How the Arm Can Influence What We See

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Abstract

We show that kinesthetic information concerning the posture and movement of the arm can influence the visually perceived size of an object.

Introduction

If we hold an object in our hand, we can both see and feel how large it is. Similarly we can both see and feel its position. Visually and tactually perceived sizes are known to interact (Rock and Harris, 1967), as are visually and tactually perceived positions (Rock and Harris, 1967; Welch and Warren, 1986) and visually perceived size and position (Gogel, 1990). In the present study we examine whether visual judgements of *size* are influenced by kinesthetic information concerning the object's *position*. Does information about the posture and the movements of the arm and hand with which one is holding an object influence the object's perceived size?

Methods

Subjects were given a 5 cm cube that they were asked to look at before the experiment started, and to hold under the table in their left hand during the experiment. In their right hand, they held a rod attached to a similar cube. They held this cube behind a mirror (see inset in figure 1). A visual simulation of a cube was presented through the mirror at the precise position at which they held the cube attached to the rod, 25 mm closer to themselves, or 25 mm further away. The simulated cube always had the same orientation as the one in their hand, but its size was varied between trials. The simulation was presented binocularly at a rate of 60 Hz per eye (taking account of the positions of the eyes and of the cube, and of the orientation of the latter, with a delay of less than 50 ms).

Subjects were not allowed to hold the cube itself in their right hand, because doing so would lead to conflicts between vision and touch whenever the simulated cube was larger or smaller than 5 cm, and would confront the subjects with the peculiar sensation of seeing the cube "through" their hand. Each presentation started with 7 seconds during which the subjects were free to move the cube in their right hand, and thereby also the visible cube, around as they liked. After that, they had to indicate whether the cube they had seen (and moved around) was larger, the same, or smaller than the one in their left hand.

A measure of response frequency was calculated for each of the 6 subjects, 9 sizes of the simulated cube, and 3 spatial relationships between the real and simulated cubes. This measure was:

$$\text{response frequency} = \frac{L-S}{L+E+S}$$

Where L, E and S are the number of times the subject responded "larger", "equal" and

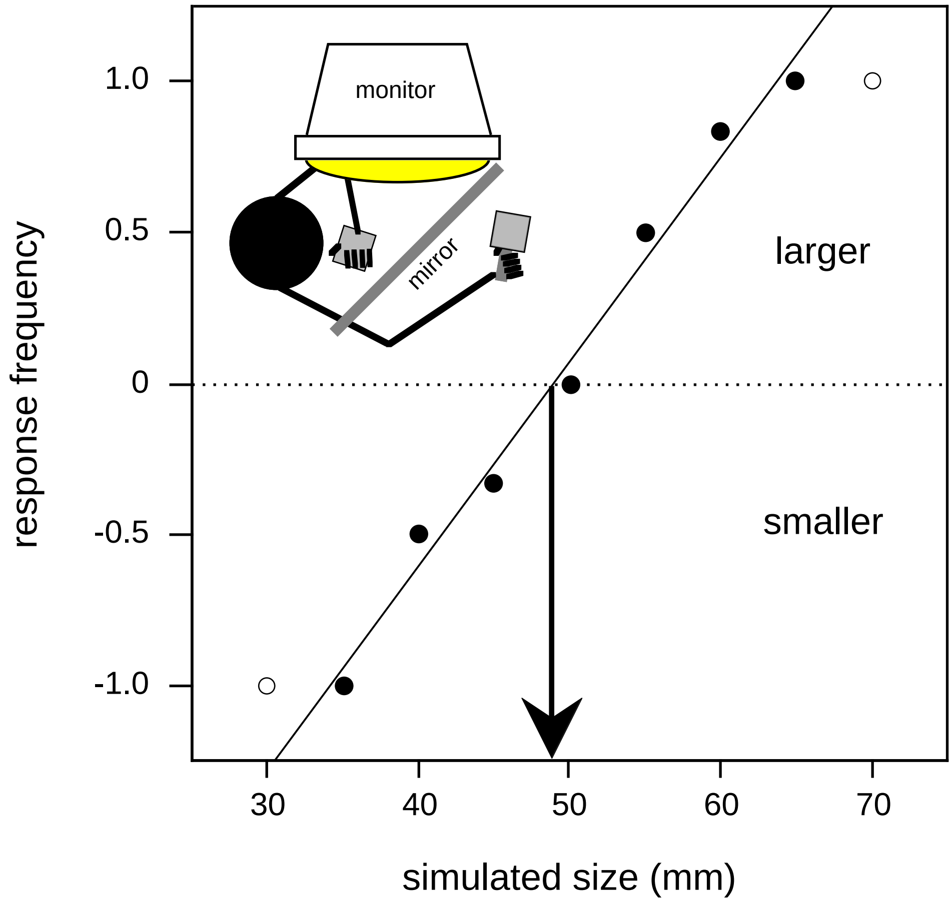

Figure 1 Sample data for one subject and condition

“smaller” respectively (each value was based on 6 presentations). From these values we estimated the size that matched the reference: the size of the simulated cube at which a linear fit to the relevant part of the data intersects the response frequency of zero. The relevant part of the data was defined as the section between the minimal and maximal obtained values of response frequency, including each of these values once. An example is shown in figure 1. The filled symbols show the values used for the fit. The arrow indicates the matching size.

Results and conclusions

Figure 2 shows the average matched size for all six subjects (± one standard error). The mismatch between the distance at which the cube was held and the simulated distance clearly influenced the perceived size. The influence was consistent with the visible cube being considered to be where it was held. When the cube was simulated 25 mm nearer than it was held, it was considered to be further away than the simulation, and thus to be larger (the same retinal size corresponds with a larger actual size if the object is further away). This is a strong effect: for a viewing distance of about 45 cm one would expect a change of about 3 mm at most in each direction, which is close to the values we find in figure 2. Thus, the kinesthetic information appears to be stronger than the conflicting visual information on distance.

As is evident from the standard errors, individual subjects made large systematic errors. Nevertheless, all subjects were very consistent in their judgements. As a

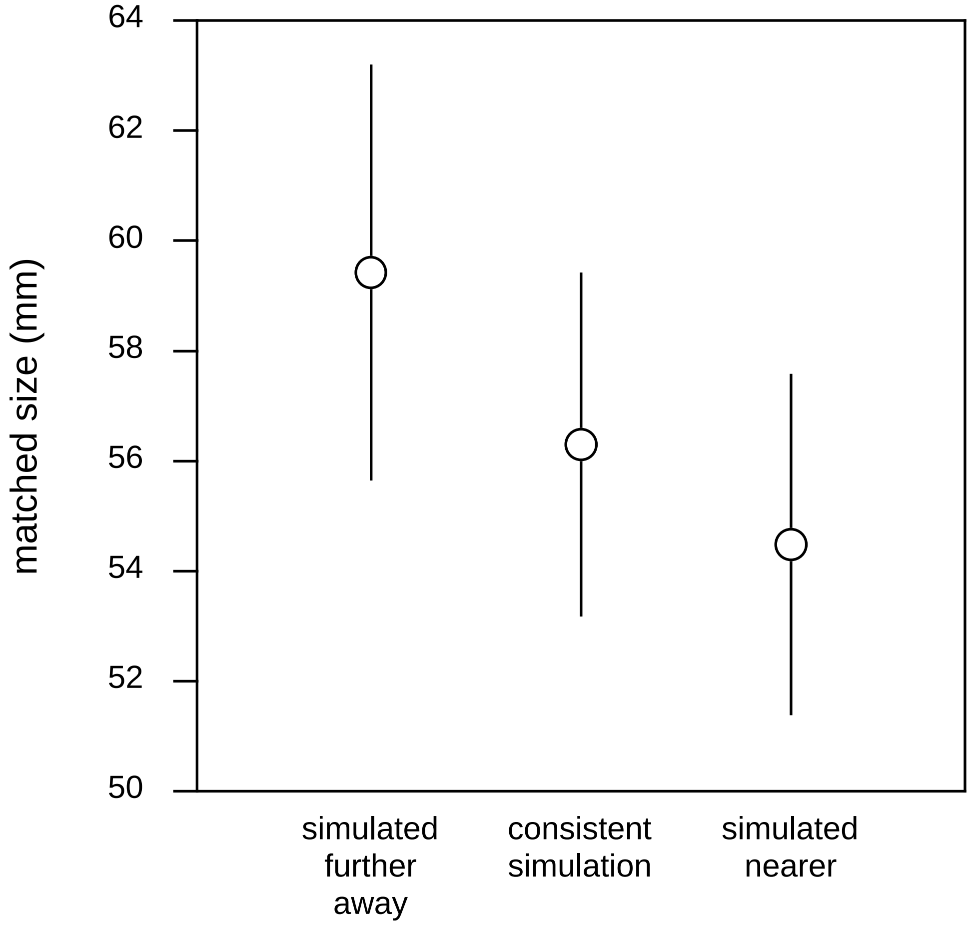

Figure 2 The average simulated size that matched the reference in the three conditions (±1SEM)

consequence, the differences between the three conditions were all significant ($p<0.05$) when tested with paired t-tests.

These results suggest that whereas vision dominates over touch for the perceived size of an object at a known distance (Rock and Harris, 1967), kinesthetic information from the arm (be it proprioception or efference copy, position or motion) dominates over information from the eyes when providing the information on distance that is required for interpreting retinal image size in terms of object size. However, there is an alternative explanation.

To ensure that subjects had optimal visual and kinesthetic information, we allowed them to move the rod around as they liked. Both vision and touch can benefit from such active, dynamic presentation (e.g. Burton, Turvey and Solomon, 1990; Johnston, Cumming and Landy, 1994; Oosterhoff, van Damme and van de Grind, 1993). This yields optimal stimuli, but the equivalence between the visual depth information in the different conditions is lost. Most importantly, unless subjects compensate for the 25 mm offsets in the positions of the simulated cube by holding the real cube nearer or further away, the simulated cube will - on average - be closer to or further from the subject on such trials. Although we tried to mask this effect by explicitly encouraging subjects to move the cube in depth, we cannot entirely exclude the possibility that failing to compensate for differences in the average distance to the simulated cube accounts for our results.

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