Measuring the speed of mental images

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Mental images seem to have a default, preferred speed. Experimental evidence suggests that the speed at which subjects viewed a real moving spot across a CRT could influence the speeds at which they imagined the same spot, but the imagined speeds strongly tended to default toward speeds between 6.5° and 9° of visual angle per second. Linear barriers placed in the path of the imagined moving spot tended to deflect the path of that image but did not alter its speed. Furthermore, the point at which subjects imagined the spot to impact appeared to be strongly influenced by the angle of departure of the same spot. A default speed of mental images could explain problems with mental reconstruction and especially the inaccurate eyewitness testimony in estimating the speed of previously seen moving objects.

It has been suggested numerous times that there are imaginal processes that resemble perceptual processes (Finke, 1980; Kosslyn, 1980; Shepard, 1984; Weber & Malmstrom, 1979). This hypothesis is based on the assumption that both the imagery and the perceptual processes occupy and use some of the same mental space and operations. One avenue not often explored, though, is the degree of correspondence between a visual stimulus and the identical imaginal process. The studies of Kosslyn (1978) and Weber and Malmstrom (1979) suggested that there is a default size at which people imagine certain types of visual images. In one study, Weber and Malmstrom (1979) found that the imagined size of different sizes and lengths of letter strings could be driven by the sizes and lengths of actual letter strings. However, the size of the image always tended to default toward a visual angle of about 1° per letter imagined, whatever the size of previously viewed letters. For example, subjects tended to imagine large objects as large but not quite as large as they were seen. Likewise, subjects tended to imagine small objects as small but not quite as small as they were seen.

Acting on these leads, we propose, first, that if there is a default size of mental images, there is also a default *speed* of mental images. We further propose that this speed lies

somewhere within the speed range of pursuit eye movements, 1° and, say, 60° of visual angle per second. Second, our own efforts to imagine accurately an automobile or a plane moving horizontally across the visual field suggested that this speed is a great deal slower, perhaps between 1° and 12° of visual angle per second. Indeed, the study by Freyd and Finke (1985) found that for representational momentum of a rotating object to show a stable, consistent effect, an object should have an implied rotational speed of about 30° of visual angle per second. Going a step further, we calculated that in their experiment the linear velocity of the fastest moving point in their rotational display was moving not faster than 5° of visual angle per second, a speed well within pursuit-eye-movement range. Finally, following the same logic, we propose that there are default characteristics for imagined objects that come into contact with barriers; for example, an imagined object might lose some of its representational momentum or change its direction of movement if it were to be imagined as either passing through or striking a barrier. It would remain to be seen whether an object passing through a barrier would be imagined to (a) refract, as a light ray, or (b) behave as a particle with mass, thus losing momentum.

In this study, we investigated the degree to which an imagined moving object could be influenced by placing linear visual barriers in front of its imagined path. There were two possible ways a moving object could behave while passing through a barrier. Suppose first that this imagined object were traveling at a constant velocity, upward at a 45° angle relative to the Earth's surface. First, it could behave as a bullet passing through a wall; in this

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case, it would lose speed and concurrently arc toward the ground rather quickly. Alternatively, this imagined object could behave as a light ray passing through a dense medium such as water or glass; in this case, it might tend to refract toward a shallower angle of incidence and not lose speed.

METHOD

Subjects

Thirty volunteer undergraduates from Wright State University participated individually in a ½-h experiment designed to test their ability to imagine a spot (ball) moving across a visual field of about 20°.

Apparatus and Stimuli

The moving object was a computer-generated (Apple IIe) ball traveling diagonally upward from left to right across a CRT, departing from a

left wall and impacting on a right wall. However, when the ball had traveled only a third of the way across the display, it disappeared with a distinct auditory beep. (See Figure 1.)

Procedure and Design

At this point, the subject was instructed to imagine the ball continuing and impacting the right wall as if the ball were still visible.

There were 10 possible paths the ball could have taken (P1-P10); the ball could depart from the left wall at the bottom or one fourth, one half, or three fourths of the way up and then impact the right wall one fourth or one half of the way up or at the top.

There were two within-subject conditions, ball speed (SLO, MED, FAS, CON) and path traveled (P1-P10). The ball moved at a speed of 3.5, 6.7, or 12.0° of visual angle per second. In the control (CON) condition, the ball was not presented at any speed; rather, the computer instantaneously traced out the first third of the ball path and the subject was then instructed merely to extend the line to the right wall in his/her imagination as quickly and as accurately as possible, simultaneously estimating the point of intersection. There was a single between-subject

Figure 1. Possible paths the ball could travel, grouped by divergent, convergent, and parallel paths. Solid lines indicate path observed, and dashed lines are the ideal imagined paths. Barriers 1 and 2 are indicated by BA1 and BA2.

Figure 2. Mean reaction times for subjects to imagine the ball traveling across a gap of 13° of visual angle, plotted as a function of ball speed and path. Dashed lines indicate the actual travel times of the ball if it had remained visible.

condition, barriers (BA0, BA1, BA2). In this condition, the subject had to imagine the ball passing through 0, 1, or 2 straight line barriers before it impacted the right wall.

We collected two separate dependent variables: estimated point of imagined impact and reaction time to make that judgment. At the instant the ball disappeared a third of the way across the screen, the internal computer clock (Timemaster II) began running. The subject then pressed the return key, simultaneously stopping the clock, when he/she estimated where the ball would have impacted the right wall had it remained visible. The right wall was then redrawn, showing an incremental scale of 0 to 38. At this point, the subject typed in the number on the scale corresponding to the position where he/she thought the ball would have impacted. (The actual ball, had it remained visible, could have impacted only at points 8, 17, 26, or 35.)

RESULTS AND DISCUSSION

All results were analyzed by grouping the image paths into three separate analyses of variance (ANOVAs): (1) divergent paths (P7,8,9,10), (2) convergent paths (P1,2,4,7), and (3) parallel paths (P1,3,6,10) (see Figure 1). P5 did not meet any of the above grouping criteria and therefore was not used in these analyses.

Reaction Times

Mean reaction times for the three path groupings (divergent, convergent, parallel) are shown in Figure 2. To avoid clutter, the CON IM (control condition, instantaneously plotted straight line) values are not plotted; however, they very nearly coincide with the MED IM values. Across all groupings, only the image-speed conditions (SLO, MED, FAS, CON) showed consistently significant differences [convergent: $F(3,81) = 9.447, p < .001$;

divergent: $F(3,81) = 9.229, p < .001$; parallel: $F(3,81) = 8.245, p < .001$]. The placement of barriers between the image and the right wall did not have any significant effects whatever on image speed (all $ps > .10$). All image speeds lie between the slowest and fastest target speeds (SLO TGT and FAS TGT) of the ball, had it remained visible. In other words, the subjects tended to imagine the slow-moving ball as slow but not as slow as they viewed it; the subjects tended to imagine the fast-moving ball as fast but not as fast as they viewed it. We estimate the default speed of the mental image across a gap of approximately 13° of visual angle to lie somewhere between the mean MED IM value of 9.96° per second and the CON IM value of 8.64° per second.

Estimated Position

The speed at which the subjects estimated the ball did not appear to be affected by the number of parallel barriers placed in the path of the image. However, the accuracy of the estimated impact point was affected by the placement of barriers. Figure 3 shows the mean absolute deviations of the estimated image impact point as a function of barriers.

ANOVAs for the three path groupings indicated significant differences only for divergent paths [$F(2,27) = 3.494, p = .043$] and for convergent paths [$F(2,27) = 6.483, p < .005$]. Accuracy of estimating the impact point of the image seems somehow affected by the barriers placed in front of the image; however, why a single barrier should affect the accuracy more than two barriers is not at all clear. The barriers variable does not appear

Figure 3. Mean absolute error deviations for imagined ball-impact position, plotted as a function of path groupings and barriers.

Figure 4. Mean signed error positions from actual impact points, plotted as a function of moving targets, line (control) condition, and paths.

to follow any predictable direction of refraction. However, the estimated position of impact of the image does seem clearly affected by the angle of departure of the ball.

Figure 4 shows that shallow angles (such as P10) seem to be "refracted" upward and steep angles (such as P7) appear to be refracted downward. In addition, the CON IM ("LINE") seems to undergo very little refraction. It is the moving ball that seems most vulnerable to this illusion. The average impact point appears to be close to the midpoint of the right wall. ANOVAs for all three path groups indicate substantially significant differences in impact points [convergent: $F(3,81) = 13.156$; divergent: $F(3,81) = 97.512$; parallel: $F(3,81) = 76.174$; all $ps < .001$]. Lest it be thought that subjects arbitrarily pick the midpoint of the right wall as a convenient answer, we would like to assure the reader that the refraction illusion is quite real. At the completion of the experiment, all subjects (and the authors) were given postexperimental trials with full knowledge of the correct impact points. We still continued to, for example, angle P1 sharply upward and P7 sharply downward.

If there is any analogy to be drawn, the subjects consistently imagined the ball path to more closely approximate the behavior of a light beam than a bullet. That is, barriers had no effect on imagined speed, but the imagined ball angle tended to refract either upward or downward when passing through barriers.

We propose that there is a default speed of mental images and that this default speed is about 9° of visual angle per second. The accuracy of the path of the visual image does not appear to be affected by the speed at which it is imagined, but perceptual barriers placed in the way

of the mental image path do seem to affect the direction of that path. There may also be practical implications for this finding of default speeds of mental images. Default speeds could significantly affect the accuracy of eyewitness testimony relating to events such as the mental reconstruction of the speed of moving vehicles. Why, for example, are most moving vehicles described as moving at about 40 mph? There is sufficient evidence (Loftus & Palmer, 1974) that eyewitnesses tend to speed up their estimates of slow-moving vehicles and slow down their estimates of fast-moving vehicles. Perhaps eyewitnesses tend to report imagined default speeds more readily than actual speeds.

REFERENCES

- FINKE, R. (1980). Levels of equivalence in imagery and perception. *Psychological Review*, *87*, 113-132.
- FREYD, J. J., & FINKE, R. A. (1985). A velocity effect for representational momentum. *Bulletin of the Psychonomic Society*, *23*, 443-446.
- KOSSLYN, S. (1978). Measuring the visual angle of the mind's eye. *Cognitive Psychology*, *10*, 356-389.
- KOSSLYN, S. (1980). *Image and mind*. Cambridge: Harvard University Press.
- LOFTUS, E., & PALMER, J. (1974). Reconstruction of automobile destruction. *Journal of Verbal Learning & Verbal Behavior*, *13*, 585-589.
- SHEPARD, R. N. (1984). Ecological constraints on internal representation: Resonant kinematics of perceiving, imagining, thinking, and dreaming. *Psychological Review*, *91*, 417-446.
- WEBER, R., & MALMSTROM, F. (1979). Measuring the size of mental images. *Journal of Experimental Psychology: Human Perception & Performance*, *5*, 1-12.