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Multiple Specification of an Object's Size for Picking it up

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Abstract

Subjects were asked to pick up disks. The apparent size of the disks was manipulated by a visual illusion. Of the two aspects of the action which depend on the objects size, only one was affected by the illusion. We conclude that different aspects of an action are controlled independently, instead of being co-ordinated on the basis of one perceptual variable.

Introduction

One consequence of using a single perceptual invariant to control the execution of an action is that the same visual information is used for different aspects of that action. Thus, if catching an approaching ball is based on the invariant 'tau', the timing of both the arm movement and the opening and closing of the hand can be expected to be based on that invariant. For intercepting moving objects, however, we found that the direction and the timing of the arm movement are based on different information on the object's motion (Smeets & Brenner, 1995). Position and time-to-contact are of course totally different physical properties, so there may be good reasons for the corresponding aspects of an action being based on different invariants. Can two aspects of an action also be based on different information about a single physical property?

To answer this question, we examined how subjects pick up brass disks. Two aspects of this action are directly coupled to one physical property: the size of the object that is to be picked up. During the reaching part of the movement, the object's size determines the opening of the hand: the larger the object, the larger the opening between thumb and finger (Jeannerod 1986). The size of the object also determines the rate at which the force to lift the object increases: the larger the object, the faster the force increases (Gordon et al., 1991). Are both aspects of picking up disks based on the same analysis of the visual information (invariant), or is each aspect of the action based on a different combination of the available visual information?

Visual illusions can be used to investigate whether different aspects of action are based on different perceptual information. An appropriate background can change the perception of specific aspects of the visual world (e.g. speed, direction, size), leaving other aspects (e.g. position) unchanged. We used a variant of the Ponzo-illusion (see Figure 1) to study the use of information on size when picking up a disk.

Methods

Eight subjects participated in the experiment. They sat behind a table, without any restraint (Figure 1). Subjects started a trial with their hand on the right side of the table with the thumb and finger 5cm apart. They were asked to pick up the brass disk in front of them, and to put it smoothly and accurately on a 9cm diameter target position on the left. Three brass disks were used, which differed slightly in size; on average they were 7cm diameter and weighed 0.9kg. We used a background with diverging lines to induce

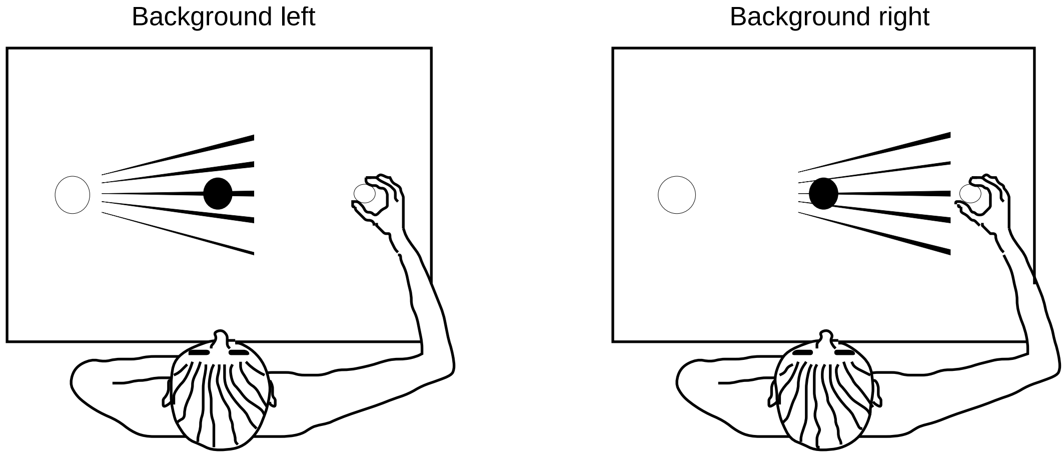

Figure 1 Experimental set-up in the two background conditions.

changes in the perceived size of the disk. With the background placed on the left side, the disk appeared smaller than with the background placed on the right.

To study the visual information used during the grasping and lifting phase, we extracted two parameters from each trial. These parameters were defined in a manner that would reveal misjudgements in size, independent of the actual size of the disk. To characterise the grasping phase, we used the parameter ‘extra grip’: the distance between thumb and finger minus the disk size. This parameter was determined when the hand was 2cm from the target, about 100ms before the fingers grasped the disk. To characterise the lifting of the disk, we used the parameter ‘extra force’: the vertical force exerted on the disk minus its weight. This parameter was determined 100ms after the fingers grasped the disk.

An analysis of variance was performed to test whether the position of the background had a significant effect on either of these two parameters.

Results

Figure 2 shows the effect of the visual illusion on the grasping and lifting of the disk. The extra grip did not depend on the illusory information on size: the opening was always about 2.2cm larger than the final grip. The difference between the two conditions was not only not significant, but also very small: 0.04cm (about 0.5% of the average disk size). Other measures of grip size (e.g. maximum opening) were also independent of the illusion. We conclude that the different positions of the background induced no change in the estimate of disk size used for grasping the disk.

The way the disk was lifted did depend on the illusory change in size. The extra force was about 0.43N larger when the disk appeared to be larger. This corresponds to an extra mass of 0.044kg. We conclude that the different positions of the background induced a 5% change in the estimate of disk size used for lifting the disk.

Discussion

The results show that lifting and grasping use different information on the disk’s size. This finding contradicts the idea that all aspects of an action are controlled by the same visual information specifying the goal of the movement; it supports the idea that different aspects of an action are controlled independently, each aspect on the basis of a specific combination of visual information on physical properties of the environment.

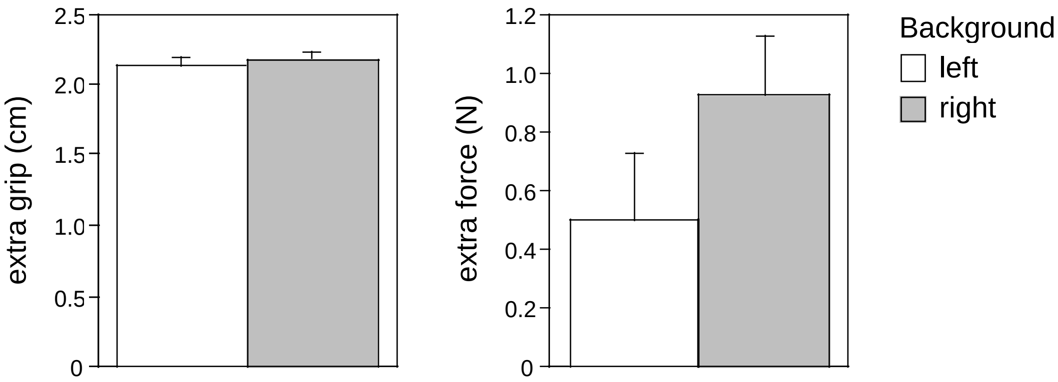

Figure 2 Results. The grasping of the disk (extra grip) was not influenced by the illusory change in the disk size (p>0.4), whereas the lifting (extra force) was influenced: more force was exerted to lift the disk when the disk seemed larger (p<0.02).

The important question which remains is why different aspects of one goal-directed action are controlled independently, instead of being co-ordinated on the basis of a single perceptual variable (invariant)? A disadvantage of the latter approach is that the nervous system has to determine an appropriate variable (which specifies the goal of the action) separately for every new task. The alternative is to use a set of simple visuo-motor units of action, which can be combined for a wide variety of tasks, without the need for recallibration of the units for every new task. Such an approach implies that the fundamental visuo-motor units of action are the same in different tasks.

For the task used in this study, one could describe the grasping phase as consisting of two units: moving the thumb to a position on the surface of a disk and moving the finger to another position. This would explain why the grasping phase is insensitive to the size-illusion: these units do not use information on size. If moving the thumb and moving the finger are indeed the fundamental units of action for grasping, one would expect that the movement of a single finger towards a point on an oriented surface shows some characteristics of the movement of a finger during grasping. This is indeed what we have found for the curvature in the path of a pointing movement (Brenner & Smeets, 1995).

This scheme is not yet a complete description of the grasping phase. We do not know which visual information (invariant) specifies the affordance of touching the surface of the object. Now we know that transport and grip are not the fundammental units of action, we can start searching for the invariants specifying the results of these movements.

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