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Motion fading is driven by perceived, not actual angular velocity

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ABSTRACT

After prolonged viewing of a slowly drifting or rotating pattern under strict fixation, the pattern appears to slow down and then momentarily stop. Here we examine the relationship between such 'motion fading' and perceived angular velocity. Using several different dot patterns that generate emergent virtual contours, we demonstrate that whenever there is a difference in the perceived angular velocity of two patterns of dots that are in fact rotating at the same angular velocity, there is also a difference in the time to undergo motion fading for those two patterns. Conversely, whenever two patterns show no difference in perceived angular velocity, even if in fact rotating at different angular velocities, we find no difference in the time to undergo motion fading. Thus, motion fading is driven by the perceived rather than actual angular velocity of a rotating stimulus.

1. Introduction

After prolonged viewing of a slowly drifting or rotating pattern under strict visual fixation, the pattern appears to slow down and then momentarily stop, even though the stationary form of the pattern remains visible. This illusory stopping or 'motion fading' has been reported to occur over rotating gratings and spinning sector disks (Campbell & Maffei, 1979, 1981; Cohen, 1965; Hunzelmann & Spillmann, 1984; Lichtenstein, 1963; MacKay, 1982), as well as stimuli comprised of dots (Hsieh & Tse, 2007, 2009a, 2009b). Several factors, including retinal eccentricity, number of sectors, dot organization, and angular velocity, have been shown to affect the time required for motion fading (Hsieh & Tse, 2007, 2009a, 2009b; Hunzelmann & Spillmann, 1984).

We have recently demonstrated that the spatial arrangement of otherwise identical orbiting dots can affect the time it takes to undergo motion fading (Hsieh & Tse, 2007). In particular, the time it takes for a set of dots rotating around a virtual center to be perceived as stopped (although in fact still continually moving) increases significantly when the dots can be grouped into the shape of a cross relative to when they cannot, even when all dot motions, in a local sense, are identical between the two conditions. This suggests that motion fading must occur at or after a stage where global motion signals have been computed on the basis of local motion signals. One reason why the time needed to undergo motion fading varies with configuration may be that, once grouped, the set of moving dots generates 'emergent motion signals'. These motion signals are 'emergent' because they are not present in the image, but instead arise from virtual contours and contour features that exist after grouping operations have linked the dots into virtual continuous contours that themselves move as the dots move (Caplovitz & Tse, 2007; Kohler, Caplovitz, & Tse, 2009). The emergent component motion signals arising from the virtual arms of a cross configuration of dots is greater than the motion signals arising from the non-cross configuration. Motion fading presumably takes longer in the case of the cross configuration because as the strength of such emergent motion signals increases, the magnitude of represented motion vectors that must adapt to zero in order for motion fading to occur also increases (Hsieh & Tse, 2007).

We have also shown that the spatial configuration of dots can influence the perceived angular velocity at which they are perceived to rotate. Specifically, we have shown that, as is the case for continuous contours (Caplovitz, Hsieh, & Tse, 2006), dots arranged to form a virtual thin, high aspect ratio ellipse will appear to rotate faster than those that form a lower aspect ratio ellipse even when the two in fact rotate at the same angular velocity (Caplovitz & Tse, 2007). This observation raises the important question of whether the effect of spatial configuration on motion fading arises from the mere presence of emergent motion signals, or whether it arises from the perceived angular velocity as determined by the emergent motion signals. In particular, does motion

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fading take longer for the cross configuration because it appears to rotate faster than the non-cross configuration?

Here we answer this question by measuring motion fading and perceived angular velocity of various dot-configuration stimuli. If motion fading is driven by perceived angular velocity, we would expect to find differences in the duration needed to undergo motion fading whenever there is a difference in perceived angular velocity, even if there is no difference in actual angular velocity. Conversely, whenever the configurations show no differences in perceived angular velocity, we expect to find no difference in the time needed to undergo motion fading, even when actual angular velocities differ. However, if motion fading is not driven solely by the perceived angular velocity of the moving stimuli, but, in part, by the actual angular velocity, then two moving patterns may differ in the time needed to undergo motion fading even when they have the same perceived angular velocity.

2. Experiment 1. High aspect ratio rotating ellipses defined by closely spaced dots take longer to undergo motion fading than lower aspect ratio ellipses

A thin, high aspect ratio ellipse will appear to rotate faster than a fatter, low aspect ratio ellipse (Caplovitz et al., 2006). This is also the case if the elliptical contours are defined by small, closely spaced dots (Caplovitz & Tse, 2007). This is particularly intriguing because the speed at which each dot is locally moving is on average greater for a fat ellipse than for a skinny ellipse, because dots comprising a fat ellipse are on average further from the center of rotation. However, when the dots are spaced too far apart, there is no effect of configuration on perceived angular velocity (Caplovitz & Tse, 2007). In Experiments 1a and 1b we measured the time it takes to undergo fading for rotating ellipses defined either by widely or closely spaced dots, with different aspect ratios, all rotating at the same slow angular velocity. Specifically, in each case we tested whether 'thinner' dotted ellipses require a longer time to stop (TTS) than 'fatter' ones. In all experiments dots were of identical luminance contrast in all conditions, to control for the potential influence of luminance contrast on perceived motion (Anstis, 2003; Stone & Thompson, 1992; Thompson, 1982; Thomoson & Stone, 1997; Thompson, Stone & Swash, 1996).

2.1. Methods

2.1.1. Observers

Seven subjects (six naïve and one author) participated in both the 'a' and 'b' versions of this experiment. All subjects had normal or corrected-to-normal vision, and the naïve subjects were paid for their participation. Before each experiment, and all the following experiments, the subjects underwent several training trials until they were accustomed to the experimental procedure.

2.1.2. Stimuli and procedures

The stimulus configurations and experimental procedures in Experiments 1a and 1b were identical except that in Experiment 1a the contours of the ellipses were defined by 12 small (0.02° visual degrees in diameter) white (128 lumen/m^2) equally spaced dots presented on a black (~0 lumen/m^2) background (Fig. 1a), while in Experiment 1b, the contours of the ellipses were defined by 32 such dots (Fig. 1b).

In each trial, a single ellipse was positioned so that its center was located 11 visual degrees along the horizontal axis either to the left or right of the central fixation spot. The ellipse had an aspect ratio that was either 'fat': 25/15 (4.85° × 2.91° visual angle) or 'thin': 25/6 (4.85° × 1.16° visual angle). The ellipse would rotate about its center at an angular velocity of either 2.94 deg/s or, as a control, a stationary ellipse would be presented. We have previously shown, using much higher angular velocities than those used

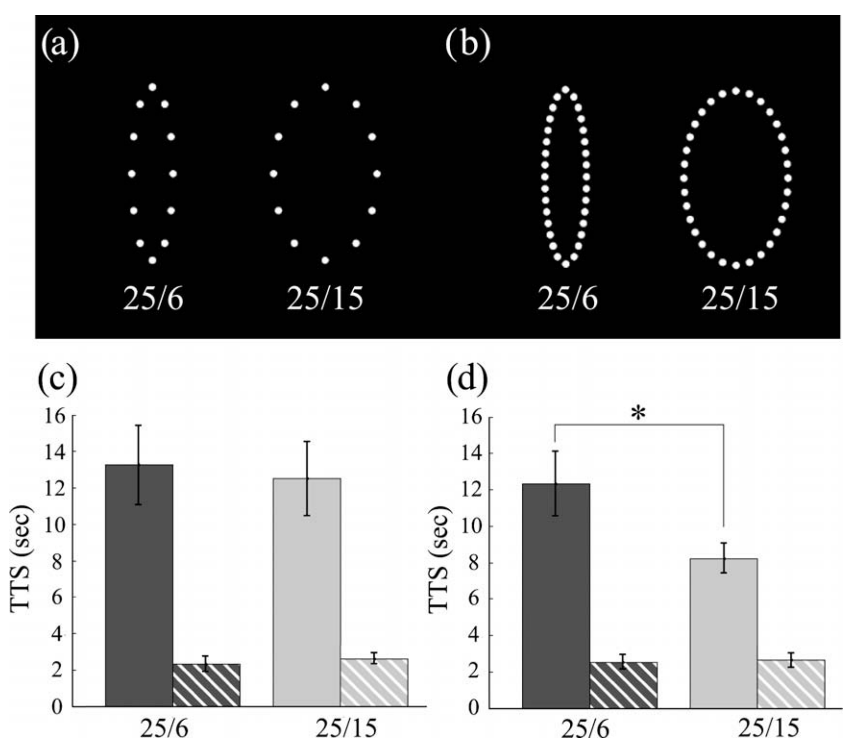

Fig. 1. Motion fading occurs faster for fatter than thinner dotted ellipses for the 32 dot case, but not for the 12 dot case. (a) The stimuli used in Experiment 1a, where ellipses were defined by 12 dots. (b) The stimuli used in Experiment 1b, where ellipses were defined by 32 dots. (c) The results of Experiment 1a. (d) The results of Experiment 1b. Solid bars indicate the time to stop (TTS) when the dotted ellipses were rotating. Striped bars indicate TTS when the ellipses were stationary. Error bars show the standard error of the mean.