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The force of appearance: Gamma movement, naïve impetus, and representational momentum

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If a moving stimulus (i.e., launcher) contacts a stationary target that subsequently begins to move, observers attribute motion of the target to the launcher (Michotte, 1946/1963). In experiments reported here, a stationary launcher adjacent to the target appeared or vanished and displacement in memory for the position of the target was measured. Forward displacement of moving targets was less (a) when launchers appeared than when launchers vanished, and (b) when targets moved in the direction of implied impetus than when targets moved in a direction orthogonal to implied impetus. Whether launchers appeared or vanished did not influence displacement of targets that remained stationary. The data were consistent with the hypothesis that forward displacement of the target decreased when observers attributed target motion to an impetus resulting from gamma movement of the launcher that was imparted to the target. More generally, the data were consistent with an impetus-based explanation of Michotte's launching effect (e.g., Hubbard & Ruppel, 2002), and suggest the apparent perception of causality is cognitively mediated rather than direct.

When a moving object contacts a stationary target, and that target then begins to move, observers may attribute the motion of the target to contact from the originally moving object (see Figure 1). Such an attribution has been referred to as a *launching effect* by Michotte (1946/1963; see also Thinès, Costall, & Butterworth, 1991), who reported that the launcher (i.e., the originally moving object) was perceived to cause the subsequent motion of the target only if (a) the direction of subsequent target motion was similar to the direction of previous launcher motion, (b) the latency between when the launcher contacted the target and when the target began to move was relatively brief, and (c) the previous velocity of the launcher was greater than the subsequent velocity of the target. Michotte argued that observers did not see events that occurred contiguously as disconnected (e.g., contact of the launcher with the target, the initiation of target motion); rather, he claimed that

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observers directly (i.e., without inference or conceptual mediation) perceived a causal relationship between the launcher and the target. The extent to which humans directly perceive such causal dynamics has subsequently been debated; some studies suggest observers may directly perceive causal dynamics (e.g., Bingham, 1987; Runeson & Frykholm, 1983; Valenti & Costall, 1997), whereas other studies suggest observers may appeal to heuristics rather than directly perceive causal dynamics (e.g., Gilden, 1991; Gilden & Proffitt, 1989; Proffitt & Gilden, 1989).

Michotte's studies relied upon the introspections of trained observers. In some of the first studies to provide behavioral data consistent with the introspections of Michotte's observers, Hubbard, Blessum, and Ruppel (2001) measured representational momentum (a mislocalization of the remembered final position of a moving target forward in the direction of target motion, see Hubbard, 1995, 2004; Thornton & Hubbard, 2002) for targets in a launching effect display. Observers viewed computer-animated displays based on the launching effect display, and after the target traveled a brief distance, both the launcher and the target vanished. Observers then used a computer mouse to indicate the location at which the target vanished, and displacement between the actual vanishing point of the target and the judged vanishing point of the target was measured. Displacement of several types of unlaunched control targets (e.g., a target presented in the absence of a launcher, a target that moved in a direction orthogonal to the previous motion of the launcher) was also measured. Consistent with representational momentum, observers indicated a location further in the direction of implied motion for targets in launching effect displays and for unlaunched control targets; however, forward displacement of targets in launching effect displays was less than forward displacement of unlaunched control targets.

Hubbard et al. (2001) suggested the decrease in forward displacement in the remembered location of a target in a launching effect display resulted from observers' attribution that motion of the launched target was due to an impetus imparted from the launcher to the target. According to naïve impetus theory, the act of setting an object into motion imparts a force or impetus to the object, and the strength of this impetus dissipates with subsequent target motion (e.g., see McCloskey, 1983; McCloskey & Kohl, 1983). If motion of the target in a launching effect display was attributed to impetus imparted from the launcher, then once that impetus had dissipated to a level below the threshold amount needed to maintain motion, the target would be expected to stop. Forward displacement in the remembered location of a target is decreased when observers expect that target to stop (Finke, Freyd, & Shyi, 1986), and so forward displacement in the remembered location of a target in a launching effect display was therefore decreased. If motion of a target was not attributed to impetus imparted from a launcher, then motion of that target would necessarily have been more autonomous or self-generated, and therefore less likely to be attributed to an impetus imparted from the launcher that would dissipate without replacement; thus, motion of an unlaunched target would not be expected to stop, and an unlaunched target would not exhibit a decrease in forward displacement.

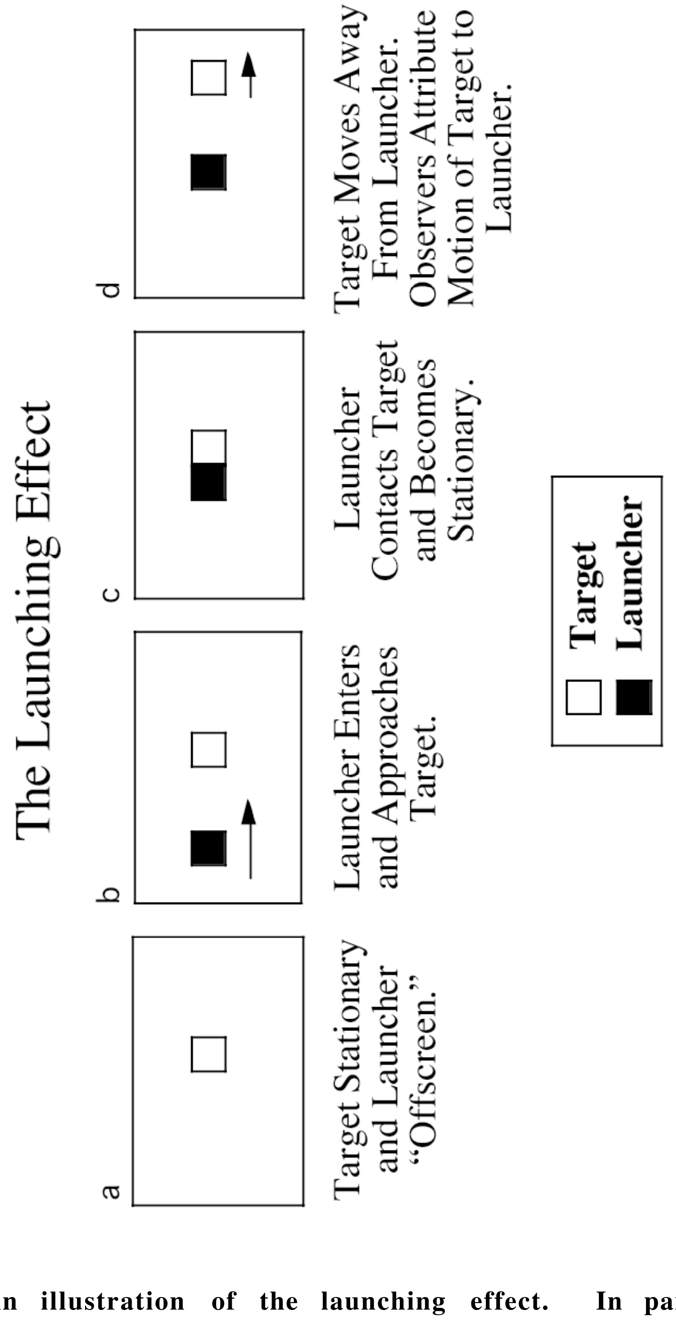

Figure 1. An illustration of the launching effect. In panel a, a stationary target is shown. In panel b, a moving launcher enters from one side of the display and moves toward the stationary target. In panel c, the moving launcher contacts the stationary target, and the launcher immediately becomes stationary. In panel d, the previously stationary target moves away from the launcher. Adapted from Hubbard and Ruppel (2002).

Several empirical findings support such an impetus-based account of displacement in the launching effect. Forward displacement of a target that moved in a direction orthogonal to the previous motion (and impetus) of the launcher (and for which Michotte's observers did not report a launching effect) was larger than forward displacement of launched targets and did not differ from forward displacement of otherwise identical targets presented in the absence of a launcher (Hubbard et al., 2001). Forward displacement of a launched target was related more to the previous velocity of the launcher than to the subsequent velocity of the target, and forward displacement of a launched target decreased with increases in the distance traveled by that target (Hubbard & Ruppel, 2002). When the launcher did not contact the target directly, forward displacement of the target decreased only if a visible intermediary stimulus bridged the gap between the final location of the launcher and the initial location of the target and served as a conduit for impetus (Hubbard & Favretto, 2003). If the launcher moved in a caterpillar fashion (the leading edge extended forward, the trailing edge then contracted, the leading edge then extended forward, etc.), a decrease in forward displacement of the target was observed if the previous expansion of the leading edge of the launcher just touched the target and the target moved at the moment the next expansion of the leading edge would have occurred (Hubbard & Ruppel, 2002). Also, a role of impetus in the displacement of launched targets is consistent with claims that representational momentum may more generally reflect naïve impetus beliefs (e.g., Kozhevnikov & Hegarty, 2001).

If displacement of a target in a launching effect display results from an attribution that impetus is imparted from the launcher to the target, then it may be that the launching effect more generally involves an attribution of impetus. However, one potential issue with an explanation of the launching effect that is based on impetus is that impetus does not correspond to a valid physical principle, and so it is not clear how a launching effect that was based on impetus could result if an observer directly perceived causality. Given that impetus does not correspond to a valid physical principle, but does correspond to a (incorrect) belief about physical principles, it should be possible to obtain impetus-like effects on the displacement of a target if the observer believes that impetus has been imparted from the launcher to the target even if the launcher had not previously been in motion. The possibility that impetus could be imparted from a stationary stimulus to a target has been discussed in the naïve physics literature (e.g., a stationary spiral tube has been suggested to impart a curvilinear impetus to a ball moving through that tube; McCloskey & Kohl, 1983; but see Cooke & Breedin, 1994), but in those cases there is already an existing motion, albeit of the target rather than of a launcher or other nontarget stimulus, and it could be argued that a stationary stimulus (e.g., such as a spiral tube) may modify or constrain the existing impetus of a target but not actually impart or create new impetus. A stronger test of the impetus account would involve a display in which a launcher and a target were both stationary prior to the motion of that target, but in which the observer would attribute motion of the target to impetus imparted from the launcher.

How might impetus be imparted from a stationary launcher to a stationary target? One possibility would be to have a launcher suddenly appear adjacent to the target, because when a stimulus suddenly appears (or is suddenly illuminated), that stimulus is perceived to expand from the center outward. This perceived motion is referred to as *gamma movement* (e.g., Bartley & Wilkinson, 1953; Harrower, 1929; Winters, 1964), and the perceived expansion resulting from gamma movement accompanying the appearance of a launcher could produce an outward-moving impetus that would be imparted to a stationary target in contact with that launcher. In contrast, if a launcher adjacent to the target suddenly vanished, the gamma movement of such a stimulus would be perceived to contract from the periphery inward, and this could produce an inward-moving impetus that would not be imparted to a stationary target in contact with that launcher. Thus, impetus would be imparted to a target when a stationary launcher appeared adjacent to that target, but impetus would not be imparted to a target when a stationary launcher adjacent to that target vanished. Accordingly, the experiments reported here examined whether gamma movement from a stationary launcher adjacent to the target and that appeared or vanished prior to motion of that target could influence displacement for that target. Such an influence would also provide important evidence that the launching effect depends upon cognitive elements such as an attribution of impetus rather than upon a direct perception of causality per se.

EXPERIMENT 1

Forward displacement of a target that moved away from the (previous) location of an adjacent launcher at the moment that launcher appeared or vanished was measured. If a stationary launcher suddenly appeared adjacent to a stationary target, gamma movement (and potential impetus) would be toward the target, whereas if a stationary launcher adjacent to a stationary target suddenly vanished, gamma movement (and potential impetus) would be away from the target. It is possible that motion of the target that began after the appearance of the launcher and that was in the direction of potential impetus from the launcher would be attributable to an impetus resulting from gamma movement of the launcher, and if so, then forward displacement of a target that moved away from the location of a launcher that appeared should be decreased relative to forward displacement of a target that moved away from the previous location of a launcher that vanished. Also, forward displacement when target motion was aligned with the direction of impetus (e.g., the launcher was adjacent to the left side of the target and target motion was toward the right) should be decreased relative to forward displacement when target motion was orthogonal to the direction of impetus (e.g., the launcher was adjacent to the left side of the target and target motion was upward or downward).

METHOD

Participants. The observers were 32 undergraduates at Texas Christian University who participated in return for extra credit in a psychology course. Sixteen observers participated in the Appear condition, and sixteen observers participated in the Vanish condition.

Apparatus. The stimuli were generated by and the responses were collected upon an Apple Macintosh IIsi computer connected to an Apple RGB color monitor.

Stimuli. The launcher and the target were square shapes 20 pixels (approximately 0.83 degrees of visual angle) in width and were presented on a white background. The launcher was a filled black square; the target was a black outline (with white interior), and the outline of the target was one pixel in width. The background of the visible stimulus display was 640 pixels in width and 460 pixels in height (approximately 26.67 x 19.17 degrees of visual angle). The location of the launcher was adjacent to the location of the target, and the launcher and target were presented in the approximate center of the display. In Appear trials, an isolated target was initially displayed, and after a one second pause, the launcher appeared adjacent to the target. In Vanish trials, both the launcher and the target were initially displayed, and after a one second pause, the launcher vanished. In Appear trials and in Vanish trials, one fourth of the trials were Impetus trials in which the target moved in the direction of potential impetus outward from the launcher (e.g., if the launcher was on the left side of the target, the target moved toward the right), and one half of the trials were Orthogonal trials in which a target moved away from the launcher in a direction orthogonal to potential impetus outward from the launcher (e.g., if the launcher was on left side of the target, the target moved upward or downward). There were twice as many Orthogonal trials as Impetus trials because there were two orthogonal directions and one impetus direction for each launcher and target configuration. In Impetus trials and in Orthogonal trials, the temporal interval between when the launcher appeared or vanished and when the target began to move was 500 ms. In Appear trials and in Vanish trials, one fourth of the trials were Target Only trials in which the launcher was not presented, and these trials were included in order to encourage observers to more actively attend to the target and to not anticipate or wait for a launcher. In all trials, target velocity was controlled by shifting the target one pixel between successive presentations, and this yielded an approximate velocity of 5 degrees/second. In all trials, the target (and in Appear trials, also the launcher) vanished after the target had traveled 30 pixels (1.25 degrees of visual angle). Each observer received 128 trials (4 sides [right, left, bottom, top] x 4 motion [target only, impetus, orthogonal, orthogonal[1]] x 8 replications) in a different random order.

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[1] Given that there were two types of Orthogonal trial for each type of Impetus trial (e.g., if a launcher appeared on the left, one Impetus trial involved motion toward the right, one

Procedure. Observers were given 10 practice trials at the beginning of the session, and practice trials were drawn randomly from the experimental trials. Observers initiated each trial by pressing a designated key. In Target Only trials, a stationary target appeared immediately after the observer pressed the designated key to begin the trial. One second later, the target began to move. In Appear trials, a stationary target appeared immediately after the observer pressed the designated key to begin the trial. One second later, the launcher appeared, and then 500 ms later the target moved away from the launcher. In Vanish trials, a launcher and a stationary target both appeared immediately after the observer pressed the designated key to begin the trial. One second later, the launcher vanished, and then 500 ms later the target moved away from the previous position of the launcher. In all trials, the cursor (in the form of a plus sign) appeared near the center of the display after the target vanished, and observers were instructed to position the center of the cursor over where the center of the target had been when the target vanished. The cursor was positioned by the movement of a computer mouse, and after positioning the mouse, observers clicked a button on the mouse in order to record the display coordinates of the cursor. Observers then initiated the next trial.

RESULTS

The difference between the true vanishing point and the judged vanishing point of the target (in pixels) was calculated along the axis of motion. Consistent with previous reports, this difference was referred to as *M displacement*[2]. Positively-signed M displacement indicated the judged vanishing point was beyond the true vanishing point (i.e., left of a leftward moving target, right of a rightward moving target, below a downward moving target, above an upward moving target), and negatively-signed M displacement indicated the judged vanishing point was behind the true vanishing point (i.e., right of a leftward moving target, left of a rightward moving target, above a downward moving target, below an upward moving target). The displacements from the two types of orthogonal trials were averaged to

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Orthogonal trial involved motion upward, and one orthogonal trial involved motion downward), “Orthogonal” is listed twice.

[2] Subsequent research has shown that the distortion along the axis of motion may be influenced by factors other than the implied momentum of the target (e.g., conceptual knowledge of the target, Reed & Vinson, 1996; direction of target motion relative to the direction of gravitational attraction, Hubbard, 1997; direction of target motion relative to a landmark, Hubbard & Ruppel, 1999), and so the more neural term *displacement* is preferred over *representational momentum* unless the distortion is attributable solely to the implied momentum of the target. Furthermore, displacement may be measured along different axes (e.g., previous studies distinguished between displacement along the axis of motion, *M displacement*, and displacement along the axis orthogonal to motion, *O displacement*), and the “M” specifies displacement along the axis of motion. Even though no other displacements are of interest in the current study, the “M” qualifier is retained in order to be consistent with previous practice.

provide a more useful mean orthogonal displacement. Target Only trials were not included in the analysis.

The M displacement scores were analyzed in a 4 (side [right, left, bottom, top]) x 2 (motion [impetus, orthogonal]) x 2 (launcher [appear, vanish]) repeated measures ANOVA in which side and motion were within-subject variables and launcher was a between-subject variable. Launcher was significant, $F(1,30) = 6.91$, $MSE = 347.62$, $p < .02$, and as predicted, forward M displacement was less in Appear ($M = -1.19$) trials than in Vanish ($M = 4.93$) trials. Motion influenced M displacement, $F(1,30) = 38.48$, $MSE = 12.98$, $p < .001$, and as predicted, forward M displacement was less in Impetus ($M = 0.48$) trials than in Orthogonal ($M = 3.27$) trials. Side was significant, $F(3,90) = 11.02$, $MSE = 14.33$, $p < .001$, and least squares comparisons revealed that Right ($M = 2.53$), Left ($M = 1.19$), and Bottom ($M = 3.69$) trials resulted in larger forward M displacement than did Top ($M = 0.08$) trials. Interpretation of Motion and Side effects is tempered by a significant Side x Motion interaction, $F(6,180) = 23.41$, $MSE = 16.46$, $p < .001$. As shown in Figure 2, forward M displacement was smaller on average when targets moved in the direction of potential impetus from the launcher than when targets moved in a direction orthogonal to potential impetus from the launcher, although this interacted with side such that forward M displacement was larger when motion of the target was along the horizontal axis (orthogonal trials for top and bottom, impetus trials for left and right). No other main effects or interactions approached significance.

DISCUSSION

As predicted, M displacement was generally smaller in Appear trials than in Vanish trials, and this pattern is consistent with the hypothesis that motion of the target in Appear trials was attributed to impetus arising from an outward illusory gamma movement of the launcher. As predicted, M displacement was generally smaller in Impetus trials than in Orthogonal trials. This pattern is consistent with the hypothesis that forward displacement should be decreased when target motion was aligned with the direction of impetus, with Michotte's finding that attributions the launcher was responsible for the motion of the target decreased as the path of subsequent target motion deviated from the path of previous launcher motion, and with the displacement patterns reported in Hubbard et al. (2001). The Side x Motion interaction (i.e., slightly larger M displacements for orthogonal motion aligned with the x axis [launcher above or below the target] than for orthogonal motion aligned with the y axis [launcher to the left or right of the target]) was consistent with the common finding that M displacement is generally larger for targets that move horizontally than for targets that move vertically (e.g., Hubbard, 1990), and so presumably reflects a general property of representational momentum rather than a property of impetus or of launching. In general, when target motion was in the direction of potential impetus arising from gamma movement of the launcher, M displacement was relatively smaller, whereas when target motion was in a direction different from potential impetus arising from gamma movement of the launcher, M displacement was relatively larger.

EXPERIMENT 2

In order to have more confidence in the impetus-based account of M displacement in Experiment 1, it would be useful to examine whether impetus arising from gamma movement of an adjacent stationary launcher that appears or vanishes influences displacement of a target that remains stationary throughout the trial. Hubbard and Ruppel (2002) found that launcher velocity (and thus presumably impetus from the launcher) did not influence displacement of a target that remained stationary after being contacted by a moving launcher, and this is consistent with observations that a force applied to a stationary physical object that is insufficient to overcome friction or resistance on that object will not influence the location of that physical object. Just as differences in launcher velocity (i.e., in the amount of impetus imparted to the target) do not influence displacement of a stationary target, whether a launcher appears or vanishes (i.e., whether impetus is toward or away from the target) should not influence displacement of a stationary target. Alternatively, if differences between displacement in Appear trials and in Vanish trials observed in Experiment 1 also occur in Experiment 2, then an impetus-based account of displacement would not be supported. Accordingly, Experiment 2 presented the same launchers used in Experiment 1, but the targets remained stationary throughout each trial. Also, given that gamma movement might be perceived to continue for a brief duration, the latency between when the launcher appeared or vanished and when the target vanished varied across trials.

METHOD

Participants. The observers were 30 undergraduates from the same participant pool used in Experiment 1, and none had participated in that experiment. Fifteen participated in the Appear condition, and fifteen participated in the Vanish condition.

Apparatus. The apparatus was the same as in Experiment 1.

Stimuli. The stimuli were the same as in Experiment 1, with the following exceptions: The target remained stationary throughout the duration of each trial. In Appear trials, the target and launcher vanished either immediately after the launcher became visible, or after an additional 500, 1000, or 1500 ms had elapsed. In Vanish trials, the target vanished immediately after the launcher vanished, or after an additional 500, 1000, or 1500 ms had elapsed. As in Experiment 1, Target Only trials were included in order to encourage observers to more actively attend to the target and to not anticipate or wait for a launcher, and in Target Only trials the target was visible for 1000 ms. Each observer received 100 trials (4 sides [right, left, bottom, top] x 5 latencies [target only, immediate, 500 ms, 1000 ms, 1500 ms] x 5 replications) in a different random order.

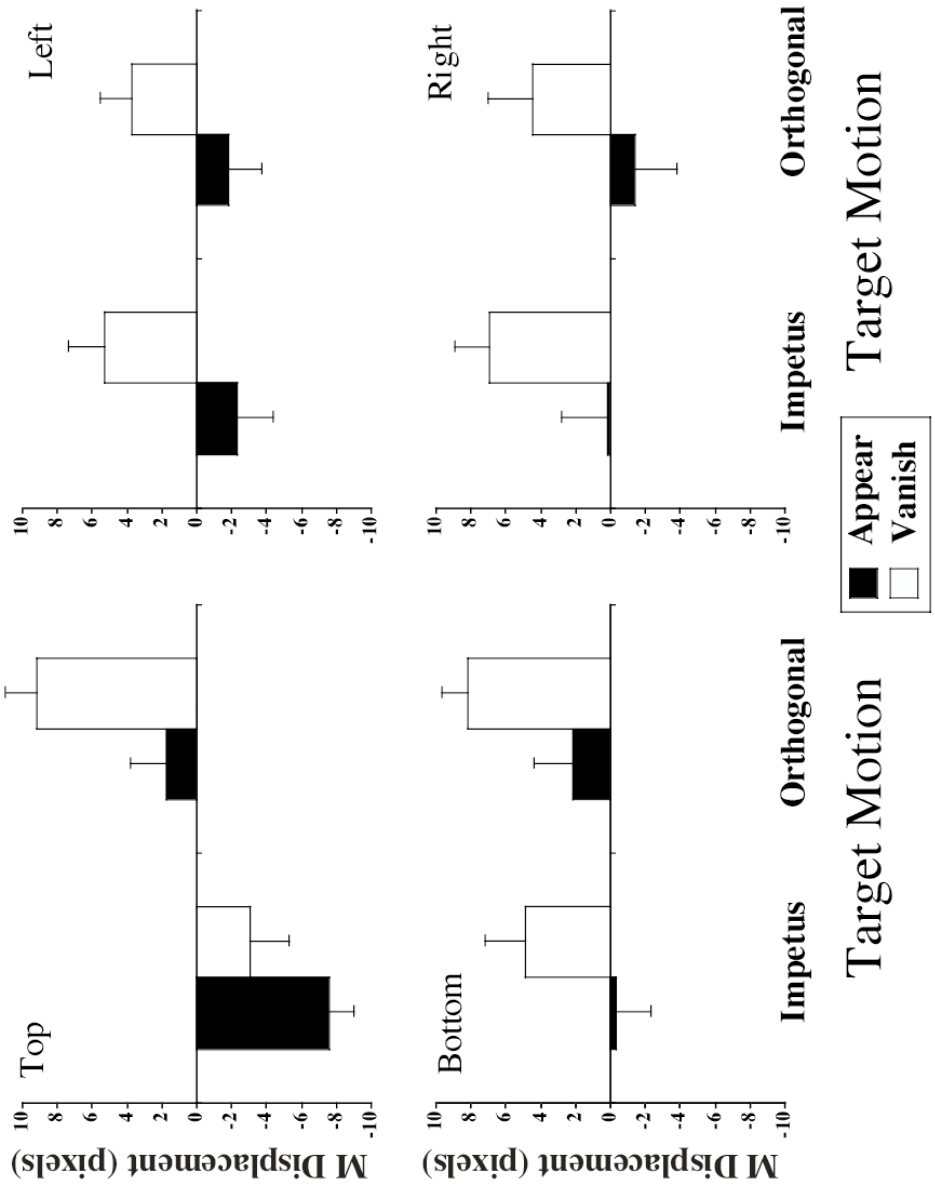

Figure 2. M displacement as a function of target motion in Experiment 1. Data for the top, bottom, left, and right conditions are in the upper left, lower left, upper right, and lower right panels, respectively. Data for Appear trials are in filled columns, and data for Vanish trials are in open columns.

Procedure. The procedure was the same as in Experiment 1, with the following exceptions: The target remained stationary throughout each trial. After the launcher appeared in Appear trials or vanished in Vanish trials, the target either vanished immediately or remained visible for an additional 500, 1000, or 1500 ms before vanishing.

RESULTS

Given that targets were not in motion, the term "M displacement" was not appropriate, and so consistent with Hubbard and Ruppel (2000, 2002), displacement of stationary targets was referred to as *T Displacement*. The T displacement scores were determined by calculating the differences between the true vanishing point and the judged vanishing point along the axis connecting the center of the launcher and the center of the target. Positively-signed T displacement indicated that the judged vanishing point was displaced away from the launcher, and negatively-signed T displacement indicated that the judged vanishing point was displaced toward the launcher. This sign convention ensured that T displacements in Experiment 2 were comparable with M displacements in Experiment 1. Target Only trials were not included in the analysis.

The T displacement scores were analyzed in a 4 (side [right, left, bottom, top]) x 4 (latency [immediate, 500 ms, 1000 ms, 1500 ms]) x 2 (launcher [appear, vanish]) repeated measures ANOVA in which side and latency were within-subject variables and launcher was a between-subject variable. Launcher was not significant, $\underline{F}(1,29) = 2.03$, $\underline{MSE} = 38.53$, $\underline{p} > .15$, nor did it interact with any other factor, all $\underline{F}$s < 1.81, all $\underline{p}$s > .15. Side was significant, $\underline{F}(3,87) = 16.25$, $\underline{MSE} = 48.85$, $\underline{p} < .001$, and least squares comparisons of all pairwise comparisons of Right ($\underline{M} = 1.15$), Left ($\underline{M} = -0.18$), Bottom ($\underline{M} = 2.20$), and Top ($\underline{M} = -2.19$) trials were significant except for the Right vs. Bottom comparison. The Side x Latency interaction was significant, $\underline{F}(9,261) = 2.60$, $\underline{MSE} = 4.56$, $\underline{p} < .01$. As shown in Figure 3, there was a trend toward a slight rightward T displacement when the launcher was on either the left or right of the target, a consistent positive T displacement (away from the launcher) when the launcher was above the target, and a consistent negative T displacement (toward the launcher) when the launcher was below the target, and the effect of latency was slightly stronger when the launcher was above or below the target than when the launcher was to the left or right of the target. No other main effects or interactions approached significance.

DISCUSSION

Whether the launcher appeared or vanished did not influence T displacement of a target that remained stationary. The data are consistent with the hypothesis that impetus imparted from the launcher was responsible for the decrease in displacement in Appear trials and in Impetus trials in Experiment 1. Given that movement of a target in a launching effect display is attributed to an impetus imparted from the launcher, movement of the target would reflect that impetus; more specifically, movement of the target would reflect that portion of impetus “left over” after the initial resistance on the target had been overcome and the target set into motion. However, if the target does not move, then the total amount of impetus imparted by the launcher would not have exceeded the amount needed to overcome the initial resistance on the target, and so the target would remain stationary. Given that the total amount of impetus imparted to the target in Experiment 2 was implied to be less than that required to overcome the initial resistance and set the target in motion (i.e., the target remained stationary), then it did not matter whether impetus from the launcher was toward or away from the target; target location was not influenced by impetus of the launcher. Also, differences in the general displacement patterns between Appear trials and Vanish trials across Experiments 1 and 2 rule out potential biases toward the edges or center of the display or other idiosyncrasies of the specific stimuli as alternative hypotheses for the M displacement patterns observed in Experiment 1.

When the launcher was on the left or right of a target that remained stationary, a minimal T displacement toward or away from the launcher was observed. When the launcher was above the target, a larger T displacement away from the launcher was observed, and when the launcher was below the target, a larger T displacement toward the launcher was observed. The positive T displacement when the target was below the launcher and the negative T displacement when the target was above the launcher are consistent with a general downward displacement of the target, and are similar to previous findings that memory for a target resting upon or suspended from some object is displaced downward when the object upon which the target was resting or from which the target was suspended is removed (e.g., Freyd, Pantzer, & Cheng, 1988). The general downward displacement when the launcher was above or below the target, coupled with the relative lack of displacement when the launcher was on the left or right of the target, is more consistent with representational gravity (a mislocalization of the remembered final position of a target in the direction of implied gravitational attraction, see Hubbard, 1995, 1997) than with any potential contribution of impetus. In general, the slight downward and rightward displacement is consistent with that reported by Hubbard and Ruppel (2000) for stationary targets on a blank background.

EXPERIMENT 3

The impetus-based account of displacement in Experiments 1 and 2 assumes that observers perceived gamma movement of the launcher. However, typical demonstrations of gamma movement usually do not involve the appearance of a stimulus adjacent to a previously visible second stimulus or the disappearance of one of two adjacent visible stimuli, and so it would be useful to confirm that observers perceive gamma movement when viewing a stationary launcher that appears or vanishes adjacent to a stationary target. Accordingly, observers in Experiment 3 were shown stimuli similar to those used in Experiment 2, and after the target (and in Appear trials, also the launcher) vanished, observers rated on a 1 to 7 scale the extent to which the launcher appeared to expand or to contract when it appeared or vanished. Also, given that gamma movement involves movement, and movement involves a change in position over time, the perception of gamma movement might extend for some brief duration after the launcher appears or vanishes. Therefore, the latency between when the launcher appeared or vanished and when the target vanished was either immediate, 500 ms, 1000 ms, or 1500 ms, and these latencies were the same as those used in Experiment 2.

Participants. The observers were 20 undergraduates from the same participant pool used in Experiments 1 and 2, and none had participated in the previous experiments.

Apparatus. The stimuli were generated by and responses collected upon an Apple Macintosh iMac computer equipped with a 15 inch color monitor.

Stimuli. The stimuli were the same as in Experiment 2, with the following exceptions: Target Only trials were not presented, and each observer viewed both Appear trials and Vanish trials. Each observer received 64 trials (2 launcher [appear, vanish] x 4 sides [right, left, bottom, top] x 4 latencies [immediate, 500 ms, 1000 ms, 1500 ms] x 2 replications) in a different random order.

Procedure. The procedure was the same as in Experiment 2, with the following exceptions: After the target and launcher vanished in Appear trials, observers rated on a 1 to 7 scale (1 = "clearly contract", 7 = "clearly expand") whether the black square (i.e., the launcher) expanded or contracted when it appeared. After the target vanished in Vanish trials, observers rated on a 1 to 7 scale (1 = "clearly contract", 7 = "clearly expand") whether the black square (i.e., the launcher) expanded or contracted when it vanished. Observers indicated their rating by pressing the appropriate key on the computer keyboard.

RESULTS

Ratings were analyzed in a 4 (latency [immediate, 500 ms, 1000 ms, 1500 ms]) x 2 (launcher [appear, vanish]) repeated measures ANOVA in which latency and launcher were within-subject variables. Launcher was highly significant, $F(1,19) = 34.70$, $MSE = 6.47$, $p < .001$, with Appear (M = 5.18) trials rated as more expanding than were Vanish (M = 2.81) trials. If the midpoint of the 1-7 rating scale (i.e., 4) is considered to reflect a neutral value of neither expansion nor contraction, ratings of launchers in Appear trials were significantly larger than this neutral value, $t(79) = 6.36$, $p < .001$, and ratings of launchers in Vanish trials were significantly smaller than this neutral value, $t(79) = -7.56$, $p < .001$. Therefore, launchers in Appear trials were perceived to expand, and launchers in Vanish trials were perceived to contract, and so observers experienced gamma movement in the predicted direction when a launcher adjacent to a stationary target appeared or vanished. Latency, $F(3,57) = 5.77$, $MSE = 0.72$, $p < .002$, and the Latency x Launcher interaction, $F(3,57) = 59.49$, $MSE = 0.74$, $p < .001$, were both significant. As shown in Figure 4, in the immediate condition there was relatively little rated expansion or contraction in Appear trials or in Vanish trials, but at latencies of 500, 1000, or 1500 ms, launchers in Appear trials were rated as expanding and launchers in Vanish trials were rated as contracting.

DISCUSSION

The ratings in Experiment 3 support the notion that observers experienced an outward or expanding gamma movement when a launcher appeared adjacent to the target and an inward or contracting gamma movement when a launcher adjacent to the target vanished. Of greater relevance to the current investigation, the ratings in Experiment 3 also support an impetus-based account of the pattern of M displacement in Experiment 1 and are consistent with previous impetus-based accounts of the decrease in forward M displacement of targets in displays based upon Michotte's launching effect. Intriguingly, the notion that impetus arising from gamma movement is sufficient to trigger a launching effect suggests that the launching effect does not result from a direct perception of causality, but instead results from a cognitively mediated perception of the stimuli. Indeed, it is hard to argue that an attribution based on a perceptual illusion involves direct perception. Even so, it might be suggested that observers directly perceive causality in a standard launching effect display, but have a cognitively mediated perception in the case of gamma movement triggering a launching effect, and that these two different mechanisms each result in a perceived launching and a decreased displacement of the target; however, such an argument seems post hoc and unparsimonious.

The ratings in Experiment 3 revealed a significant interaction of latency and of whether the launcher appeared or vanished on judgments of whether the launcher was perceived to expand or contract. Although this interaction and the main effect of latency on ratings were not of primary concern in the current investigation, the rapid increase and asymptote of ratings in Appear trials and the rapid decrease and asymptote of ratings in Vanish trials are interesting findings; however, it is not clear from the data whether gamma movement actually continued for at least 1500 ms (after the target appeared or vanished) or whether gamma movement terminated more quickly (and thus ratings for longer latencies reflected remembered expansion or contraction rather than perceived expansion or contraction). For our purposes here, it is sufficient to note that Experiment 1 used a latency of 500 ms between when the launcher appeared or vanished and when the target began to move, and that ratings of expansion or contraction 500 ms after the launcher appeared or vanished in Experiment 3 revealed a strong gamma movement of the launcher in the predicted direction. Thus, ratings in Experiment 3 are consistent with the claim that observers in Experiment 1 perceived gamma movement of the launcher and with the more general impetus-based account of displacement in the launching effect.

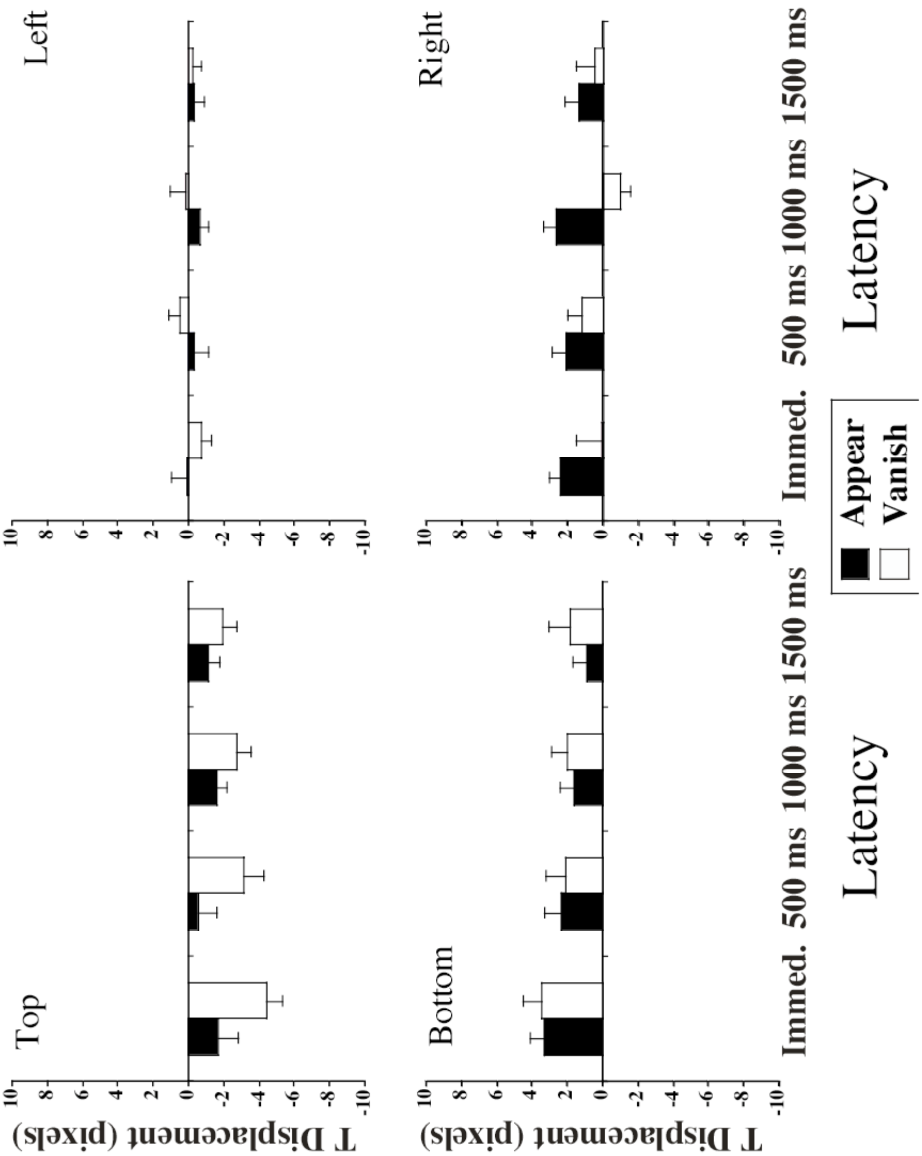

Figure 3. T displacement as a function of latency in Experiment 2. Data for the top, bottom, left, and right conditions are in the upper left, lower left, upper right, and lower right panels, respectively. Data for Appear trials are in filled columns, and data for Vanish trials are in open columns.

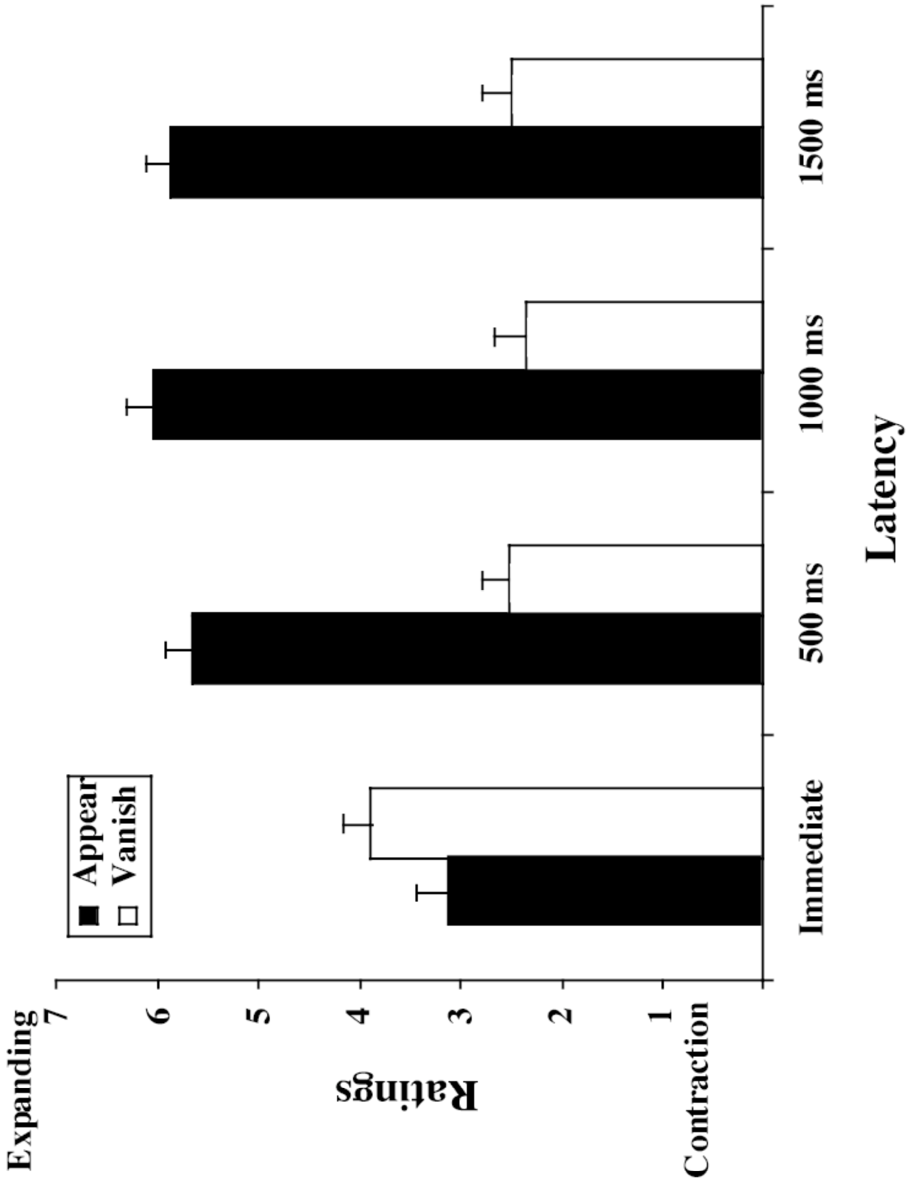

Figure 4. Ratings of expansion or contraction in Experiment 3. Data for Appear trials are in filled columns, and data for Vanish trials are in open columns.

GENERAL DISCUSSION

When a stationary launcher appeared adjacent to a stationary target, and that target then moved away from the launcher shortly after the launcher appeared, forward displacement in the remembered position of that target was reduced if the direction of target motion was aligned with the direction of a potential outward gamma movement from the launcher. This reduction in forward displacement in remembered position of the target is similar to that previously observed for a target in a launching effect display in which a moving launcher contacted an initially stationary target that subsequently moved in the same direction as the previous motion of the launcher. A similar reduction in forward displacement in the remembered position of the target was not observed if the direction of target motion was orthogonal to the direction of a potential outward gamma movement from the launcher, if a launcher adjacent to a stationary target vanished and the target began to move after the launcher vanished, or if the target remained stationary. This lack of reduction in displacement when the target moved in an orthogonal direction or remained stationary is similar to that previously observed in memory for the final location of a target in a modified launching effect display in which a moving launcher contacted an initially stationary target that subsequently moved in an orthogonal direction or remained stationary. All of these displacements are consistent with the hypothesis that impetus generated by illusory gamma movement of a stationary launcher that suddenly appears is sufficient for inducing a launching effect.

One alternative explanation is that the displacement pattern resulted from apparent motion between the location of the launcher and the location of the target. In the absence of biasing context (e.g., as in McBeath & Shepard, 1989; Shepard & Zare, 1983), apparent motion would be expected to operate along a straight path between the launcher and the target, and so perhaps a stronger apparent motion in Impetus trials than in Orthogonal trials resulted in a smaller displacement. However, the launcher only appeared or vanished once per trial and the target was continuously visible, and so it does not seem likely that apparent motion between the launcher and the target would have been evoked. A second alternative explanation is that decreased displacement in Appear trials reflected the use of a visible launcher as a landmark because forward displacement of a target is decreased when a target moves away from a landmark (Hubbard & Ruppel, 1999). However, a bias toward the (previous) location of a landmark is often larger in memory than in perception, and so if the launcher was used as a landmark, then Appear trials (in which the landmark was visible during target motion) should have exhibited larger forward displacement than did Vanish trials (in which the landmark was not visible during target motion). It is also not clear how a landmark explanation could account for differences in displacement between Impetus trials and Orthogonal trials in Experiment 1 (see also Hubbard et al., 2001).

A third alternative explanation involves differences in attentional focus in Appear trials and in Vanish trials. Observers exhibit higher accuracy in identifying probes located slightly in front of the final position of a moving target than in identifying probes located slightly behind the final position of a moving target (Kerzel, Jordan, & Müsseler, 2001), and this suggests attention is focused slightly in front of a moving target. If the sudden appearance or vanishing of the launcher involved an allocation of (at least some) attention to the current or previous location of the launcher, then at least some attention would have been focused behind the target. Allocating at least some attention to the current or previous location of the launcher might have “pulled” the representation of the target backward by shifting the center of attention away from a focus slightly in front of the target and toward the current or previous location of the launcher, thus reducing the forward displacement of the target. To the extent that appearing may be more salient than vanishing, Appear trials resulted in a greater allocation of attention backward than did Vanish trials, and so forward M displacement was decreased more in Appear trials than in Vanish trials. Although such a view is consistent with suggestions that attention may be required for representational momentum (Kerzel, 2003; but see Hayes & Freyd, 2002), it is not clear if such an attention-based account is consistent with the differences in displacement between Impetus trials and Orthogonal trials in Experiment 1.

The data are consistent with Hubbard et al.’s (2001; Hubbard & Ruppel, 2002) suggestion that the launching effect involves an attribution that impetus was imparted from the launcher to the target. The data suggest that an apparent perception of causality in the launching effect may depend more on the belief that motion (or impetus resulting from motion) occurred than on actual motion, and that the presence of such belief is sufficient to produce an attribution of impetus. Given that impetus does not correspond to a valid physical principle, any role of impetus in the launching effect suggests that the apparent perception of causality in the launching effect may depend on cognitive mediation (e.g., a belief in impetus and an attribution that impetus from the launcher was imparted to the target) rather than reflecting direct perception per se. The existence of such a cognitive mediation could help account for the apparent perception of causality in many of Michotte’s studies in which stimuli would not have experienced causal principles per se (e.g., a spot of light “launching” a colored square). Even if an impetus-based explanation of the launching effect is incorrect, the finding that an apparent launching effect occurred even when movement of the launcher was illusory suggests that the launching effect does not demonstrate that causality is directly perceived. More broadly, the data provide an example of the effect of context and expectancy on displacement in spatial representation, and also further our understanding of how mental representation models properties of the world.

REFERENCES

Bartley, S. H., & Wilkinson, F. R. (1953). Some factors in the production of gamma movement. *Journal of Psychology, 36,* 201-206.

Bingham, G. P. (1987). Kinematic form and scaling: Further investigations on the visual perception of lifted weight. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 155-177.

Cooke, N. J., & Breedin, S. D. (1994). Constructing naive theories of motion on the fly. *Memory & Cognition, 22,* 474-493.

Finke, R. A., Freyd, J. J., & Shyi, G. C. W. (1986). Implied velocity and acceleration induce transformations of visual memory. *Journal of Experimental Psychology: General, 115,* 175-188.

Freyd, J. J., Pantzer, T. M., & Cheng, J. L. (1988). Representing statics as forces in equilibrium. *Journal of Experimental Psychology: General, 117,* 395-407.

Gilden, D. L. (1991). On the origins of dynamical awareness. *Psychological Review, 98,* 554-568.

Gilden, D. L., & Proffitt, D. R. (1989). Understanding collision dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 372-383.

Harrower, M. R. (1929). Some experiments on the nature of gamma movement. *Psychologische Forschung, 13,* 55-63.

Hayes, A. E., & Freyd, J. J. (2002). Representational momentum when attention is divided. *Visual Cognition, 9,* 8-27.

Hubbard, T. L. (1990). Cognitive representation of linear motion: Possible direction and gravity effects in judged displacement. *Memory & Cognition, 18,* 299-309.

Hubbard, T. L. (1995). Environmental invariants in the representation of motion: Implied dynamics and representational momentum, gravity, friction, and centripetal force. *Psychonomic Bulletin & Review, 2,* 322-338.

Hubbard, T. L. (1997). Target size and displacement along the axis of implied gravitational attraction: Effects of implied weight and evidence of representational gravity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 1484-1493.

Hubbard, T. L. (2004). Representational momentum and related displacements in spatial memory: A review of the findings. *Manuscript submitted for publication.*

Hubbard, T. L., Blessum, J. A., & Ruppel, S. E. (2001). Representational momentum and Michotte's (1946/1963) “Launching Effect” paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 294-301.

Hubbard, T. L., & Favretto, A. (2003). Naive impetus and Michotte's “Tool Effect:” Evidence from representational momentum. *Psychological Research/ Psychologische Forschung, 67*, 134-152.

Hubbard, T. L., & Ruppel, S. E. (1999). Representational momentum and landmark attraction effects. *Canadian Journal of Experimental Psychology, 53,* 242-256.

Hubbard, T. L., & Ruppel, S. E. (2000). Spatial memory averaging, the landmark attraction effect, and representational gravity. *Psychological Research /Psychologische Forschung, 64*, 41-55.

Hubbard, T. L., & Ruppel, S. E. (2002). A possible role of naive impetus in Michotte's “Launching Effect:” Evidence from representational momentum. *Visual Cognition, 9,* 153-176.

Kerzel, D. (2003). Attention maintains mental extrapolation of target position: Irrelevant distractors eliminate forward displacement after implied motion. *Cognition, 88,* 109-131.

Kerzel, D., Jordan, J. S., & Müsseler, J. (2001). The role of perception in the mislocalization of the final position of a moving target. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 829-840.

Kozhevnikov, M., & Hegarty, M. (2001). Impetus beliefs as default heuristics: Dissociation between explicit and implicit knowledge about motion. *Psychonomic Bulletin & Review, 8*, 439-453.

McBeath, M. K., & Shepard, R. N. (1989). Apparent motion between shapes differing in location and orientation: A window technique for estimating path curvature. *Perception & Psychophysics, 46,* 333-337.

McCloskey, M. (1983). Naive theories of motion. In D. Gentner & A. L. Stevens (Eds.), *Mental models*. Hillsdale, NJ: Erlbaum (pp. 299-324).

McCloskey, M., & Kohl, D. (1983). Naive physics: The curvilinear impetus principle and its role in interactions with moving objects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9,* 146-156.

Michotte, A. (1963). *The perception of causality* (T. R. Miles & E. Miles, Trans.). New York: Basic Books. (original work published 1946).

Proffitt, D. R., & Gilden, D. L. (1989). Understanding natural dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 15,* 384-393.

Reed, C. L., & Vinson, N. G. (1996). Conceptual effects on representational momentum. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 839-850.

Runeson, S., & Frykholm, G. (1983). Kinematic specification of dynamics as an informational basis for person-and-action perception: Expectation, gender recognition, and deceptive intention. *Journal of Experimental Psychology: General, 112,* 585-615.

Shepard, R. N., & Zare, S. L. (1983). Path-guided apparent motion. *Science, 220,* 632-634.

Thinès, G., Costall, A., & Butterworth, G. (Eds.). (1991). *Michotte's experimental phenomenology of perception*. Hillsdale, NJ: Erlbaum.

Thornton, I. M., & Hubbard, T. L. (Eds.). (2002). *Representational momentum: New findings, new directions*. New York: Psychology Press/Taylor & Francis.

Valenti, S. S., & Costall, A. (1997). Visual perception of lifted weight from kinematic and static (photographic) displays. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 181-198.

Winters, J. J. (1964). Gamma movement: Apparent movement in figural aftereffects experiments. *Perceptual and Motor Skills, 19,* 819-822.

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