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The field-size effect: Short motions look faster than long ones

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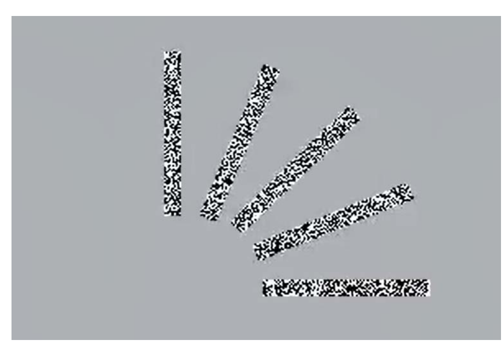
ABSTRACT

Reducing the amount of motion information can surprisingly make motion look faster (e.g., motion behind Venetian blinds). We found that a textured pattern moving to the right at speeds ranging from 0.34 to 5.5°/s appeared to move 50% faster when viewed through a short (0.5°) compared with a long (4.5°) horizontal slot. Perceived speed varied inversely with the log of the slot length. We varied the length of rectangular apertures over a tenfold range and manipulated their size, shape, and orientation. We attribute the field-size effect mostly to landmarks provided by the ends of the slots, but we also examined temporal and spatial frequency and lateral inhibition of motion.

1. Introduction

The apparent speed of seen motion can be affected by the size of the aperture through which it is viewed. Displaying a moving pattern through a short rather than a long slot potentially sub-samples the image and reduces the amount of motion energy. One might have expected this decline in motion energy to make the motion sub-optimal and less salient (Watson & Ahumada, 1985), but surprisingly, it can make the motion look appreciably *faster*. This aperture effect is known as the field-size effect (Snowden, 1997; Ryan & Zanker, 2001; Boyraz & Treue, 2011). Movie 1 shows an example (see Experiment 1). A fine random-dot texture moves behind two slots, one long and one short, against a grey background. Although the texture moves at the same speed behind both slots, it looks appreciably *faster* behind the smaller window. Movie 2 shows that this speedup depends upon slot orientation, hence upon the effective *path length.* The motion looks much faster behind the vertical slot, in which many random dots move through short paths, rather than behind the horizontal slot, in which a few dots move through long paths. Intermediate orientations seem to move at intermediate speeds (see Experiment 4).

Movie 1. Both textures move at the same, but motion looks faster when seen through the short slot.



Movie 2. Texture looks slowest when seen through horizontal slot, fastest when seen through vertical slot, and intermediate in speed when viewed through intermediate

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orientations. Snowden (1997) and Ryan and Zanker (2001) have described the basic field-size effects in which textures moved behind stationary slots of different lengths., while Boyraz and Treue established neural activity in MT that correlated with psychophysical results. Our aim here was to systematically determine the causes of this field size effect. We varied slot length (Experiment 1), spatial scale of slots as per Brown (1931) (Experiment 2), slot orientation (Experiments 3 and 4), figure-ground configuration of the motion (Experiment 5), the prevalence of discrete edge landmarks (Experiment 6), whether dynamic edge landmarks promote the effects (Experiment 7), and whether there was lateral inhibition of motion (Experiment 8). In these experiments, we measured these apparent speedups with a matching method. Our aim here is to look for the critical stimulus variables that drive the perceptual effects. In particular, we found that the presence of stationary landmarks, such as the ends of short slots near to the moving textures, played a decisive role in the apparent speedups.

2. General procedure

We used a similar procedure in all the experiments that follow. Stimuli were displayed on the screen of a Macintosh computer and viewed in a dimly lit room from a distance of 57 cm. The moving random-dot textures comprised dense, 50% black (0.03 cd/m^2) and 50% white (13.2 cd/m^2) dots. Dot diameters were 2.25 min arc, except for Experiment 6, for which they were 4.5 min arc. The random-dot texture (downloaded from Random.org/Lists/Bitmaps) drifted to the right behind a stationary test slot cut into a large grey (4.0 cd/m^2) background screen, while a second random-dot texture drifted to the left at an adjustable speed behind a horizontal matching slot. The size, shape and orientation of the slots varied in different experiments. Observers struck designated keys to adjust the physical speed of this second, matching texture until it appeared to be moving at the same speed as the test motion. When satisfied with their match they struck the space key, which recorded their settings for later analysis offline and randomized the initial conditions for the next trial. All slots were stationary in all experiments, and the texture moved in opposite directions behind the two slots to avoid any perceptual locking together. All observers gave their informed consent, and all experiments were in accordance with the Declaration of Helsinki.

3. Experiment 1: horizontal slot length affects apparent speed

3.1. Experiment 1a

Experiment 1a tested the effects of path length on apparent speed. The matching horizontal slot was 4.5° long, 0.5° high. Test slots had horizontal lengths of: 11%, 27%, 53%, 82% and 100% of the matching slot length (namely 0.5°, 1.2°, 2.4°, 3.7° and 4.5°, measured from left to right) and were 0.5° high. The speed of the random-dot texture behind the variable-length test slot was randomly selected on each trial from the set 0.5°, 1°, 1.57°, 2.75°, 4.12° and 5.5°/s (These speeds are in the ratios 0.3:0.6:1:2:3:4).

The observer struck two designated keys to adjust the speed seen through the 4.5° long slot to match the apparent speed seen through the test slot. Each combination of 5 slot lengths and 6 speeds was measured 3 times by each of 5 observers (total readings = 450 = 5 × 6 × 3 × 5).

3.1.1. Results

Results are plotted in Fig. 1a (mean of 5 Ss). The x-axis shows the slot lengths as a percentage of the long 4.5° matching slot. The parameter for the six curves is the physical speed of the stimuli. The y-axis shows the estimated (i.e., perceptually-matched) speeds. These estimates are normalized, so that a speed of 1.0 would represent veridical perception and a speed of 1.2 (for example) would represent a speed overestimate of 20%. In Fig. 1a all the curves slope up to the left, showing that shorter slot lengths increased perceived speeds. In addition, the uppermost two curves show that the two slowest stimulus speeds were strongly overestimated.

The same data are collapsed across speeds and re-plotted as the bar graphs in Fig. 1b to reveal the influence of slot length. Fig. 1b shows that the shorter the slot, the faster the texture seen through it appeared to move.

3.2. Experiment 1b

To check the effects of landmarks, we re-ran the previous experiment on three observers, and added five new conditions that were the same as the previous five conditions except that each test slot was now bordered with a black outline that was 7.5 arcmin wide. Thus the slot lengths were: 11%, 27%, 53%, 82% and 100% without outlines, and 11%, 27%, 53%, 82% and 100% outlined. These ten conditions were randomly interleaved. The adjustable matching slot had no such border. Otherwise the procedure was the same as before. It was felt that this outline might increase perceptual speeds by strengthening stationary landmarks (Castet & Wuerger, 1997; Leibowitz, 1955).

3.2.1. Results

Our results showed no additional speed enhancement. Collapsing our results for all observers, speeds and slot lengths, we found that outlining the slots increased perceived speeds by only a trivial 3%. In Fig. 1c, our results, collapsed across all speeds, reveal that shortening the slot progressively increased the perceived speed; and the datum points with and without outlines are intermingled. Since outlining the slots did not significantly affect the settings, we fitted all the results with a single line. We found the combined values of perceived speed declined with the *logarithm* of the slot lengths ($r^2 = -0.966$). Thus each halving of the slot length increases the perceived speed by a fixed amount.

3.3. Experiment 2: a replication of Brown (1931)

Experiment 1 found an inverse log-linear relationship between perceived speed of a moving random-dot texture and aperture length. This stimulus was different from that used previously by Brown (1931). In Experiment 2, we replicated his work by using horizontal rows of touching black disks, rather than random-dot textures. We used two slot sizes of equal aspect ratio, one twice the linear spatial scale of the other (Fig. 2). The upper slot was 2.25° long and 22 min arc high, containing disks of diameter 22 min arc. The lower slot was twice the size, namely 4.5° long and 44 min arc high, containing disks of diameter 44 min arc. Three disks could be seen behind each slot – small disks behind the small test slot, and large disks behind the large matching slot. The small test pattern was randomly assigned on each trial to one of five speeds: 0.5, 1, 2, 3, or 4°/s, and the observer adjusted the speed of the large pattern to a subjective match. Five observers participated.

3.3.1. Results

Results are plotted in Fig. 3. The graph shows that the larger pattern had to move 57% faster than the smaller pattern to be subjectively matched, with $r^2 = 0.998$. (We attribute the +0.64 intercept in matched speed to experimental noise). Veridical perception would give a line of unit slope, y = x (lower dashed line in Fig. 3). Results duplicating J.F. Brown's results would have given a line of slope 2, i.e., y = 2.0x (upper dashed line), but this was not the case. Across all five speeds, we found a mean percent increment of 57% – not 100% as J.F. Brown reported.

3.4. Experiment 3: slot orientation (vertical versus horizontal) affects apparent speed

In Experiment 3, we measured the perceived speed of random-dot textures that moved horizontally behind either a horizontal slot (4.5°,