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When does the Titchener Circles illusion exert an effect on grasping? Two- and three-dimensional targets

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Abstract

This study used the Titchener Circles illusion to investigate the functional dissociation of the dorsal visuomotor and ventral perceptual systems. In order to investigate the visual requirements for an action to be driven by the dorsal stream, two-dimensional (2D) and three-dimensional (3D) targets were compared. Thirteen subjects made visual open loop manual estimations or grasping actions towards 2D and 3D versions of the illusion. No illusion effect was found for immediate grasping, but the illusion did influence manual estimation, irrespective of whether the target was 2D or 3D. It is suggested that the underlying representations used to drive grasping actions towards 2D targets are fundamentally the same as those used to drive natural grasping actions. While stereoscopically specified depth may be important to the dorsal visuomotor system, it does not appear to be necessary in order for an action to be based on dorsal representations. It is suggested that an action must be goal directed in order for that action to be driven by dorsal stream processes.

Keywords: Action; Visuomotor; Perception; Dorsal; Ventral

1. Introduction

Visual information gathered from the world around us could potentially be put to use in various ways. We use visual information to discriminate between objects, group similar looking objects together, define their spatial relationships to each other. We can use information displayed by other people in their faces and bodily postures to tell us something of their emotions and attitudes, towards each other and towards ourselves. We can also use visual information to determine our own position within the environment, with relation to other objects and people. The widely different purposes for which visual information could be utilised suggests that different representations may be needed for performing these functions.

Visual perception appears to be largely insensitive to distortions of perspective and scale, and changes in lighting conditions and viewing angles. We can recognise an object as one and the same object across extensively varied lighting, distances and viewing angles. We can make sense of the spatial relationships between people and objects presented on television screens, despite the fact that we know the real sizes and distances cannot be as they appear. What is important for visual perception is the relative size and distance of objects in a visual display.

On the other hand, when using visual information to guide actions towards objects, information about object-relative size and distance is not adequate. In order to interact successfully with an object, a more veridical representation of size and distance must be calculated, and it must be calculated with respect to the viewer [23].

Goodale and Milner [12], and Milner and Goodale [23] have proposed that these different types of representation involved in visual perception and visually guided action are the result of the functioning of two different cortical projections diverging after primary visual cortex. A ventral stream, projecting from V1 to inferotemporal cortex is hypothesised to be involved in visual perception, and a dorsal stream projecting from V1 to posterior parietal cortex is hypothesised to be involved in the visual guidance of action.

Ungerleider and Mishkin [26] first proposed the two visual streams hypothesis, suggesting that the ventral stream was

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involved in visual identification and the dorsal stream in spatial localisation of objects. Much of the evidence for Goodale and Milner's functional reinterpretation of the two visual streams [12] came from neuropsychological patients who exhibited patterns of abilities and deficits resulting from damage to one or other of the two pathways. Patient D.F., with damage to the ventral stream, has poor visual perception of shape and orientation, irrespective of how this information is conveyed [13,3]. However, she is able to make accurate hand and finger movements towards objects whose properties she is unable to perceive. An optic ataxic patient with parietal damage, R.V., shows the reverse pattern of impairments. When D.F. and R.V. were presented with pairs of shapes for same/different judgements, R.V. scored 80–90% correct, while D.F. was severely impaired. However, when asked to pick up the shapes in a precision grip, D.F. performed similarly to non-brain-damaged controls, whereas R.V. chose unstable grasp points [11]. This double dissociation between damage to the two visual streams and their resulting behavioural impairments supported the proposal that the visual mechanisms underlying the perception of objects are distinct from those mediating the control of skilled action.

1.1. Illusions: dissociation in normal observers

Visual illusions are a possible means by which the dual route hypothesis can be tested, and offer a way of dissociating the functions of the dorsal and ventral streams in non-brain-damaged individuals. In size or shape illusions the way in which an array is perceived differs from its physical dimensions. If this were due to coding elements of the array relative to each other, the illusion would be expected to have different effects on systems mediating perception and control of action.

This dissociation has been demonstrated using the Titchener Circles illusion (see Fig. 1), which shows two identically sized circles, one surrounded by small circles and one surrounded by large circles. Subjects typically report that the circle surrounded by large circles looks smaller than the circle surrounded by small circles. Aglioti et al. [1] designed a three-dimensional (3D) version of the Titchener Circles illusion using thin plastic disks as the target centre circles. Subjects were asked to pick up the left or right disk, depending on whether they looked the same or different in size. Maximum in-flight aperture between finger and thumb was used as a measure of accuracy of grip. This has been shown in previous studies to be finely tuned and scaled to the size of the objects to be grasped [19,20,17]. Subjects' grip was scaled to the real size of the disks, although their choice of which disk to pick up indicated their perceptual susceptibility to the illusion.

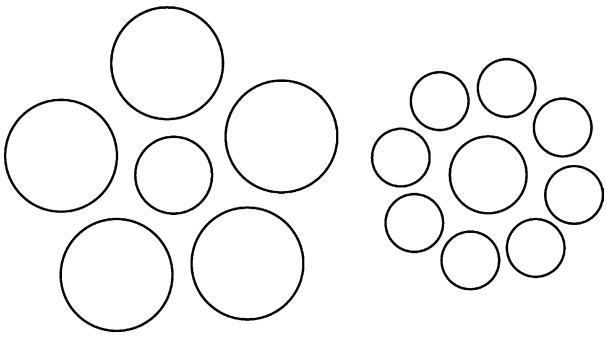

Fig. 1. The Titchener Circles illusion.

Haffenden and Goodale [14] repeated this study in visual open loop conditions so subjects could not use visual feedback to scale their grip. They also used a continuous measurement for perception in which subjects were required to make a manual estimation of the width of the disk by opening their index finger and thumb a matching amount, also in open loop conditions. This task used similar musculature to the grasping response, but as it is not a goal-directed action towards the object, it is considered to represent a 'read-out' of the information in the perceptual system. D.F. has been found to be unable to make accurate manual estimations of the size of shapes [13]. Grip aperture was again scaled to the physical size of the disks, but manual estimations were biased in the direction of the illusion, providing further evidence for the separation of visual processing for perception and guidance of action.

Not all studies investigating visual illusions have found that grasping is immune to illusory effects. For example, Daprati and Gentilucci [4] found an effect of the Müller-Lyer illusion on grasping, although it was smaller than that found in a perceptual matching task and a drawing task. Pavani et al. [24] suggested that there may be attentional differences between the perceptual and motor responses in previous comparisons of perception and action using the Titchener Circles illusion. That is, in Aglioti et al.'s [1] and Haffenden and Goodale's [14] studies, the perceptual condition required a comparison between the two arrays of circles. In contrast, in the visuomotor condition subjects had to pick up one disk based on a judgement of whether the two disks were the same or different in size. Once this choice has been made, subjects can focus their attention on the array of circles containing the disk to be grasped, and ignore the other array. Pavani et al. [24] repeated the Titchener Circles experiment using only one array of circles at a time and found that the perceptual illusion was much smaller, and was of similar magnitude to the effect on action. Franz et al. [7] also considered separate versions of the Titchener Circles illusion and found that when only one set of circles was presented at a time, the illusion effect in grasping and in a perceptual matching task was equivalent. They also showed that when both arrays of circles are presented, there is a much larger effect of the illusion when measured by direct comparison between the two centre circles than when measured by assessment of the individual target circles. This is addressed in the current study by requiring subjects to either grasp or estimate only one of the target circles; no direct comparison of the circles is invited.