Visual impressions of active and inanimate resistance to impact from a moving object

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Abstract

Images of moving objects presented on computer screens may be perceived as animate or inanimate. A simple hypothesis, consistent with much research evidence, is that objects are perceived as inanimate if there is a visible external contact from another object immediately prior to the onset of motion, and as animate if that is not the case. That hypothesis is disconfirmed in the present research. Objects moving on contact from another object were perceived as actively resisting the impact of the other object on them if they slowed rapidly. Rapid slowing is consistent with the laws of mechanics for objects moving in an environment that offers friction and air resistance. Despite that, ratings of inanimate motion were lower than ratings of active resistance for objects that slowed rapidly. The results are consistent with the hypothesis that there is a perceptual impression of active (animate) resistance that is evoked by the kinematic pattern of rapid slowing from an initial speed after contact from another object.

Visual impressions of active and inanimate resistance to impact from a moving object

Many studies have presented short movies depicting one or more moving objects. The stimuli are highly abstracted: the objects are usually simple geometrical shapes such as squares and there are no contextual markers such as a visible surface on which the objects move. The most plausible hypothesis, a priori, would be that the moving objects are perceived just as objects in motion. In fact, however, studies have reported evidence for perceptual impressions of much more than just motion. Evidence indicates that there are two broad classes of perceived motion, animate and inanimate (Scholl & Tremoulet, 2000; Schultz & Bülthoff, 2013).

Figure 1 depicts a typical stimulus presentation that gives rise to an impression of inanimate motion, specifically physical causality, originally studied by Michotte (1946/1963) and by many others since (Hubbard, 2013a, 2013b; Scholl & Tremoulet, 2000; White, 2017). One object (hereafter the target) is stationary in the centre of the frame. Another object, the launcher, enters from the side and moves horizontally at constant speed to contact the target. At contact the launcher stops moving and the target starts moving in the same direction at constant speed, eventually exiting from the frame. The stimulus could be perceived as two unconnected movements, but in fact observers reliably report an impression that the launcher made the target move (Michotte, 1946/1963; Schlottmann, Ray, Mitchell, & Demetriou, 2006). That is, the target's motion is perceived as caused by the impact from the launcher, not as animate or self-initiated motion. This perceptual impression is usually termed the "launching effect". Several other kinds of visual causal impression have been reported (Hubbard, 2013a, 2013b; Michotte, 1946/1963; Scholl & Tremoulet, 2000; White, 2017), but the launching effect has dominated research in this area.

In many other studies object motion has been presented without apparent external cause (i.e. without a launcher). In some cases specific mental states or capacities such as agency, intentions, goals, emotions, and personality characteristics are attributed to the objects (Heider & Simmel, 1944; Luo & Baillargeon, 2005; Parovel, Guidi, & Kreβ, 2018; Scholl & Tremoulet, 2000; Tremoulet & Feldman, 2006). Motion of single geometrical objects can still be perceived as animate, even if no specific mental states are perceived or attributed to the object (Kassin, 1982; Schultz & Bülthoff, 2013, 2019; Tremoulet & Feldman, 2000). Several motion cues result in identification of motion as animate or internally caused. These include trajectory forms, such as smooth (as opposed to irregular) trajectories (Rakison & Poulin-Dubois, 2001; Tremoulet & Feldman, 2000); relation of motion trajectory to visible objects (Parovel et al., 2018; Tremoulet & Feldman, 2006); motion onset without physical contact from another object (Rakison & Poulin-Dubois, 2001); detection of correlated versus uncorrelated motions of two objects (Dittrich & Lea, 1994; Rochat, Morgan, & Carpenter, 1997); kinematic features of paths taken towards objects, specifically in relation to perception of motion as goal-directed (Csibra, 2008; Southgate, Johnson, & Csibra, 2008); equifinality, which refers to different motion paths from a common starting-point converging on a common end-point (Biro & Leslie, 2007); and apparently spontaneous reversal of direction (Luo, Kaufman, & Baillargeon (2009). As an example, Schultz and Bülthoff (2013) presented a small moving dot with apparently random changes in direction of motion and found that it was reliably perceived as animate. Motion of a single dot is perceived as conforming to physical laws that govern biological motion, resulting in distorted perception of trajectories (Viviani & Stucchi, 1989).

Where is the boundary between perceived animate and perceived inanimate motion? Studies of perceived animate motion have presented stimuli in which objects move without apparent external cause. In contrast, stimuli for perceived inanimate motion involve initiation of motion immediately upon contact from another object.[1] A simple hypothesis, plausible in light of the research evidence, is that motion is perceived as inanimate if there is visible external contact from another object immediately prior to the onset of motion, which is then perceived as the cause of the motion (Michotte, 1946/1963), and as animate if that is not the case (Premack, 1990; Schultz & Bülthoff, 2019).

There are some indications that that simple hypothesis might not be correct. One concerns a perceptual phenomenon reported by Michotte (1946/1963) and called by him "triggering". The stimulus is a standard launching stimulus of the type depicted in Figure 1, but the target's speed is faster than the launcher's. With such stimuli, Michotte reported that the launcher is perceived as initiating motion that is then perceived as the target's own. This contrasts with his interpretation of stimuli in which the target's speed is not perceptibly faster than the launcher's, in which the target's motion is perceived as the launcher's motion transferred onto the target. Perceiving the target's motion as its own motion does not necessarily mean that it is perceived as animate: perhaps it could be perceived as an inanimate mechanism with an internal source of energy to power motion. It is at least suggestive, however. Another relevant finding comes from a study by White (2012). A typical stimulus began like a launching stimulus in that an object (A) moved towards and contacted a stationary object (B). When object A contacted object B, object A moved rapidly back in the direction from which it had come and object B moved in that direction as well but rapidly came to a halt. This gave rise to a perceptual impression that object B pushed object A. This also implies motion initiated by some mechanism internal to object B, even though it started to move only when contacted by object A.

White (2007, 2009) presented typical launching stimuli to investigate impressions of force in collision events. In White (2007) ratings were obtained of the perceived force exerted by the target on the launcher (target force), and in White (2009) ratings were obtained of the perceived resistance put up by the target when contacted by the launcher (target resistance). The same stimuli were used in both experiments. When the launcher remained stationary after contact, as in the typical launching effect stimulus (Michotte, 1946/1963), ratings of both target force and target resistance were generally low, but ratings of target resistance tended to be higher than ratings of target force. Moreover, ratings of target resistance tended to be higher at lower speeds of target motion. Thus, the motion of the target is perceived in terms of resistance to the launcher more than in terms of exerting force on the launcher.

"Resistance" is an ambiguous term. It could refer to the mere inertia of massive inanimate objects, or to an animate entity reacting to force exerted on it. Objects acted on can be either animate or inanimate: people can be pushed just as billiard balls can. So it is not clear whether the targets in the stimuli used by White (2009) were perceived as inanimate objects with inertia or as animate objects actively resisting the effect of the launcher. There is, in principle, a simple way to tell the difference. In the laws of physics forces are exerted at contact: objects that are not in contact do not exert mechanical force on each other (though they may exert magnetic and gravitational force). Animate objects, however, may resist being made to move by adjusting their motion after it has started. Thus, in principle, perceived inertial (inanimate) resistance should be determined only by the initial speed of the target after contact, whereas perceived animate resistance should be determined also by change in motion of the target after contact has occurred.

Of course, rapid slowing of motion initiated by contact forces is not incompatible with the laws of physics. Objects slow down because of friction with the surface on which they are moving, irregularities in their shape, and air resistance. The rate of slowing depends on the values of those factors. For example, a massive cube resting on a rough carpet will hardly move, even if a hefty kick is administered to it. Constant velocity after contact can occur in outer space, but never at the surface of the Earth. The key point, however, is that effects of interactions with the surface and medium encountered by the target are not inertial resistance to the contact force exerted by the launcher. That kind of resistance occurs only at the moment of contact.

The main aim of the present research is to investigate further the perception of resistance by the target to the launcher's impact on it, in particular whether perceived resistance of the target is affected by the behaviour of the target after contact, and whether that resistance is perceived as animate or inanimate resistance. Studies of perceived causality and force have used stimuli in which the target moves at constant speed after contact (Hubbard, 2013a; Michotte, 1946/1963; White, 2009). In the present research, in some stimuli the target slowed at different rates from the same initial velocity after contact. Simple slowing was used, as opposed to more complex changes in motion that would be expected only of an animate object, so that the stimuli would be consistent with a depiction of an object slowing under constant friction or air resistance. If resistance is perceived just as the inertial resistance of an inanimate object, reported resistance should be influenced only by the initial speed of the target and not by subsequent changes in its motion. If that result were found, it would rule out the hypothesis that resistance is perceived as animate. If reported resistance is affected by changes in the target's subsequent motion, that would be suggestive of a perceptual impression of animate resistance.

Experiment 1

Method

Participants

The participants were 28 volunteer first-year undergraduate students with normal or corrected to normal vision, participating in return for course credit. Informed consent was obtained from all participants.

Apparatus and stimulus materials

Stimuli consisted of frame sequences generated by a Macintosh G3 computer and displayed on a Mitsubishi Diamond Plus 71 16" CRT colour monitor. The frames were presented in phase with the computer's vertical blank signal and therefore appeared at the refresh rate of 74Hz. Each frame was 500 pixels (18.5 cm) wide by 300 pixels (11.1 cm) high. The boundaries of this frame appeared on the screen as thin black lines (to provide a rationale for the appearance and disappearance of the objects as they entered and exited the frame). These disappeared between trials, leaving the screen uniform white. All sequences consisted of 200 frames, lasting 2.7 seconds. The background of each frame was uniform white throughout. Stimuli were variations on that depicted in Figure 1. Object boundaries were clearly defined and object motion appeared smooth to the eye. Both objects were 1.75 cm in diameter.

Design

There were three independent variables, all within-subjects. Speed of launcher prior to contact was manipulated with two values, 10.8 and 21.6 cm/s. Initial speed of target after contact was manipulated with two values, 8.1 and 13.5 cm/s. Change in speed of the target after contact was manipulated with five values. Four of these were different rates of slowing. One (very rapid slowing) brought the target to a halt about one quarter of an object diameter from its initial location. A second (rapid slowing) brought the target to a halt about one object diameter away from the launcher. A third (moderate slowing) brought the target to a halt about halfway between its initial location and the edge of the frame. A fourth (gradual slowing) brought the target to a halt just short of the edge of the frame. In all cases the actual stopping point varied depending on target initial speed, but moderate slowing at both initial speeds always yielded a stopping location between those for both initial speeds with the other two rates of slowing. The fifth value was constant speed. These manipulations yielded a total of 20 stimuli.

There were two dependent measures, ratings of the amount of force the launcher exerted on the target and of how strongly the target resisted the force exerted on it by the launcher. The rationale for having two dependent measures was that participants would be less likely to guess the aims and hypotheses of the study, or even to infer that target resistance was the specific interest of the study.

Procedure

The experiment was run in a small laboratory, empty except for the equipment used for the experiment and with fluorescent lighting giving a low ambient light level. Participants were seated so that their faces were approximately 75cm from the screen and were permitted to adjust this distance slightly for personal comfort. The experimenter introduced the experiment by giving the participant written instructions, as follows:

"In this experiment you will see a series of short movies, about one or two seconds in duration, each involving two objects. One object is a black circle and the other object is a white circle. In each movie the white circle will initially be stationary in the middle of the frame. The black circle will move in from the left and come into contact with the white circle, after which the white circle will move off.

"Your task is to rate how much force you see the black circle exerting on the white circle, and how strongly the white circle resists the force exerted on it by the black circle. So, for each movie, you will have the following two questions to answer:

"How much force did the black circle exert on the white circle when they came into contact?"

"How strongly did the white circle resist the force exerted on it by the black circle when they came into contact?"

"You should answer the first question by writing a number from 0 to 100, where 0 means "no force at all" and 100 means "maximum possible force". You can put any number between 0 and 100. The more force you see the black circle exerting on the white circle, the higher the number you should put, up to a maximum of 100.

"You should answer the second question by writing a number from 0 to 100, where 0 means "no resistance at all" and 100 means "maximum possible resistance". You can put any number between 0 and 100. The more strongly you see the white circle resisting the force exerted on it by the black circle, the higher the number you should put, up to a maximum of 100.

"When you are ready to start, I shall start showing you the movies. First, I shall say, “ready?”. This is a cue for you to watch the screen. When you say “yes”, I shall show the movie."

When the participant indicated that they understood the instructions, the experimenter initiated the procedure for the first stimulus and proceeded through the remainder in the manner described above. Each stimulus was presented once. Stimuli were randomly ordered and a different random order was generated for each participant. At the end of the session participants were thanked and given course credit and a debriefing sheet, which informed them about the research topic but did not mention the specific hypotheses being tested.

Results

Data were analysed with a 2 (launcher speed, 10.8 v. 21.6 cm/s) x 2 (target initial speed, 8.1 v. 13.5 cm/s) x 5 (target acceleration[2], very rapid slowing v. rapid slowing v. moderate slowing v. gradual slowing v. constant) within-subjects analysis of variance (ANOVA). Post hoc paired comparisons, here and in the subsequent experiments, were carried out using the Tukey test and effect sizes were calculated using partial eta squared. The results for the target resistance measure are of primary interest, but the results for both measures are reported.

Launcher force measure

There was a significant effect of launcher speed, *F* (1, 27) = 81.60, MSE = 902.81, $p < .001$, $\eta_p^2 = .75$, with a higher mean at 21.6 cm/s (68.5) than at 10.8 cm/s (45.6). There was a significant effect of target initial speed, *F* (1, 27) = 9.72, MSE = 194.60, $p < .01$, $\eta_p^2 = .26$, with a higher mean at 13.5 cm/s (58.8) than at 8.1 cm/s (55.2). Both results replicate those found in the studies in White (2007, 2009). There were no other significant results; in particular, for the main effect of target acceleration, $F < 1$. Means for this are shown in Table 1.

Target resistance measure

There was a significant effect of launcher speed, *F* (1, 27) = 13.87, MSE = 534.77, $p < .001$, $\eta_p^2 = .34$, with a higher mean at 21.6 cm/s (49.4) than at 10.8 cm/s (42.1). There was a significant effect of target initial speed, *F* (1, 27) = 177.95, MSE = 295.88, $p < .001$, $\eta_p^2 = .87$ with a higher mean at 8.1 cm/s (55.4) than at 13.5 cm/s (36.0). Both results replicate those reported in White (2009).

The key result was a significant effect of target acceleration, *F* (4, 108) = 158.18, MSE = 431.12, $p < .001$, $\eta_p^2 = .85$. Resistance ratings were highest for very rapid slowing (80.0) and lowest for constant speed (18.5). Means and results of post hoc paired comparisons are shown in Table 1, with significant differences found in all cases. Thus, the more rapidly the target slowed to a halt, the more resistance was reported.

This was qualified by a significant interaction with target initial speed, *F* (4, 108) = 3.63, MSE = 288.57, $p < .01$, $\eta_p^2 = .12$. Simple effects analysis revealed significant effects in accordance with the respective main effects in all cases. The difference between the means was smaller at very rapid slowing than at any other value, and this may account for the interaction. With very rapid slowing, the end-point of the target's motion is very similar at both initial speeds, and this could indicate that the end-point of motion contributes to the perception of resistance, as well as the rate of slowing. There were no other significant results.

Discussion

Target acceleration had no significant effect on the perceived force reported for the launcher. Contrasting with that, the main result was a strongly significant effect of target acceleration on ratings of target resistance, with a substantial effect size of .85. Clearly, perceived target resistance is affected not just by the target's initial speed but also by its motion after contact. The question posed to the participants specified resistance to force exerted by the launcher at the moment of contact. Despite that, responses to the question were strongly affected by what happened after contact. It is not clear, however, whether the percept is of animate resistance or inanimate resistance. The results are consistent with the hypothesis that resistance is perceived as animate but they are also consistent with the possibility of an incorrect understanding of inanimate resistance as involving change in motion after contact as well as at contact. Experiment 2 was designed to discriminate these two possibilities by using explicit measures of animate and inanimate motion.

Experiment 2

Method

All details of method were as in Experiment 1 except for the following. There were 28 participants, none of whom had participated in Experiment 1. There was no measure of launcher force. There were two measures for the target, worded as follows:

"The white circle actively resists being pushed by the black circle.".

"The white circle's motion is the natural motion of an inanimate object after being pushed.".

These are hereafter designated the "active resistance" and "inanimate motion" measures, respectively. There was no explicit mention of the word "animacy" in the active resistance measure because it was felt that the word "actively" was sufficient to identify the resistance in question as not inertial.

Results

Data were analysed separately for each measure with a 2 (launcher speed, 10.8 v. 21.6 cm/s) x 2 (target initial speed, 8.1 v. 13.5 cm/s) x 5 (target acceleration, very rapid slowing v. rapid slowing v. moderate slowing v. gradual slowing v. constant speed) within-subjects ANOVA.

Active resistance measure

There was a significant effect of launcher speed, F (1, 27) = 5.32, MSE = 534.88, $p < .05$, $\eta_p^2 = .16$, with a higher mean at 21.6 cm/s (40.8) than at 10.8 cm/s (35.3). There was a significant effect of target initial speed, F (1, 27) = 126.80, MSE = 479.98, $p < .001$, $\eta_p^2 = .82$, with a higher mean at 8.1 cm/s (49.0) than at 13.5 cm/s (28.2).

There was a significant effect of target acceleration, F (4, 108) = 100.00, MSE = 669.25, $p < .001$, $\eta_p^2 = .79$. Active resistance ratings were highest for very rapid slowing (73.4) and declined to a low of 11.3 for constant speed. Means and results of post hoc paired comparisons are shown in Table 2, with significant differences in all cases.

This was qualified by a significant interaction with target initial speed, F (4, 108) = 2.78, MSE = 490.73, $p < .05$, $\eta_p^2 = .09$. Simple effects analysis revealed significant effects in accordance with the respective main effects in all cases. As in Experiment 1, the difference between the means was smaller at very rapid slowing than at any other value of target acceleration. There were no other significant results.

Inanimate motion measure

There was a significant effect of target initial speed, F (1, 27) = 13.65, MSE = 889.05, $p < .001$, $\eta_p^2 = .34$, with a higher mean at 13.5 cm/s (68.5) than at 8.1 cm/s (59.2). There was a significant effect of target acceleration, F (4, 108) = 18.72, MSE = 649.38, $p < .001$, $\eta_p^2 = .41$. Means and results of post hoc paired comparisons are shown in Table 2. There was a general trend of means increasing as the rate of slowing lessened, that is, in the opposite direction to the effect on the active resistance measure, though not all comparisons yielded statistically significant differences, as Table 2 shows. However, the lowest mean of 47.4 was found for very rapid slowing and this was significantly different from all others.

There was one other significant result, an interaction between launcher speed and target initial speed, F (1, 27) = 6.80, MSE = 791.81, $p < .05$. Simple effects analysis yielded two significant results. With target speed of 13.5 cm/s there was a higher mean when launcher speed was 21.6 cm/s (72.4) than when it was 10.8 cm/s (64.6), F (1, 27) = 5.31, MSE = 803.12, *p* < .05. With a launcher speed of 21.6 cm/s there was a higher mean when target initial speed was 13.5 cm/s (72.45) than when it was 8.1 cm/s (56.9), *F* (1, 27) = 18.11, MSE = 930.42, *p* < .001.

Discussion

Results on the active resistance measure closely resembled those on the target resistance measure in Experiment 1. The most important was the strong effect of target acceleration, with resistance ratings at their highest for the very rapid slowing stimulus and declining to a minimum for the constant speed stimulus. The effect sizes were also similar (.85 in Experiment 1 and .79 in Experiment 2). There were significant main effects of launcher speed and target initial speed that resembled the corresponding effects in Experiment 1. There was a significant interaction between target initial speed and target acceleration that had the same pattern as that found in Experiment 1.

Results on the inanimate motion measure did not resemble the results on the target resistance measure in Experiment 1. Most importantly, mean ratings tended to increase as the rate of slowing lessened and were at their highest for the constant speed stimulus. This is the opposite direction of difference to that found on the target resistance measure in Experiment 1. Furthermore, the highest mean was found on the only stimulus that presents a physical impossibility for objects moving at or near the surface of the Earth. Any rate of slowing can occur, depending on friction and air resistance. But, at least for horizontal motion, constant speed cannot occur if no force is being exerted on the object. The results therefore show evidence of perception or cognition that is at variance with the facts.

The close resemblance between the findings on the active resistance measure in this experiment and the target resistance measure in Experiment 1 indicate that participants in Experiment 1 were probably reporting the same thing as participants in Experiment 2, namely active resistance by the target. The results on the inanimate measure disconfirm the hypothesis that participants in Experiment 1 were perceiving or judging inanimate motion of the target. It could still be objected, however, that the wording of the active resistance measure does not explicitly mention animacy. In Experiment 3, therefore, a form of words involving explicit reference to animacy was used. It could also be objected that the inanimate measure did not make sufficiently explicit what factors are involved in determining the motion of an inanimate object after contact. In Experiment 3, therefore, a form of words specifying friction and air resistance as influences on target motion was used. To preclude any possibility that ratings on one measure might be influenced by the presence and wording of the other measure, these were tested with different groups of participants.

Experiment 3

Method

Details of method were as for Experiment 1 except for the following. There were 52 participants, none of whom had participated in Experiment 1 or Experiment 2. One more stimulus was added to the target acceleration variable, a stimulus in which the target increased speed after contact. There were two dependent measures, run as a between-subject variable with 26 participants receiving each measure.

The active resistance measure was worded as follows: "The black circle actively slows by its own power after being pushed by the white circle." After this in the instructions came the following statement: "("By its own power" means that the black circle is animate and slows down deliberately or intentionally.)".

The inanimate motion measure was replaced by what will be called a "natural forces" measure, worded as follows: "The black circle slows due to natural external forces after being pushed by the white circle". After this in the instructions came the following statement: "("Natural external forces" means things like friction with a surface on which an object is moving, air resistance, and contact with another object.)" For both measures the statement in brackets was not included on the rating scales filled out by the participants, but the instructions reminding them of it were in front of them throughout the experimental session.

Results

Data were analysed separately for each measure with a 2 (launcher speed, 10.8 v. 21.6 cm/s) x 2 (target initial speed, 8.1 v. 13.5 cm/s) x 6 (target acceleration, very rapid slowing v. rapid slowing v. moderate slowing v. gradual slowing v. constant speed v. increasing speed) within-subjects ANOVA.

Active resistance measure

There was a significant effect of target initial speed, F (1, 25) = 142.81, MSE = 263.75, $p < .001$, $\eta_p^2 = .85$, with a higher mean at 8.1 cm/s (55.5) than at 13.5 cm/s (40.0).

There was a significant effect of target acceleration, *F* (5, 125) = 65.47, MSE = 1251.38, $p < .001$, $\eta_p^2 = .72$. The trend in the means resembled that found in the first two experiments, but not all paired comparisons were statistically significant. Means and results of post hoc paired comparisons are reported in Table 3.

There was a significant interaction between those two variables, *F* (5, 125) = 9.85, MSE = 386.70, $p < .001$, $\eta_p^2 = .28$. Simple effects analysis revealed significant effects in accordance with the respective main effects in all cases. As in Experiment 1, the difference between the means was smaller at very rapid slowing than at any other value of target acceleration, but this time it was not significant, *F* (1, 25) = 1.60, MSE = 192.13. There were no other significant results. In particular, the main effect of launcher speed was not significant, $F < 1$.

Natural forces measure

There was a significant effect of target initial speed, *F* (1, 25) = 5.10, MSE = 1126.76, $p < .05$, $\eta_p^2 = .17$, with a higher mean at 8.1 cm/s (42.4) than at 13.5 cm/s (48.5).

There was a significant effect of target acceleration, *F* (5, 125) = 16.01, MSE = 2281.18, $p < .001$, $\eta_p^2 = 39$. Means and results of post hoc paired comparisons are reported in Table 3. As the table shows, the means for very rapid slowing, rapid slowing, and moderate slowing were not significantly different and a decline in means set in after that.

There was a significant interaction between those two variables, *F* (5, 125) = 9.11, MSE = 589.23, $p < .001$, $\eta_p^2 = .27$. Simple effects analysis revealed significant results in accordance with the main effect of target acceleration at both values of target initial speed. There were just two significant simple effects of target initial speed, at gradual slowing, *F* (1,

25) = 22.08, MSE = 1158.61, $p < .001$, and at constant speed, F (1, 25) = 8.83, MSE = 594.96, $p < .01$, both in accordance with the main effect. There were no other significant results.

Paired comparisons between measures

The trends on the target acceleration variable were in the same direction on both measures, so paired comparisons on individual stimuli using one-way ANOVA were carried out to ascertain whether stimuli were rated similarly on both measures. Significant results are reported in Table 4. This shows six significant results, in all of which the higher mean was found on the active resistance measure.

Discussion

The results on the active resistance measure resembled those of the previous two experiments except that there was, in this experiment, no significant effect of launcher speed.

The results on the natural forces measure, however, did not resemble the results on the inanimate measure in Experiment 2. There was a significant effect of target acceleration in the opposite direction from that found in Experiment 2. Most likely this is an effect of the change in wording. The wording of the natural forces measure, including the explicit reference to friction and air resistance, might have sufficed to remind participants of relevant knowledge, which those in Experiment 2 did not consider. However, that would imply that ratings on the natural forces measure do not reflect perceptual impressions, but instead post-perceptual processing based on deliberative consideration of knowledge activated from long-term memory. This issue will be further addressed in the general discussion.

General discussion

The main aim of this research was to test the possibility that some motion patterns for the target in a launching effect stimulus are perceived as animate, in the sense of offering active or deliberate resistance to the launcher's impact. In Experiment 1 an otherwise undefined measure of perceived resistance was used; in Experiment 2 the term "active resistance" was used; in Experiment 3 a measure of the target slowing by its own power, explicitly defined in terms of animacy and intentionality, was used. Launching effect stimuli were presented in which the target slowed from its initial velocity at various rates, from very rapid slowing to a halt, in a distance equal to a quarter of the target's diameter, to very gradual slowing in which the target came to a halt at the edge of the frame. In addition stimuli were presented in which the launcher moved at constant speed (all experiments) or increased in speed (Experiment 3).

Perception of active resistance

For an inanimate object with no internal motive force moving horizontally at the surface of the Earth, slowing is inevitable because of friction and air resistance. Thus, all rates of slowing are compatible with the laws of mechanics. Moreover, resistance to the force exerted by the launcher only occurs at contact; any change in speed after contact is not due to resistance to the launcher or, to put it more accurately, to contact forces between launcher and target. It might be expected, therefore, that ratings on any measure of target resistance to the launcher would be zero or close to zero, regardless of the rate of slowing.

In fact, in all the experiments ratings of resistance were high for stimuli showing rapid slowing, and declined as the rate of slowing decreased. In each experiment at least one mean over 80 on the various 101-point scales used in the research was found, in each case for the combination of launcher speed 21.6 cm/s, target initial speed 8.1 cm/s, and very rapid slowing. Paired comparisons showed significantly higher ratings of stimuli with comparatively rapid slowing on the active resistance measure than on the natural forces measure in Experiment 3. Even though participants in the natural forces conditions in Experiment 3 were given explicit information about what was meant by "natural external forces", they still gave lower means on that measure than other participants gave on the active resistance measure. The close resemblance of the results on the target resistance measure in Experiment 1 and the active resistance measure in Experiment 2 indicate that participants in Experiment 1 interpreted that measure as a measure of animate or intentional resistance, even though words suggestive of animacy were not used in the stimulus materials. That is, participants in Experment 1 were not prompted with the idea of animate resistance, but their ratings still closely resembled those of participants in other experiments who were so prompted. Animate resistance, therefore, was a spontaneous interpretation. Variations in wording of the resistance measure resulted in little if any differences in results, suggesting that the results show reporting of a perceptual impression that is not much affected by explicit knowledge activated by the wording of the measure. This contrasts with the results on the various inanimate measures (see next sub-section).

It is likely, therefore, that rapid slowing of the target after contact from the launcher is perceived as animate, intentional resistance to being pushed by the launcher. Of course that is not the only kind of animate motion that can occur. For example, previous studies of perception of object motion have found that one object can be perceived as fleeing from another (Heider & Simmel, 1944). Given that, it is possible that, with stimuli in which the target's speed increased after contact, the target could also be perceived as animate and as fleeing from the launcher. This is a possibility for further research to investigate.

Ratings of inanimate motion and natural forces

Ratings of inanimate motion (Experiment 2) and natural forces (Experiment 3) were obtained primarily for purposes of comparison with ratings on the animate resistance measures and no particular hypothesis was proposed for them. As it turned out, the results on these measures varied considerably between the experiments. In Experiment 2, the lowest rating on the inanimate measure was found for very rapid slowing (significantly lower than all others) and there was trend for means to increase as the rate of slowing declined. In Experiment 3, there was a significant tendency in the opposite direction on the natural forces measure, with the highest means for the three stimuli with the most rapid slowing, and a decline in means after that. Given that all the stimuli could have been perceived as inanimate motion to the same degree, these results are surprising.

Surprising results also occurred for the constant speed stimuli. As was discussed above, constant speed of the target is not possible for an inanimate object at or near the surface of the Earth because it will inevitably be slowed by air resistance and friction, Yet, on the inanimate motion measure in Experiment 2, the constant speed stimulus received a higher mean rating than any other stimulus, and it was significantly higher than all but two of the other stimuli. In Experiment 3 it was rated significantly lower than most of the slowing stimuli on the natural forces measure. Even so, in Experiment 3, the mean for the constant speed stimuli on the natural forces measure was higher than that on the active resistance measure.

The variability of results across the different measures of inanimate motion probably indicates effects of wording on judgments. It is likely that adding specification of air resistance and friction as a note to the natural forces measure activated some sort of knowledge from long-term memory and that judgments on that measure were influenced by the activated knowledge. If that was the case, it implies that the knowledge in question was not activated by the wording of the measure used in Experiment 2, because of the contrary nature of the results. It is therefore mysterious what might have guided judgments in Experiment 2. In any case, the ratings are unlikely to have reflected perceptual impressions - that is, products of perceptual processing - because those would have been more nearly constant across the experiments. Whatever perceptual impressions might have occurred, the ratings on the inanimate motion measures do not seem to have been strongly determined by them.

In addition, whatever knowledge of moving objects was activated by either the stimuli or the instructions was, on the whole, not accurate. Claims have been made that judgments of object mass made from information about object collisions are derived by optimal Bayesian inference based on correct understanding of the laws of mechanics with allowance for noise and uncertainty in the data (Sanborn, Mansinghka, & Griffiths, 2013). While that might be the case for mass judgments, it seems that it cannot be the case for the judgments made on the inanimate measures in the present research. A hypothetical perceiver equipped with a Newtonian understanding of mechanics and a Bayesian inferential mechanism would surely interpret all the stimuli in which the target slowed as inanimate because they are all consistent with the laws of mechanics for inanimate motion. There are no visible cues to animacy in the target, which is a simple disc shape. And, as we have seen, there is no circumstance under which the laws of mechanics would predict constant speed for an object in the presence of friction and air resistance. In Experiment 2, ratings on the inanimate measure were higher for the constant speed stimulus than for any stimulus in which the target slowed after contact. It is hard to imagine how that could occur for any perceiver equipped with a Newtonian understanding of mechanics, no matter what kind of judgment process occurred.

Active resistance and triggering

Many studies have shown that motion of small geometrical objects can be perceived as animate (Heider & Simmel, 1944; Kassin, 1982; Scholl & Tremoulet, 2000; Tremoulet & Feldman, 2000, 2006). One factor that all published studies seem to share is that there was no apparent, visible cause of the object's motion. That is, it was not brought about by a launcher impacting on it. The present research is possibly the first to show that some degree of perception of animacy can occur when the target's motion is, or appears to be, initiated by contact from a launcher. It is possible that the triggering impression (Michotte, 1946/1963) and the reactive pushing impression studied by White (2012) are also cases of target motion being perceived as animate, but further investigation would be necessary to determine whether that is the case or not.

Triggering occurs under conditions different from those under which active resistance is perceived. In the case of triggering the target starts to move, and continues, at a higher speed than the launcher had been moving at. In the case of active resistance the target starts, in most cases, at a slower speed than the launcher, and slows even more. Qualitatively, therefore, they are likely to be different percepts. In each experiment there were some stimuli where target initial speed was faster than the launcher's speed: this occurred where launcher speed was 10.8 cm/s and target initial speed was 13.5 cm/s. If relative speeds of the two objects made a difference to perceived resistance, then significant interactions involving launcher speed and target initial speed would be predicted. No such interaction was found. It is possible that the difference in speed was not perceived, especially since the initial speed rapidly changed as the target slowed, and that a greater difference in speed would have some sort of impact on the results. As far as the present research is concerned, there is no sign that perceived active resistance varies depending on whether the target's initial speed is faster or slower than the launcher's speed. Therefore triggering and active resistance, even if they both represent perceptual impressions of an animate object, appear to be different phenomena.

Methodological considerations

Consistency of results on the resistance measures across the three experiments suggests that a perceptual impression was being reported. It is not possible to be certain of that, however. There is good evidence that perceptual impressions of causality and animacy do occur (White, 2017); as Scholl and Tremoulet (2000) pointed out, such impressions are automatic, encapsulated, and not under the control of the perceiver. Rolfs, Dambacher, and Cavanagh (2013) presented a large number of launching stimuli to the same retinal location and found adaptation specific to that location, such that subsequent launching stimuli were more likely to be reported as non-causal. That further supports the hypothesis that the launching effect is a perceptual phenomenon. However, explicit reports of causal impressions can be influenced by post-perceptual processing (e.g. Gemelli & Capellini, 1958), and there is certainly the opportunity for the resistance judgments in the present research to be influenced by more or less explicit and more or less accurate knowledge of physics (di Sessa, 1993). The consistency in the results and the high means found on the resistance measures for some stimuli indicate that, in the case of active resistance, any such knowledge would have to be shared by virtually all of the participants.

Is it possible that judgments were affected by the features of the objects in the stimuli? The objects were discs, so it is possible that they were perceived as spherical objects rolling on a perfectly flat and even surface. In that case, lack of slowing might be perceived as natural. However, research on phenomenal causality has failed to find effects of object features on the causal impression (Hubbard, 2013a; Michotte, 1946/1963). In most of Michotte's studies the objects were rectangular, and it would be expected that a rectangular object would come to a halt much more quickly than a rolling sphere, because of greatly increased friction with the surface. However, Michotte reported that varying the perceptible features of the object (even using a wooden ball in one experiment) made no difference to the causal impression. It is unlikely, therefore, that judgments in this research were affected by the shape of the objects.

Conclusion

Stimuli involving moving geometrical shapes reliably give rise to impressions of causality, force, mass, and animacy, the last of which may or may not include mentalistic attributes such as personality characteristics and intentions, as shown in the pioneering study by Heider and Simmel (1944) and by many other studies since (Parovel et al., 2018). There is much still to learn about the conditions under which these different kinds of impression occur. Up to now, impressions of animate motion have been shown only for objects moving without apparent external cause. The present research has shown that a target, the motion of which is normally perceived as caused by the launcher contacting it (Hubbard, 2013a, 2013b; Michotte, 1946/1963; Scholl & Tremoulet, 2000; White, 2017), can be perceived as actively resisting the push given by the launcher under conditions where its motion is consistent with inanimate slowing in conformity with the laws of mechanics. In the introduction several motion cues were listed that favour interpretation of motion as animate. Active resistance was perceived in the present research for a stimulus that did not exhibit any of those cues.

Footnote

1. In an otherwise typical launching effect stimulus, the launching effect can still occur if the launcher stops short of the target (Michotte, 1946/1963; Yela, 1952). This happens, however, only when the gap is small and the launcher is moving on a path that would have brought it into contact with the target if motion had continued, and the impression is that the gap is not just a gap but a medium through which causality or force is transmitted from the launcher to the target.

2. To physicists there is no such thing as deceleration: any change in speed is regarded as acceleration.

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Table 1

Means for the main effects of target acceleration on the launcher force and target resistance measures, Experiment 1

Target acceleration	Launcher force	Target resistance
Very rapid slowing	56.1	80.0[a]
Rapid slowing	57.1	59.4[b]
Moderate slowing	57.5	42.9[c]
Gradual slowing	56.4	27.9[d]
Constant speed	58.0	18.5[e]

Note. Means not sharing the same superscript within the target resistance column differ by $p < .05$ (Tukey).

Table 2

Means for the main effects of target acceleration on the active resistance and inanimate motion measures, Experiment 2

Target acceleration	Active resistance	Inanimate motion
Very rapid slowing	73.4^{a}	47.4^{a}
Rapid slowing	51.0^{b}	62.0^{b}
Moderate slowing	35.1^{c}	68.7^{bc}
Gradual slowing	22.2^{d}	65.9^{bc}
Constant speed	11.3^{e}	75.4^{c}

Note. Means not sharing the same superscript within columns differ by $p < .05$ (Tukey).

Table 3

Means for the main effects of target acceleration on the active resistance and natural forces measures, Experiment 3

Target acceleration	Active resistance	Natural forces
Very rapid slowing	81.3^{a}	57.0^{a}
Rapid slowing	70.6^{a}	62.8^{a}
Moderate slowing	61.6^{b}	61.2^{a}
Gradual slowing	40.5^{c}	44.2^{ab}
Constant speed	22.2^{d}	31.7^{bc}
Increasing speed	10.4^{d}	15.7^{c}

Note. Means not sharing the same superscript within columns differ by $p < .05$ (Tukey).

Table 4

Significant results on comparisons between measures for individual stimuli, Experiment 3

	Means			
Stimulus	Active resistance	Natural forces	*F*	MSE
LS = 10.8; TIS = 8.1; VRS	82.6	55.2	7.65	1277.76
LS = 10.8; TIS = 8.1; RS	79.4	58.8	6.77	818.58
LS = 10.8; TIS = 13.5; VRS	82.4	56.7	9.71	881.46
LS = 21.6; TIS = 8.1; VRS	83.5	58.0	6.64	1269.03
LS = 21.6; TIS = 8.1; RS	75.7	58.7	4.17	900.68
LS = 21.6; TIS = 13.5; VRS	76.8	58.2	4.01	1123.64

Note. LS = launcher speed; TIS = target initial speed; VRS = very rapid slowing; RS = rapid slowing.

Figure caption

Figure 1. Typical stimulus for the launching effect. In panel A, the white disc (the target) is stationary in the middle of the frame and the black disc (the launcher) is moving towards it. Panel B shows the launcher approaching the target. Panel C shows the frame in which the launcher contacts the target. At this point the launcher stops moving and the target moves away with the same or slightly lesser speed as the launcher's pre-contact speed. Panel C shows the target moving away from the launcher after contact. Motion continues until the target exits the frame.

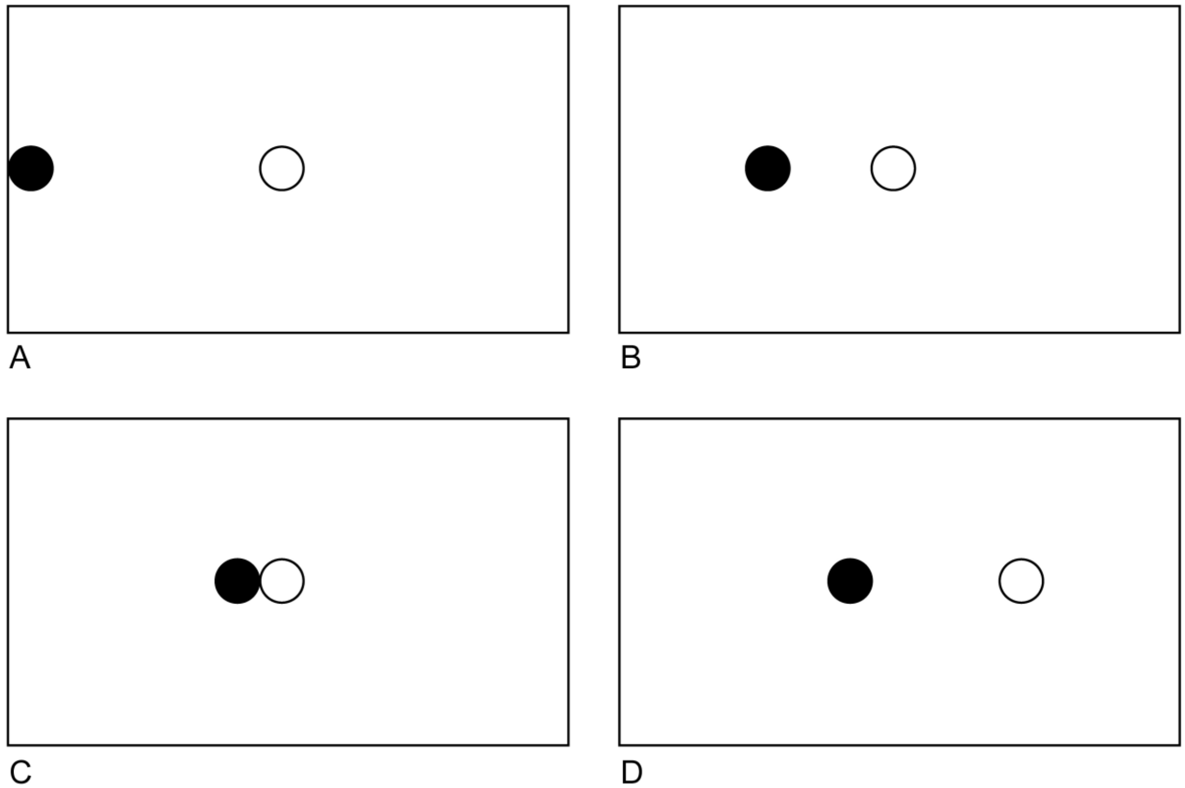

Figure 1