the position of their 'unseen' hand. Visual input appears to dominate over other sensory modalities in this situation. People tend to make a greater reaching error in the direction suggested by the mirror, compared to control conditions.[3,4]

Weighted integration

The brain appears to integrate proprioceptive & visual (position-) information by a system of weighting based on unimodal efficiency.[1,2,6] One model is direction-dependent integration. Visual information appears dominant in the azimuthal, left-right, direction. Whereas proprioception plays a larger role in the radial, near-far, direction.[1,2]

Experiment 1: Forward reach

Participants (n = 15) had to reach to unseen targets situated behind a mirror in which they saw the reflection of a set of 'virtual' targets corresponding in position to the unseen targets. They fixated on the reflection of their own left hand or a block of wood.

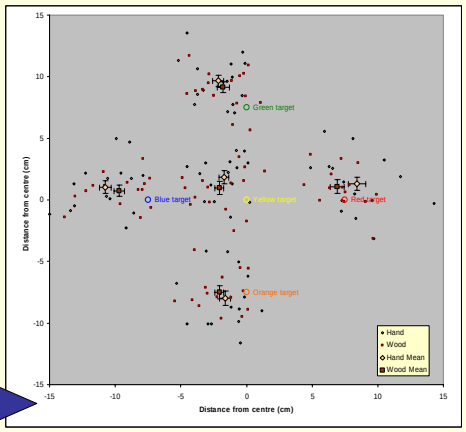


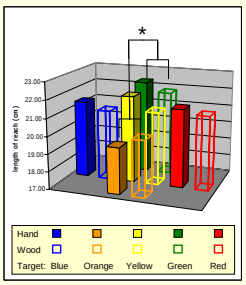
Methods:

- **Participants sat looking at a mirror in which they saw the reflections of five coloured targets & their left hand (or a control block of wood).**
- **The task consisted of reaching to one of the unseen targets behind the mirror from one of the starting positions with the unseen right hand.**
- **Six pseudo-randomised trials per target; five target conditions and two visual conditions (reflection of the left hand vs. reflection of a block of wood).**
- **In each trial:**
  1. **Participants viewed the reflection of their left hand / wood (9 sec).**
  2. **They were then told which target to gaze towards in the mirror (1 sec).**
  3. **They were instructed to reach for the target with their unseen right hand.**
  4. **The landing position of the reaching finger was recorded on graph paper.**
  5. **The right hand was then placed in the starting position for the next trial.**

Results E1:

Participants showed directional & distance errors; they reached more to the left & right for the left-right targets & nearer & further for the near-far targets when viewing a reflection of their left hand than when viewing a block of wood.



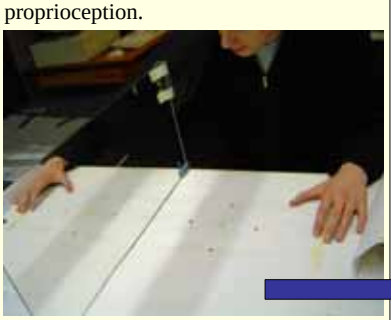


There was a significant interaction between the length of the reach & the position of the targets in the near-far direction.

Left-right (directional) error was significantly greater than near-far (distance) error.

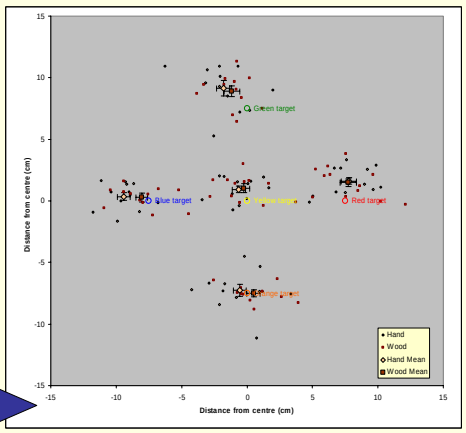
E2: Leftward reach

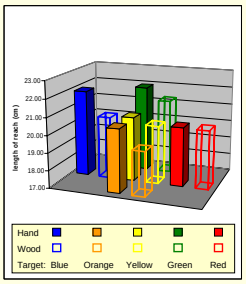
To study the effect of the direction of reach, a second experiment was set up. Participants (n = 12) reached sideways, perpendicular to the mirror. The difference in reaching errors between the left-right and near-far dimensions will change if the direction of the reach has an influence on the integration of vision & proprioception.



Results E2:

Participants showed a distance error; they reached more to the left & right for the left-right targets when viewing a reflection of their left hand than when viewing a block of wood. There was no directional error (near-far).





There was no significant interaction between the length of the reach & the position of the targets in any direction.

Left-right (distance) error was not significantly greater than near-far (directional) error

Conclusions:

• The mirror results reported in this study suggest that a visual bias is present even when participants only have to make a straight reach (and are explicitly aware of this fact).

• In forward reaching, the left-right (direction) errors were significantly greater than the near-far (distance) errors. This suggests a greater weighting of the visual information in this direction when reaching. This supports a direction-dependent weighting view of the integration of vision and proprioception (in this direction of reach).

• When reaching leftward, the left-right (distance) errors were again the largest, however they were not significantly different from the near-far (direction) errors. This suggest that the difference in reaching-errors between the directions of the targets is not due solely to the direction of the reach. However, it also does not suggest a clear direction-dependent weighting in this type of reach.

References:

1. Van Beers, R.J. et al. (1999). Integration of proprioceptive and visual position-information: An experimentally supported model. *Journal of Neurophysiology*, **81**:1355-64.
2. Van Beers, R.J. et al. (2002). When feeling is more important than seeing in sensorimotor adaptation. *Current Biology*, **12**:834-7.
3. Holmes, N.P. et al. (2004). When mirrors lie: "Visual capture" of arm position impairs reaching performance. *Cognitive Affective & Behavioral Neuroscience*, **4**:193-200.
4. Holmes, N.P. et al. (2005, submitted). Reaching with alien limbs: Visual exposure to prosthetic hands in a mirror biases proprioception without accompanying illusions of ownership.
5. Ramachandran, V.S. et al. (1995). Touching the phantom limb. *Nature*, **377**:489-90.
6. Sober, S.J. & Sabes, P.N. (2005). Flexible strategies for sensory integration during motor planning. *Nature Neuroscience*, **8**: 490-7.

More information: Crossmodal Research Group, Experimental Psychology Department, University of Oxford: www.psy.ox.ac.uk/xmodal/default.htm; M.Sc. Neuroscience & Cognition, Utrecht University: www.neuroscience-cognition.org

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