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RESEARCH NOTE

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Size illusion influences how we lift but not how we grasp an object

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Abstract Reaching out for an object is often described as consisting of two components that are based on different visual information. Information on the object's position and orientation guides the hand to the object, while information on the object's shape and size determines how the fingers move relative to the thumb to grasp it. We propose an alternative description, which consists of determining suitable positions on the object – on the basis of its shape, surface texture, and so on – and then moving one's thumb and fingers to these positions. This could lead to the same performance without requiring distinct visual information on the object's orientation or size. If so, an illusory change in size need not influence the distance between thumb and fingers when reaching out for an object. However, as the object's size is used to estimate its weight, the illusory change in size should influence the force that is exerted to lift the object. To find out whether this is so, eight subjects were asked to pick up brass disks from a fixed position straight in front of them. The illusory change in size was brought about by presenting five converging lines in two different configurations under the disks. As predicted, the illusion influenced the force used to lift the disks, but not the distance between the subjects' thumbs and fingers when reaching for the disks.

Key words Motor control · Visual pathways · Illusions · Prehension · Human

Introduction

Visual information concerning various object properties is analysed separately within our brains (Livingstone and Hubel 1988; Zeki and Shipp 1988). This has the advantage that the most suitable analysis can be used in each case. However, as a result, we are occasionally confronted with a perceived movement that does not correspond with the change in the object's perceived position (Abrams and Landgraf 1990; Brenner et al. 1996) or a perceived distance between two objects that does not correspond with the difference between their perceived positions (Loomis et al. 1992).

The separate visual analysis of diverse properties is also evident in the information used for visually guided action. In order to bring one's hand to a static target, one only needs to know the target's instantaneous position. Consequently, not having seen a target move (because it did so during a saccade) does not prevent one from moving one's hand to the target's new position (Bridgeman et al. 1979; Goodale et al. 1986), and illusory perceived motion of a target does not influence how one subsequently points at it (Bridgeman et al. 1981). When trying to hit a moving target, the target's velocity is essential information. In that case, subjects attune the velocity of their hand to suit that of the target, and illusory changes in target velocity do influence the velocity of the hand (Brenner and Smeets 1996; Smeets and Brenner 1995).

The preceding account illustrates the importance of knowing which object properties drive the aspects of an action that one is interested in. To gracefully pick up an object, the forces and movements of the fingers have to be appropriate for the object's position, shape, weight, surface texture, orientation, size, and so on (Iberall et al. 1986; Johansson and Westling 1984). For instance, how far the thumb and fingers have to be separated to grasp the object depends on the object. As the distance between thumb and fingers has to be about right *before* the hand reaches the object, it seems logical to assume that visual information on the object's size is involved (Jeannerod 1986). However, an illusory change in size hardly influences the distance between the finger and thumb when reaching out for an object (Aglioti et al. 1995). We suggest that this is because the opening between the finger and thumb is *not* determined by visual information about the size of the object, but by visual information about the positions at which the object will be grasped. This also results in a larger separation between

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thumb and fingers for larger objects, but on the basis of different visual information: information about positions rather than about size. If position and size are analysed separately (which is quite likely considering that *size* is an intrinsic object property whereas *position* pertains to the object's relationship to the observer), they may not be equally susceptible to illusions.

Once an object has been grasped, force has to be exerted to pick it up. One cannot see how much force is required to lift an object. Nevertheless, visual information can help predict this force, both by providing clues as to the material and by providing information on the object's size. Gordon et al. (1991a) showed that subjects consistently apply more force to lift a large object than to lift a small object of the same weight. When the weight is not kept constant, but varies in accordance with the volume, subjects apply a force that is appropriate for the volume (Gordon et al. 1991b). In the present study, subjects were asked to pick up brass disks of various sizes (Fig. 1). The use of a single material ensured that size was predictive of weight, so that the force required to lift the disk could be anticipated on the basis of its size. We examined whether a variation on a well-known size illusion (the Ponzo or railway-line illusion) influences this force.

Materials and methods

Figure 1 shows the general layout of the experiment. The disks that were to be picked up were painted black. They were all 3 cm thick, had diameters of 6.3, 7.0 or 7.7 cm and weighed 0.79, 0.97 or 1.17 kg, respectively. Eight subjects took part in the experiment, including the authors.

Subjects started each movement holding a 5-cm-diameter disk that was attached to the table on the right. They were instructed to pick the central black disk up and place it on the 9-cm-diameter disk on the left. They were asked to do so with a single flowing movement. The black disk was always initially straight in front of the subject. A background of converging lines (our version of the Ponzo illusion) could be placed at one of two positions. The diameter of the disk appeared to be about 0.8 mm smaller when the background was on the left (Fig. 1A) than when it was on the right (Fig. 1B).[1] The three disk sizes and two background positions were presented in random order (to each subject), with the limitation that each combination was presented ten times.

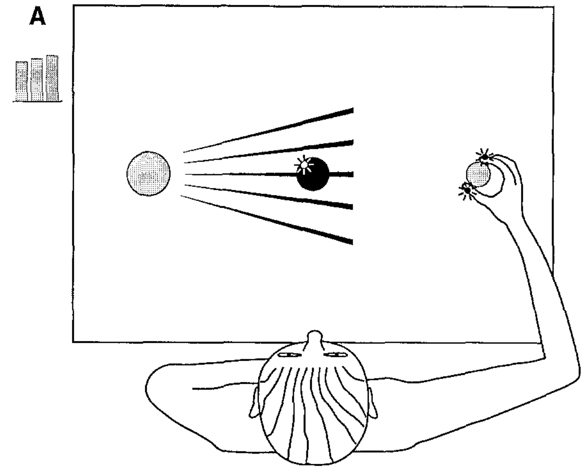
The positions of the thumb and index finger (middle finger for two subjects who preferred to grasp with that finger) and that of the central disk were determined to within 0.1 mm at a rate of 250 Hz with a movement analysis system based on infra-red light-emitting diodes (Optotrak 3010; Northern Digital). Trials were discarded if the markers were not visible throughout the movement. Altogether, 43 of the 480 trials (eight subjects, three disk sizes, two background positions, ten times each) had to be discarded.

The position traces were filtered (cut-off frequency 10 Hz) and a correction was applied for the fact that the light-emitting diodes were attached to the nails rather than to the tips of the finger and thumb. From these values, the maximal distance between the finger and thumb (in three-dimensional space) was determined for each trial. The force exerted to lift the disks was determined indirectly.

When lifting an object, the vertical force increases gradually until the object starts to move (Gordon et al. 1991a). The rate at which the vertical force increases depends on the anticipated weight of the object (Gordon et al. 1991a). Thus, the time between the moment the disk is grasped and the moment it starts to move provides information about the anticipated weight. If the subject expects the disk to be heavier than it actually is, he will increase the vertical force slightly faster than he would otherwise, so that the disk will start moving earlier than expected. If he expects it to be lighter, he will increase the force more slowly, so that the disk will start moving later than expected. The rate of change in force was therefore quantified by determining the time interval between the moment the disk was grasped and the moment it started to move. The moment at which the velocity of the hand was lowest was taken as the moment the disk was grasped. The velocity of the hand was defined as the mean of the tangential velocities of the finger and thumb. The disk was considered to move if its velocity exceeded 0.025 m/s.

[1] The magnitude of the illusion was assessed by having subjects match the disks in their original positions with a similar disk (same height; choice of diameters) in the other position.

A



B

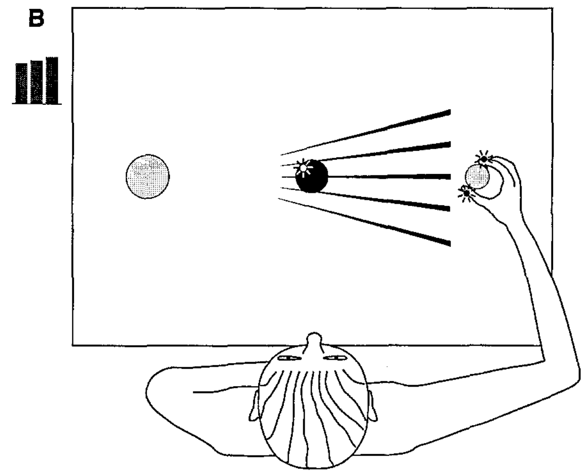


Fig. 1A, B Schematic representation of a top view of the experimental set-up (approximately to scale). The *histograms* on the *left* indicate the shading used in Fig. 3 for the two background conditions

Results

Figure 2 provides an example of how the maximal distance between the finger and thumb (D) and the time interval between the moment the disk was grasped and the moment it started to move (T) were determined. The

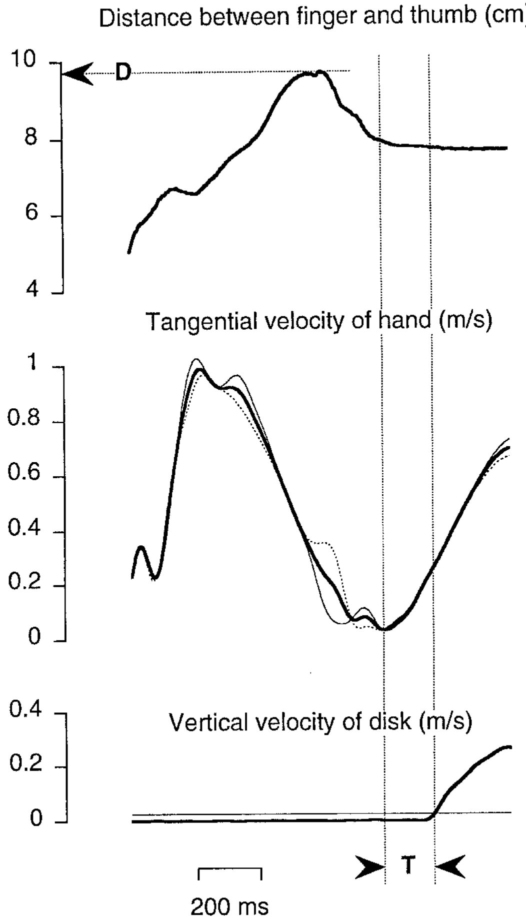


Fig. 2 Three measures from a single trial showing the values we used for our further analysis. The velocity of the hand (*thick trace*) was defined as the mean of the velocities of the finger (*thin dashed trace*) and thumb (*thin continuous trace*). The disk was considered to move if its velocity exceeded 0.025 m/s (*thin line*) (*D* maximal distance between the finger and thumb when grasping the disk, *T* time between the moment the disk was grasped and the moment it started to move)

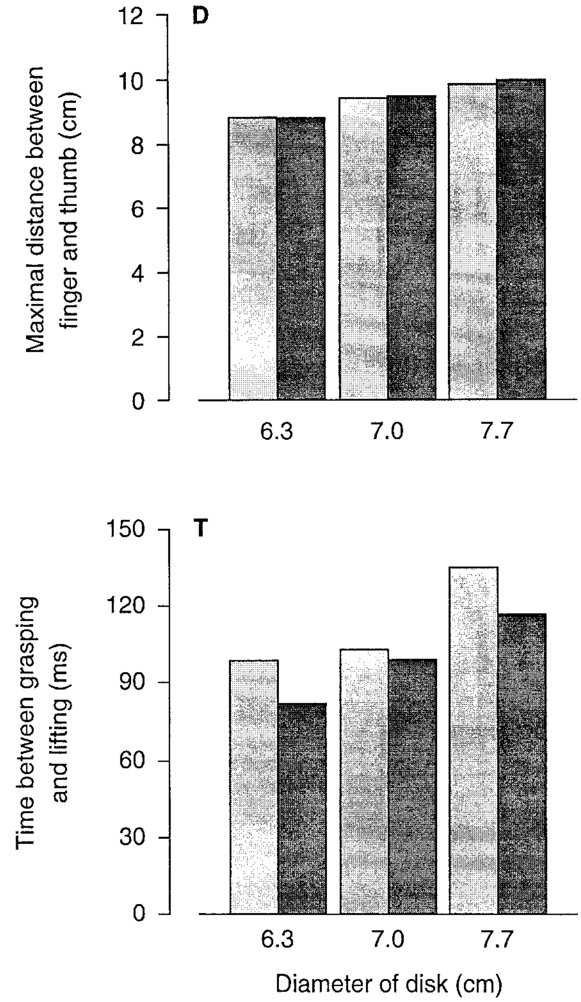


Fig. 3 Influence of the illusion on the maximal distance between the finger and thumb when grasping the disk (*D*) and on the amount of time between the moment the disk was grasped and the moment it started to move (*T*)

mean values of all eight subjects for both of these measures are shown in Fig. 3. Pairs of bars in Fig. 3 show the influence of the illusion for each of the three disk sizes.

An analysis of variance with factors *disk size*, *subject* and *direction of illusion* revealed the expected significant influence of disk size on the maximal hand opening (D), and significant differences in the maximal hand opening between subjects (both $P<0.01$). No other effects were significant ($P>0.05$). Most importantly, although the mean maximal hand opening was about 0.3 mm larger when the disk appeared to be larger, there was no significant influence of the illusion ($P=0.18$).

A similar analysis on the time between grasping and picking up the disk (T) revealed significant influences of disk size, subject and illusion ($P<0.01$). Various interactions involving subjects were also significant. There was no significant interaction between disk size and illusion ($P=0.42$). The influence of the illusion was as predicted: disks that looked larger (and thus heavier) started to move sooner. This influence of the illusion was not due to a universal change in the speed of the movement: neither the illusion nor disk size influenced the peak tangential velocity of the hand while reaching for the disk. The most likely explanation is therefore that the rate at which subjects increased the vertical force was larger (for disks that looked larger) because they expected such disks to be heavier.

Discussion

Our illusion did not appear to influence the distance between the thumb and fingers when grasping the disk, confirming previous findings with a different size illusion (Aglioti et al. 1995). In contrast, the illusion clearly did influence the time it took to pick up the disk, which is consistent with the finding of Gordon et al. (1991a, b) that more force is applied to lift larger objects (even if they are not heavier).

Failures of perceptual illusions to influence our action have previously been interpreted as evidence for separate visual mechanisms for perception and action (Aglioti et al. 1995; Bridgeman et al. 1981; Goodale and Milner 1992). The finding that an illusion that failed to influence how subjects grasped an object did influence how they lifted it contradicts this interpretation. It is consistent with the notion that grasping is guided by the positions at which one intends to place one's fingers, whereas lifting requires anticipation of the object's weight on the basis of its size. These results support the idea that different aspects of an action – or even of a single movement – are controlled independently by different aspects of the visual information (Brenner and Smeets 1996; Jeannerod et al. 1992; Smeets and Brenner 1995).

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