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BRIEF REPORT

Perceived causality, force, and resistance in the absence of launching

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Abstract In the launching effect, a moving object (the launcher) contacts a stationary object (the target), and upon contact, the launcher stops and the target begins moving in the same direction and at the same or slower velocity as previous launcher motion (Michotte, 1946/1963). In the study reported here, participants viewed a modified launching effect display in which the launcher stopped before or at the moment of contact and the target remained stationary. Participants rated perceived causality, perceived force, and perceived resistance of the launcher on the target or the target on the launcher. For launchers and for targets, increases in the size of the spatial gap between the final location of the launcher and the location of the target decreased ratings of perceived causality and ratings of perceived force and increased ratings of perceived resistance. Perceived causality, perceived force, and perceived resistance exhibited gradients or fields extending from the launcher and from the target and were not dependent upon contact of the launcher and target. Causal asymmetries and force asymmetries reported in previous studies did not occur, and this suggests that such asymmetries might be limited to typical launching effect stimuli. Deviations from Newton's laws of motion are noted, and the existence of separate radii of action extending from the launcher and from the target is suggested.

Keywords Perception of causality · Launching effect · Naïve physics · Perception of force · Causal asymmetry

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If observers see a moving object contact a stationary object, and that stationary object immediately begins moving in a similar direction and at a similar or slower velocity, then those observers often have a vivid impression that contact from the first (initially moving) object caused subsequent motion of the second (initially stationary) object. This has been referred to as the *launching effect* (Michotte, 1946/1963) and has been studied by researchers interested in perception of causality (for review, Hubbard, 2013b). The extent to which perception of causality in the launching effect is linked to (perception of) qualities such as force or resistance has been a topic of increasing interest, and findings from several studies highlight differences between subjective perception of causality and objective physical laws governing object motion (e.g., Hubbard, 2013a; White, 2006a,b, 2007, 2009). The current investigation presented a modified launching effect display in which (1) the moving object approached a stationary object and stopped before or at the moment of contact and (2) the stationary object remained stationary. Ratings of perceived causality, perceived force, and perceived resistance exerted by each object on the other object were collected, and implications of the findings are considered. For convenience, the initially moving object is referred to as the *launcher*, and the initially stationary object is referred to as the *target*.

White (2007) pointed out that physical objects in a launching effect scenario would (consistent with Newton's laws of motion) exert equal forces on each other. Thus, if observers' responses are consistent with Newton's laws, the launcher and the target would be rated as exerting equal levels of force. However, spontaneous reports of observers who view launching effect displays usually mention the launcher's effect on the target but do not mention the target's effect on the launcher (Michotte, 1946/1963). Consistent with this, the launcher is usually rated as more causal and as exerting more force than the target (Hubbard & Ruppel, 2013; White, 2007, 2009), and these patterns are referred to as *causal asymmetry* (White, 2006a) and *force asymmetry* (White, 2012a), respectively. Similarly, the physics of colliding objects does not distinguish between force and resistance, and so if observers' responses are consistent with Newton's laws, ratings of perceived force should equal ratings of perceived resistance. However, White (2009, 2011b) argued that an active or self-propelled object was likely to be perceived as exerting force and a passive or stationary object was likely to be perceived as exerting resistance. Similarly, White (2009, 2012a,b) suggested that an object is perceived as exerting force if its behavior could be matched to a motor representation of action, whereas an object is perceived as exerting resistance if its behavior could not be matched to a motor representation of action.

White (2011a) presented modified launching effect displays in which the launcher stopped before contacting the target and an intermediary stimulus bridged some or all of the spatial gap between the final location of the launcher and the initial location of the target. Ratings of the force of the launcher were not influenced by spatial gap size, whereas ratings of causality decreased as spatial gap size increased (cf. Michotte, 1946/1963; Yela, 1952). Ratings of the force of the launcher were higher if no intermediary was present, whereas ratings of causality were higher if an intermediary was present and bridged more of the spatial gap (cf. Young & Falmier, 2008). Ratings of causality were consistent with Hubbard and Favretto's (2003) finding that representational momentum (a shift in the judged location of a target in the direction of anticipated motion; for review, Hubbard, 2005, 2014) of the target in a similar display was decreased if the spatial gap between the final location of the launcher and the initial location of the target was bridged by an intermediary. Given that such a decrease is typical of launched targets (Hubbard, 2013a; Hubbard & Ruppel, 2002), the intermediary might be perceived as conveying influence of the launcher (perhaps in the form of an impetus that dissipated with subsequent target motion) to the target (cf. McCloskey, 1983; tool effect, Michotte, 1951/1991).

Michotte (1946/1963) suggested launcher motion toward the target in the launching effect was perceived as intentional (i.e., it was unlikely the launcher would by chance move toward the target; White, 2012a). If launcher motion toward the target is perceived as intentional, then cessation of launcher motion prior to contact with the target might be perceived as due to (intentional) resistance from the target (cf. reaction effect; Kanizsa & Vicario, 1968). Just as perceived force might span a spatial gap between the final location of the launcher and the initial location of the target (White, 2011a), so too might perceived resistance span the same spatial gap. Given that the likelihood of a launching effect decreases with increases in spatial gap size between the final location of the launcher and the initial location of the target (Michotte, 1946/1963; Yela, 1952), increases in spatial gap size might also influence perceived resistance. However, White's finding that spatial gap size did not influence ratings of force predicts that perceived resistance of the target would not be influenced by spatial gap size. Accordingly, in the study reported here, the launcher stopped before or at the moment of contact, and ratings of perceived causality, perceived force, and perceived resistance of the launcher on the target and of the target on the launcher were collected.

Methods

Participants

The participants were 48 undergraduates from University of South Carolina Upstate, who were naïve to the hypotheses and received partial course credit. Sixteen participants provided ratings of causality, 16 participants provided ratings of force, and 16 participants provided ratings of resistance.

Apparatus

The stimuli were displayed upon, and the data were collected with, a Gateway desktop computer connected to a 17-inch (c.43-cm) color monitor with a refresh rate of 60 Hz and a resolution of 1024 × 768 pixels. Participants' head and eye movements were unconstrained, and the average viewing distance was approximately 60 cm.

Stimuli

Launchers and targets The launcher and the target were squares 20 pixels (approximately 0.83 degrees of visual angle) in width and in height. The launcher was red, the target was blue, and the background was white. Targets were presented near the center of the display, and once a target appeared, it remained stationary and visible until the end of the trial. Launchers and targets were vertically aligned, and the launcher appeared 200 pixels to the right or left of the target. The launcher began moving toward the target as soon as it appeared, and launcher velocity was approximately 70 pixels/s (6 deg/s). Launcher motion ceased when the launcher contacted the target (i.e., 0 pixel gap) or there was a 40, 80, 120, or 160 pixels gap between the launcher and target, thus resulting in launcher trajectory lengths of 200, 160, 120, 80, and 40 pixels, respectively. By keeping the initial distance of the launcher from the target constant, participants could not predict where the launcher would stop. Had launcher trajectory length been constant, larger spatial gaps would have necessitated more distant initial launcher locations that could have cued participants where the launcher would stop, and this might have influenced subsequent ratings.

Rating scales Rating scales were adapted from White (2007, 2009). For ratings of perceived causality, participants were asked "To what extent did the red (blue) object cause (or was responsible for) any motion or change in the blue (red) object? Please rate on a zero (no causality at all) to 100 (maximum possible causality) scale". For ratings of perceived force, participants were asked "How much force did the red (blue) object exert on the blue (red) object? Please rate on a zero (no force at all) to 100 (maximum possible force) scale". For ratings of perceived resistance, participants were asked "How much resistance did the red (blue) object exert on the blue (red) object? Please rate on a zero (no resistance at all) to 100 (maximum possible resistance) scale".

Procedure

Participants first received a practice session consisting of 10 trials that included examples of each gap size by direction combination. There was a 1000 ms delay after participants pushed a designated key to begin the trial, and then the target appeared. After 250 ms, the launcher appeared and moved toward the target. The launcher and target were visible for 1500 ms after launcher motion ceased, and then the launcher and target simultaneously vanished. After 250 ms, the rating scale appeared near the top of the display and remained visible until participants entered their rating into a keyboard attached to the desktop computer. Participants then initiated the next trial.

Design

Each participant completed two blocks of trials. One group of participants rated causality in both blocks, a second group of participants rated force in both blocks, and a third group of participants rated resistance in both blocks. In one block, participants rated causality, force, or resistance of the launcher on the target, and in the other block, participants rated causality, force, or resistance of the target on the launcher. Order of blocks was counterbalanced across participants. Each participant received 40 trials [5 gaps (0, 40, 80, 120, 160 pixels) × 2 directions (leftward, rightward) × 4 replications] in a different random order in each block.

Results

Ratings of perceived causality, perceived force, and perceived resistance are shown in Fig. 1 and were analyzed in separate 2 (source: launcher, target) × 5 (gap: 0, 40, 80, 120, 160) × 2 (direction: leftward, rightward) repeated measures ANOVAs.

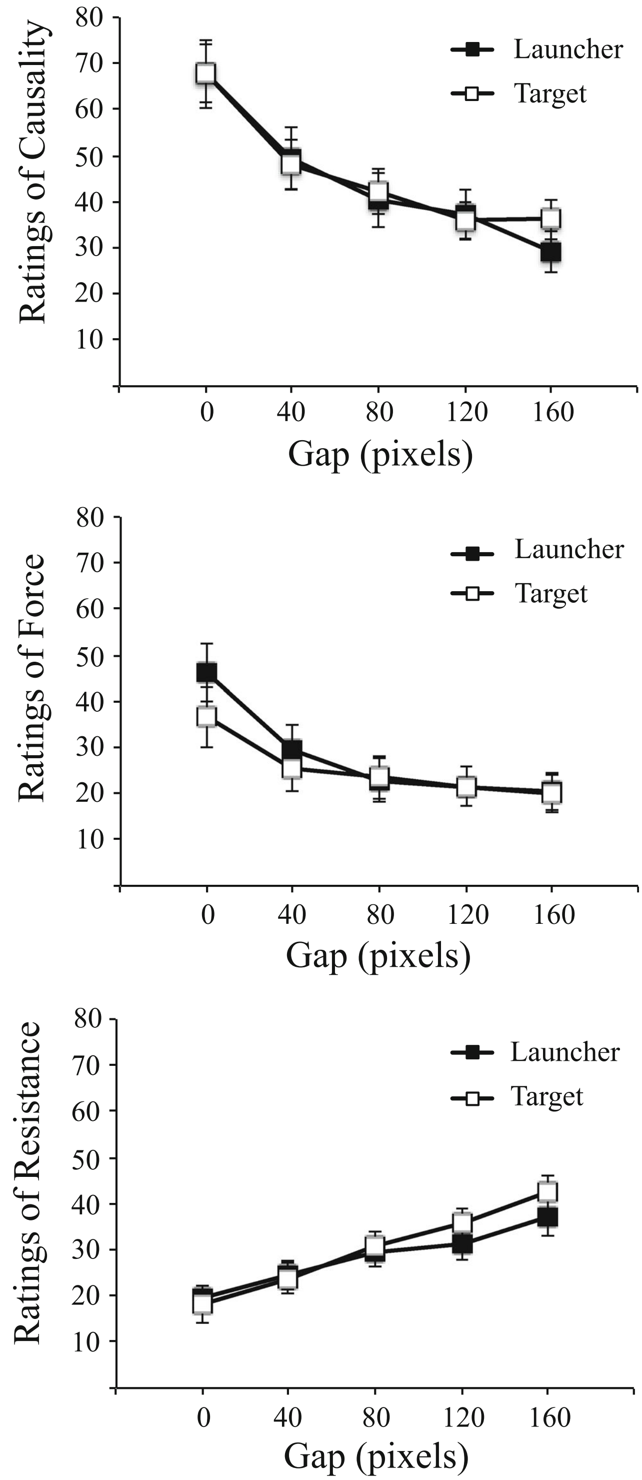

Fig. 1 Ratings of causality (*top panel*), force (*middle panel*), and resistance (*bottom panel*) as a function of the size of the spatial gap between the final location of the launcher and the location of the target. Ratings for the launcher are shown as *filled squares*, and ratings for the target are shown as *open squares*. *Error bars* show standard error of the mean

Perceived causality

Gap was significant, $F(4,60) = 24.17$, $MSE = 507.24$, $p < .0001$, and least square comparisons (with a Bonferroni correction for 10 comparisons of .05/10 = .005 required for significance) revealed the 0 gap ($M = 67.75$, $SE = 2.82$) resulted in higher ratings than the 40 ($M = 48.73$, $SE = 2.82$), 80 ($M = 41.36$, $SE = 2.82$), 120 ($M = 36.58$, $SE = 2.82$), and 160

($M = 32.70$, $SE = 2.82$) gaps, the 40 gap resulted higher ratings than the 120 and 160 gaps, and the 80 gap resulted in higher ratings than the 160 gap (all *p*s < .003). Additionally, there were trends for the 40 gap to result in higher ratings than the 80 gap ($p < .07$) and for the 80 gap to result in higher ratings than the 160 gap ($p < .04$). Rightward motion ($M = 46.26$, $SE = 2.68$) resulted in slightly higher ratings than leftward motion ($M = 44.59$, $SE = 2.64$), $F(1,15) = 6.03$, $MSE = 37.06$, $p < .03$. Whether participants rated perceived causality of the launcher ($M = 44.75$, $SE = 2.87$) or the target ($M = 46.10$, $SE = 2.44$) was not significant, $F(1,15) = 0.04$, $MSE = 3838.35$, $p > .84$. As shown at the top of Fig. 1, perceived causality decreased with increases in gap size, and there was no difference between ratings for the launcher and for the target. No other effects approached significance.

Perceived force

Gap was significant, $F(4,60) = 9.80$, $MSE = 484.63$, $p < .001$, and least square comparisons (with a Bonferroni correction of .05/10 = .005 required for significance) revealed the 0 gap ($M = 41.45$, $SE = 2.75$) resulted in higher ratings than the 40 ($M = 27.57$, $SE = 2.75$), 80 ($M = 23.29$, $SE = 2.75$), 120 ($M = 21.59$, $SE = 2.75$), and 160 ($M = 20.29$, $SE = 2.75$) gaps (all *p*s < .0007). Additionally, there was a trend for the 40 gap to result in higher ratings ($p < .07$) than the 160 gap. Rightward motion ($M = 27.65$, $SE = 2.32$) resulted in slightly higher ratings than leftward motion ($M = 26.02$, $SE = 2.82$), $F(1,15) = 6.84$, $MSE = 31.12$, $p < .02$. Whether participants rated perceived force of the launcher ($M = 28.22$, $SE = 2.37$) or the target ($M = 25.46$, $SE = 2.23$) was not significant, $F(1,15) = 0.92$, $MSE = 667.59$, $p > .35$. Interpretation of these main effects is tempered by a significant Gap x Source interaction, $F(4,60) = 3.98$, $MSE = 75.15$, $p < .007$. As shown in the middle of Fig. 1, perceived force decreased with increases in gap size. The launcher was rated as exhibiting more force than the target with smaller gaps, and there was no difference between ratings for the launcher and for the target with larger gaps. No other effects approached significance.

Perceived resistance

Gap was significant, $F(4,60) = 10.97$, $MSE = 385.94$, $p < .0001$, and least square comparisons (with a Bonferroni correction of .05/10 = .005 required for significance) revealed the 0 gap ($M = 18.95$, $SE = 2.46$) resulted in lower ratings than the 80 ($M = 30.25$, $SE = 2.46$), 120 ($M = 33.59$, $SE = 2.46$), and 160 ($M = 33.92$, $SE = 2.46$) gaps, and the 40 gap ($M = 24.26$, $SE = 2.46$) resulted in lower ratings than the 160 gap (all *p*s < .002). Additionally, there were trends for the 40 gap to result in lower ratings than the 80 gap ($p < .09$) and the 120 gap ($p < .01$), the 80 gap to result in lower ratings than the 160 gap ($p < .007$), and the 120 gap to result in lower ratings than the 160 gap ($p < .07$). Whether participants rated perceived resistance of the launcher ($M = 28.53$, $SE = 1.56$) or the target ($M = 30.26$, $SE = 1.67$) was not significant, $F(1,15) = 0.30$, $MSE = 808.61$, $p > .59$. As shown at the bottom of Fig. 1, perceived resistance increased with increases in gap size, and there was no difference between ratings for the launcher and for the target. Direction × Gap was marginally significant, $F(4,60) = 2.39$, $MSE = 76.38$, $p < .07$, such that the increase in ratings with increases in gap size was slightly larger for leftward motion than for rightward motion. No other effects approached significance.

Discussion

Increases in the size of the spatial gap between the final location of the launcher and the location of the target resulted in decreases in ratings of perceived causality and ratings of perceived force and increases in ratings of perceived resistance. Although White (2011a, 2014) and Hubbard and Ruppel (2013) found a dissociation of ratings of perceived causality and ratings of perceived force, the current study did not find such a dissociation, but did find a dissociation of ratings of perceived causality or perceived force and ratings of perceived resistance. Interestingly, perceived force and perceived resistance did not depend upon contact of the launcher and target (such dependence would have resulted in ratings of 0 if the launcher stopped before contact), but instead appeared to involve gradients or fields extending beyond the edges of the launcher and the target. Such findings are not consistent with physical principles governing motion and collision of objects, but are consistent with existence of expectations regarding anticipated contact of the launcher and the target. Previous studies suggested a stationary object is not perceived as exerting force (White, 2006b, 2011b; but see White, 2012b) or as causal (White, 2006a), but the current study suggests a stationary target can be perceived as exerting force (and resistance) and as causal.

The causal asymmetry and force asymmetry observed in previous studies of launching effect stimuli were not observed in the current study, nor was a resistance asymmetry observed. However, unlike targets in those previous studies, targets in the current study remained stationary after contact (i.e., there was no visible effect or perceived action on the target). This suggests that causal asymmetry or force asymmetry might be related to the presence of a visible effect or perceived action of the launcher on the target (cf. White, 2009, 2012a,b). Such a hypothesis is consistent with findings regarding ratings of causality and ratings of force when launchers or targets shattered upon contact (Hubbard & Ruppel, 2013). In general, if a target is launched (or shattered), there is a visible effect or perceived action and such asymmetries occur, but if a target is not launched (or not shattered), there is no visible effect or perceived action and such asymmetries do not occur. Thus, causal asymmetry and force asymmetry do not necessarily occur in all causal perception, but might be limited to stimuli in which one object has a visible effect or perceived action on another object. Relatedly, if the launcher is perceived to stop just when its force (resistance) equals the force (resistance) of the target, then neither force asymmetry nor resistance asymmetry (nor causal asymmetry) would be predicted.

A physical description of moving and colliding objects does not distinguish between physical force and physical resistance; however, ratings in the current study suggest that participants did distinguish between perceived force and perceived resistance. Perceived force of the launcher was rated similarly to perceived force of the target, and perceived resistance of the launcher was rated similarly to perceived resistance of the target, and this is consistent with Newton's laws. However, perceived force and perceived resistance were rated differently from each other; for the launcher and for the target, as ratings of perceived force increased or decreased, ratings of perceived resistance decreased or increased, respectively, and this is inconsistent with Newton's laws. This latter finding reflects a *force-resistance asymmetry*, and data from the current study and from White (2009, 2011b, 2012a) suggest this asymmetry is not influenced by which object is active or perceived as the causal object or which object is passive or perceived as the effect object.

The effect of spatial gap size on perceived force and perceived resistance suggests gradients of force or resistance extend from the launcher and from the target. A launcher that stopped closer to the target was perceived to exhibit more force (encounter less total resistance), and a launcher that stopped farther from the target was perceived to encounter more resistance (exhibit less total force). These patterns suggest the presence of a radius of action for the launcher and a radius of action for the target. Michotte (1946/1963) defined the radius of action for the launcher as the distance traveled by a launched target that was attributable to the launcher. In the current study, the target was not launched, but the radius of action of the launcher is reflected in the extension of perceived causality, perceived force, and perceived resistance beyond the edge of the launcher. Given that Michotte and subsequent researchers claimed the target was not causal, the possibility of a radius of action for the target was not previously considered. However, the current study suggests a radius of action for the target might be defined as the distance within which cessation of launcher motion might be attributed to (causality, force, or resistance from) the target.

It is puzzling why ratings of perceived causality, perceived force, and perceived resistance do not correspond more closely to Newton's laws. One possibility is that perception of causality involves heuristics rather than perception (e.g., an "impetus heuristic" might account for impressions of launching; Hubbard, 2013a; Hubbard & Ruppel, 2002). As with all heuristics, it is not necessary that predicted outcomes be based on correct principles or perfectly accurate; rather, it is only necessary that predicted outcomes be good enough to allow the organism to survive (and reproduce). Consistent with this, ratings of perceived causality, perceived force, and perceived resistance might not be limited by mechanical constraints. More broadly, perception of causality might also be influenced by agency or intentions attributed to the stimulus (e.g., social causality; for review, Hubbard, 2013c) or anticipation of future behavior (e.g., momentum-like effects in perception, learning, and behavior; for review, Hubbard, 2015). Indeed, perception (representation) of causality might be expected to deviate from Newton's laws to the extent that non-mechanical information can influence such perception (representation).

If the size of the spatial gap between the final location of the launcher and the location of the target increased, then perceived causality and perceived force decreased, whereas perceived resistance increased. Different effects of spatial gap size on perceived force and on perceived resistance are not consistent with physical principles governing object motion and collision, which do not distinguish between force and resistance. Neither causal asymmetry nor force asymmetry (nor resistance asymmetry) of the launcher and target were observed if the target remained stationary, and this suggests such asymmetries occur only if there is a visible effect or perceived action of one object on another object (e.g., as in launching or shattering). The ratings of perceived causality and perceived force are not consistent with previous claims that a stationary object cannot be perceived as causal or as exerting force. Perception of causality, force, or resistance across a spatial gap suggests observers anticipate a subsequent contact or represent object forces as gradients or fields, and this is consistent with notions of separate radii of action for the launcher and for the target. Although naïve conceptions of force have been investigated, naïve conceptions of resistance and the relationship of resistance and force have received less consideration, and are potentially important topics for future investigation.

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