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REPRESENTATIONAL MOMENTUM, FLASH-LAG, AND MOTION CAPTURE

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Abstract

When a stationary object was aligned with the middle of a moving target's trajectory, observers' memory for the location of that stationary object was not displaced; memory for the location of the target at the time the stationary object was presented was displaced backward (i.e., in the direction opposite to target motion), and memory for the final location of the target was displaced forward (i.e., in the direction of target motion). When a stationary object was aligned with the end of a moving target's trajectory, observers' memory for the location of the stationary object was displaced forward, and displacement increased with increases in target velocity and decreased with increases in the distance of the stationary object from the moving target. It is suggested that representational momentum for the moving target made the target appear in front of the stationary object when the stationary object was presented before the end of target motion (thus accounting for the flash-lag effect), and that residual spreading activation from the moving target displaced the memory for the stationary object forward when the stationary object was presented at the end of target motion (thus accounting for motion capture).

Memory for the final position of a previously-viewed moving target is often displaced forward in the direction of target motion, and this has been referred to as *representational momentum* (e.g., Freyd & Finke, 1984; for review, see Hubbard, 2005). Although numerous studies have demonstrated that the presence and relative location of a nearby stationary stimulus can influence displacement in memory for the location of a moving target (Hubbard, 2005), there has been little investigation of whether the representational momentum of a moving target can influence displacement in memory for the location of a nearby stationary stimulus. Evidence will be presented that suggests the representational momentum of a moving target influences memory for a nearby stationary object, and more specifically, that representational momentum from a moving target might contribute to the flash-lag effect and to motion capture.

Experiment 1: Representational Momentum and Flash-lag

A briefly presented stationary object that is aligned with a moving target (that continues in motion after the stationary object vanishes) is perceived to lag behind the location of the moving target, and this has been referred to as the *flash-lag effect* (Nijhawan, 1994; for review, Krekelberg & Lappe, 2001; Nijhawan, 2002). In most accounts, the lagging of the flashed object reflects a delay or distortion in the perception of the flashed object, and perception of the moving target is thought to be veridical. However, the existence of representational momentum is consistent with an account of the flash-lag effect that emphasizes distortions in spatial localization of the moving target: the flash-lag effect might emerge from forward displacement in the representation of the location of a moving target at the time the flashed object was presented.

General Method

The general method is illustrated in Figure 1. A target consisting of five sequentially presented black squares 20 pixels (0.83 deg) in width, referred to as *inducing stimuli*, exhibited leftward or rightward implied motion on a white background. Each inducing stimulus was shifted by 40 pixels from the coordinates of the preceding inducing stimulus. Each inducing stimulus was visible for 250 ms, and the ISI between inducing stimuli was 250 ms. A stationary object consisting of a black outline square 20 pixels in width was presented 20 pixels above or below the target at the midpoint of the target's trajectory (in Exps. 1A, 1B, and 1D) or at the end of the target's trajectory (in Exp. 1C). The stationary object was visible for 250 ms.

In Experiment 1A (*N* = 17), observers used a 5 point scale (1 = "behind", 2 = "slightly behind", 3 = "exactly the same", 4 = "slightly in front of", 5 = "in front of") to indicate whether the stationary object appeared behind, aligned with, or in front of the target.

In Experiments 1B (*N* = 11), 1C (*N* = 11), and 1D (*N* = 12), a probe for the location of the stationary object or for the location of the target (at the time the stationary object was presented) appeared 250 ms after the target vanished. Probes for the stationary object or for the target were vertically aligned with the stationary object or the target, respectively, and were horizontally offset by -4, -2, 0, +2, or +4 pixels from the location of the stationary object or the target, respectively. Observers judged whether the probe was at the same location as the stationary object or the target, and then pressed a designated key to indicate their response.

In Experiment 1B, the stationary object was aligned with the middle of the target trajectory, and probes were for the location of the stationary object or for the location of the target at the time the stationary object had been presented.

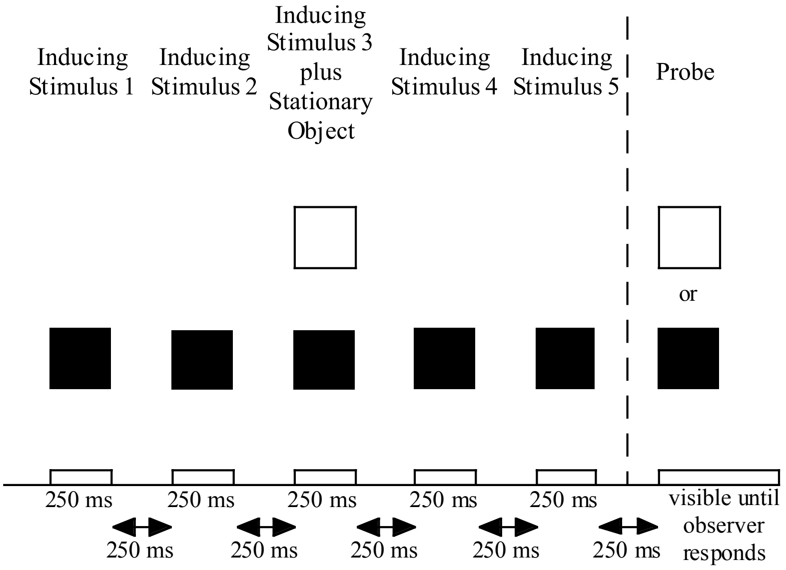

Figure 1. The structure of a trial in Experiment 1. A set of 5 static inducing target stimuli (black filled squares) were presented for 250 ms each, and there was a 250 ms ISI between inducing stimuli. A stationary object (black outline square) was presented concurrently with the third inducing stimulus (Exps. 1A, 1B and 1D; in Exp. 1C, the stationary object was presented concurrently with the final inducing stimulus, and that condition is not shown in Figure 1). There was a 250 ms retention interval after the final inducing stimulus vanished. In Experiment 1A, the rating scale (not shown in Figure 1) then appeared. In Experiments 1B, 1C, and 1D, a probe for the location of the stationary object (Exps. 1B and 1D) or the moving target (Exps. 1B, 1C, and 1D) then appeared.

In Experiment 1C, the stationary object was aligned with the final location of the target on half of the trials, and was not presented on the other half of the trials. All probes were for the final location of the target.

In Experiment 1D, the stationary object was aligned with the middle of the target trajectory, and probes were for the location of the stationary object or for the final location of the target.

Results

In Experiment 1A, the average rating (M = 2.82) was smaller than the "exactly the same" value of the rating scale, $t(16) = -2.06$, $p < .05$. This pattern is consistent with the flash-lag effect, and so the implied motion stimuli were successful in eliciting a flash-lag effect.

The distributions of *same* responses as a function of probe position in Experiments 1B, 1C, and 1D are shown in Figure 2. Weighted mean estimates of displacement (the sum of the products of the proportion of *same* responses and the distance of the probe from the location of the stationary object [for probes of the stationary object] or from the location of the moving target [for probes of the moving target], in pixels, divided by the sum of the proportions of *same* responses) were calculated for each observer.

In Experiment 1B, the average weighted mean for targets was smaller than zero (M = -0.28), $t(10) = -2.58$, $p < .02$, but the average weighted mean for stationary objects did not differ from zero (M = -0.17), $t(10) = -1.83$, $p > .07$. Memory for stationary objects was not displaced, but memory for targets at the time the stationary object was presented was displaced backward. Probes for the target appeared 1250 milliseconds after the stationary object vanished, and the backward displacement is consistent with previous data regarding the time course of representational momentum (i.e., forward displacement peaks after a few hundred milliseconds, and then displacement becomes negative, Freyd & Johnson, 1987).

In Experiment 1C, the average weighted mean when the stationary object was presented was larger than zero (M = 0.50), $t(10) = 4.96$, $p < .0001$, and the average weighted mean when the stationary object was not presented was larger than zero (M = 0.60), $t(10) = 7.95$, $p < .0001$. The average weighted mean was not influenced by whether the stationary object had been presented, and so the backward displacement of the target in Experiment 1B did not result from interference from the stationary object.

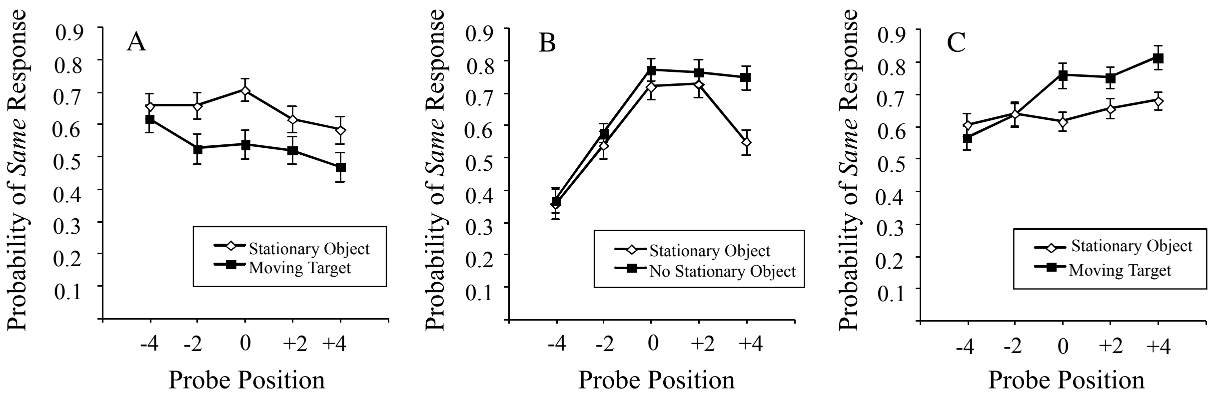

Figure 2. The data from Experiment 1. Panel A contains data from Experiment 1B; panel B contains data from Experiment 1C, and panel C contains data from Experiment 1D.

In Experiment 1D, the average weighted mean for targets was larger than zero (M = 0.41), $t(11) = 5.89$, $p < .001$, but the average weighted mean for stationary objects did not differ from zero (*M* = 0.11), *t*(11) = 1.68, *p* > .09. Representational momentum of the target was not influenced by the presence of the stationary object, and so backward displacement in Experiment 1B did not result from interference from the stationary object.

Discussion

The data from Experiment 1 are consistent with the hypothesis that representational momentum of the moving target contributes to the flash-lag effect. When a stationary (flashed) object is presented prior to the end of target motion, representational momentum of the target at the time the stationary object is presented results in the representation of the target being displaced forward, and so the moving target is represented as in front of the stationary (flashed) object. Within a few hundred milliseconds, the forward displacement for the location of the target at the time the stationary (flashed) object had been presented decays and possibly reverses. The brief duration of representational momentum of the target concurrent with the presentation of the stationary object is long enough for observers to note the apparent misalignment of the stationary object and target they perceive at that time.

Experiment 2: Representational Momentum and Motion Capture

Motion of a nearby object or context can result in perceived motion of a stationary object (e.g., stationary flickering dots on a drifting grating or on an apparent surface exhibiting apparent motion appear to move in the same direction as the grating or the apparent surface), and this has been referred to as *motion capture* (e.g., Festa-Martino & Welsh, 2001; Ramachandran, 1985). Motion capture might involve representational momentum of a target influencing the representation of a nearby stationary object. If so, then variables that influence representational momentum of a target (e.g., velocity) should influence displacement of a nearby stationary object. Previous discussions of representational momentum (e.g., Erlhagen & Jancke, 2004; Hubbard, 1995; Müsseler et al., 2002) speculated displacement results from asymmetrical spreading activation in the direction of target motion, and so displacement of a stationary object in the direction of target motion might result from spreading activation from the target. Spreading activation decreases with distance, and so displacement of the stationary object should decrease when the stationary object is more distant from the target.

General Method

The target, stationary object, and probes were the same as in Experiment 1, but with the following exceptions: The stationary object was always vertically aligned with the endpoint of target motion. There was a wider range of probe positions, and probes were horizontally offset by -9, -6, -3, 0, +3, +6, or +9 pixels from the stationary object or the target.

In Experiment 2A (*N* = 14), probes were for the location of the stationary object or for the final location of the moving target.

In Experiment 2B (*N* = 14), target velocity varied (ISI for fast velocity was 250 ms, ISI for slow velocity was 500 ms). Probes were for the location of the stationary object.

In Experiment 2C (*N* = 15), vertical distance of the stationary object from the target varied (20, 60, or 100 pixels). Probes were only for the location of the stationary object.

Results

The distributions of *same* responses as a function of probe position are shown in Figure 3, and weighted mean estimates of displacement were calculated as in Experiment 1.

In Experiment 2A, there were no differences between the average weighted mean for stationary objects (*M* = 0.60) and the average weighted mean for targets (*M* = 0.77), *t*(13) = 1.09, *p* > .29. The average weighted means for stationary objects, *t*(13) = 2.78, *p* < .02, and for targets, *t*(13) = 3.77, *p* < .003, were larger than zero. Memory for the stationary object was displaced in the direction of motion of the nearby moving target, and this is consistent with motion capture and with the hypothesis that the representation of the stationary object was influenced by the representational momentum of the target.

In Experiment 2B, the average weighted mean for stationary objects accompanied by fast targets (*M* = 0.99) was larger than the average weighted mean for stationary objects accompanied by slow targets (*M* = 0.65), *t*(13) = 2.27, *p* < .05. The average weighted means for stationary objects accompanied by slow targets, *t*(13) = 4.20, *p* < .001, or by fast targets, *t*(13) = 4.13, *p* < .001, were larger than zero. The larger forward displacement of stationary objects accompanied by fast targets is consistent with the larger representational momentum typically exhibited by fast targets (Hubbard, 2005), and is consistent with the hypothesis that displacement of the stationary object results from representational momentum of the target.

In Experiment 2C, distance of the stationary object from the target was significant, *F*(2,28) = 4.61, *MSE* = 0.69, *p* < .02, and least squares comparisons revealed forward displacement of stationary objects 20 pixels (*M* = 1.03) distant was larger than forward displacement of stationary objects 60 pixels (*M* = 0.62) or 100 pixels (*M* = 0.40) distant. The average weighted mean was larger than zero for stationary objects 20 pixels distant, *t*(14) = 5.01, *p* < .001, and 60 pixels distant, *t*(14) = 3.26, *p* < .01, but was not larger than zero for stationary objects 100 pixels distant, *t*(14) = 2.04, *p* < .07. The decrease in displacement of the stationary object with increases in distance of the stationary object from the target is consistent with the hypothesis that representational momentum of the target contributes to displacement of the stationary object, as spreading activation from the representation of the target to the representation of the stationary object would decrease with increases in the distance between the target and the stationary object.

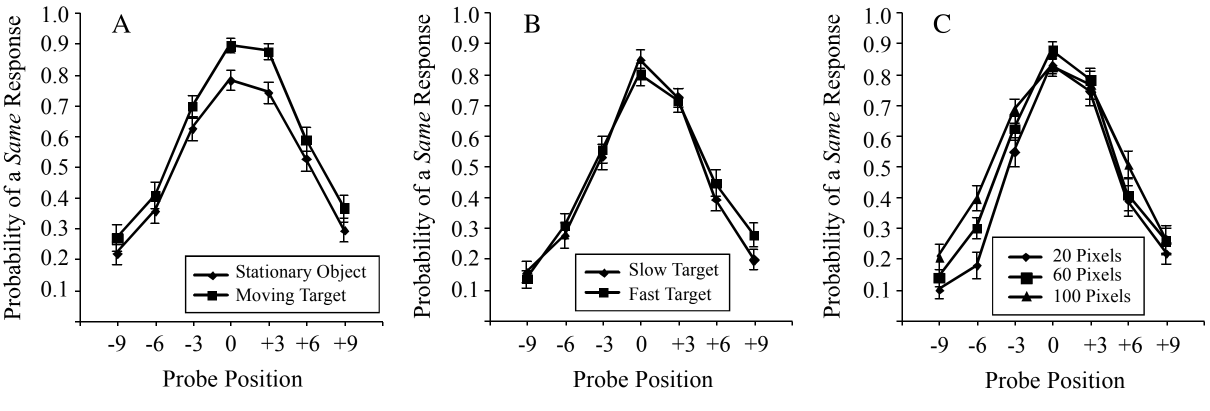

Figure 3. The data from Experiment 2. Panel A contains data from Experiment 2A; panel B contains data from Experiment 2B, and panel C contains data from Experiment 2C.

Discussion

The data from Experiment 2 are consistent with the hypothesis that representational momentum of the target contributes to motion capture of the stationary object. Memory for a stationary object briefly presented near the final location of a moving target and at the time the moving target disappeared was displaced in the direction of motion of that target. The magnitude of this displacement was larger when the target moved at a faster velocity or when the stationary object was closer to the final location of the target, and these patterns are consistent with effects of velocity on representational momentum and with suggestions that representational momentum results from spreading activation. Such an influence of the representational momentum of a moving target on memory for a stationary object suggests motion capture includes dynamics of motion in addition to kinematic aspects of motion.

General Discussion

The data from Experiments 1 and 2 are consistent with the hypothesis that representational momentum from a moving target can influence the perceived location of a nearby object. This finding complements previous literature that found effects of nearby context on representational momentum of a target. More specifically, the data reported here suggest that the flash-lag effect and motion capture might result from influences of the representational momentum of a moving target that contribute to changes in the perceived configuration of the moving target and stationary object and contribute to changes in the remembered location of the stationary object. Of course, a hypothesized role for representational momentum in the flash-lag effect and in motion capture does not suggest that representational momentum is the only cause of these effects, and does not rule out the possibility that other mechanisms (e.g., faster processing of moving targets than of stationary objects in the flash-lag effect) could contribute to these effects. By providing a single mechanism (representational momentum), the discussion here draws together phenomena in spatial cognition (e.g., representational momentum, flash-lag effect, motion capture) previously considered to be unrelated.

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