THE “LAUNCHING EFFECT” DEPENDS ON SIZE OF COLLIDING OBJECTS

Michele Vicovaro, Luigi Burigana
Department of General Psychology, University of Padua, Italy
michele.vicovaro@studenti.unipd.it luigi.burigana@unipd.it

Abstract

Suppose that two squares are aligned horizontally on a computer screen. At a point in time one square (A) starts moving towards the other (B), which remains stationary. When A and B come into contact, the latter starts moving with the same velocity as A, while A comes to a stop. Albert Michotte (1946) demonstrated that, under these stimulus conditions, observers usually have the impression that A “launches” or “pushes” B, a perceptual effect he called the “Launching Effect”. Michotte claimed that features of objects A and B (e.g., their size) exert only a slight influence on the phenomenon, however to our knowledge no research has systematically tested this claim. In our experiment we manipulated the size of two simulated spheres, and found that the velocity ratio most favouring the perception of the Launching Effect actually depends on the size of both spheres.

Many philosophers and psychologists agree that the concept of causality is the “cement” of the universe. As soon as one grasps the concept of causality, events in the world start to be conceived as relations between causes and effects. This makes an evolutionary advantage: cause-effect connections may be generalized in order to predict future events. The Belgian researcher Albert Michotte (1946) was a pioneer in demonstrating that causality can be directly perceived. He performed novel experiments showing how the perception of causality directly depends on stimulus conditions. In one of his experiments, he presented observers with two small squares aligned horizontally. At a moment one square (*A*) started moving towards the other (*B*), which remained stationary. When *A* and *B* came into contact, the latter started moving with the same velocity as *A*, while *A* came to a stop (see Figure 1 for a 3D version of Michotte’s stimuli). Observers reported the impression that *A* “launched” or “pushed” *B*, a perceptual effect called the “Launching Effect”. Michotte maintained that the Launching Effect is a purely perceptual phenomenon, that it may be explained in terms of Gestalt-theoretic principles, and is not influenced by observers’ experience with real mechanical collisions. Scholl and Tremoulet (2000) reformulated Michotte’s theorization in terms of perceptual module, thus emphasizing the “cognitive impenetrability” of the phenomenon. A compelling argument for this thesis is that the Launching Effect occurs even when *A* and *B* are fuzzy coloured shadows (Michotte’s Experiment 27), or when object *A* is a real wooden sphere, and object *B* is just a shadow (Michotte’s Experiment 28). This suggests that physical plausibility of collisions is not a necessary condition for the perception of the phenomenon, thus discrediting the possible role of past experience with real collisions. Recent experimental findings have further supported this claim: given appropriate contextual stimuli, the Launching Effect may occur even when spatiotemporal relations between *A* and *B* should exclude real collisions (Choi & Scholl, 2004; Bae & Flombaum, 2010).

In addition, Michotte (1946, p. 78) reported the qualitative observation that shape and dimension of *A* and *B* may influence the “vividness” of the Launching Effect, but classified this influence as slight and marginal. He did not elaborate this qualitative observation in detail. In partial contrast with Michotte’s view of “purely perceptual” character of the effect we are discussing, the possible influence of objects’ shape and dimension on its perception might suggest that observers' experience with real collisions can have a role in the process. Despite its importance, this topic has not received much attention in the literature on the perception of causality. In an early study, Natsoulas (1961) presented observers with classic Michottean stimuli, and varied both velocity and size of the stimuli. His results confirmed that size had a relatively small influence on the Launching Effect. However, one possible reason for this finding could be that Natsoulas used large steps of variation of the velocity ratio between *A* and *B*, and this may have overshadowed the effect of size.

People without formal instruction in Physics correctly predict that postcollision velocity of object *B* is decreasing with the size (implied mass) of *B* and decreasing with the size of *A* (De Sá Teixeira, De Oliveira, & Viegas, 2008; Vicovaro, in press). Even 5.5-6.5 months old infants expect the outcome of a collision to be dependent on size of colliding objects (Kotovski & Ballairgeon, 1998). The aim of our experiment is to verify whether the size of colliding objects also influences visual perception of the Launching Effect. Michotte's claim that perception of the Launching Effect is not influenced by past experience with mechanical collisions would be supported if we find that size of the stimuli does not influence perception of the Launching Effect. Otherwise, we should conclude that observers' experience with mechanical events may exert at least a partial influence on the phenomenon.

Experiment

One critical variable for the perception of the Launching Effect is the ratio between the pre-collision velocity of object *A* ($v(A)$) and the post-collision velocity of object *B* ($v(B)$). In particular, Michotte (1946) reported that the Launching Effect is replaced by a "Triggering Effect" when $v(B)$ is twice $v(A)$. *Triggering Effect* means that the post-collision motion of *B* appears self-generated, rather than generated by the collision with *A*. Natsoulas (1961) also found that when $v(A)$ is three times $v(B)$, observers have the impression of "braked launch", i.e., the impression that the post-collision motion of *B* is braked by some force, rather than exclusively generated by the collision with *A*. Even though the *Braking Effect* is not reported in most studies on perception of causality, its existence was proved by Minguzzi (1968) in an extensive series of experiments. In our experiment we presented observers with a three-dimensional version of Michotte's stimuli (see Figure 1), and determined a "braking threshold" and a "triggering threshold". The *braking threshold* is the minimum value of ratio $v(A)/v(B)$ above which observers will perceive the Braking Effect. The *triggering threshold* is the minimum value of ratio $v(B)/v(A)$ above which observers will perceive the Triggering Effect. When ratios $v(A)/v(B)$ and $v(B)/v(A)$ are both below their respective braking and triggering thresholds, then observers will perceive the Launching Effect.

In our experiment, we wanted to determine whether the braking and triggering thresholds depend on size of colliding objects. If it is true that experience with physical events of collisions influences the Launching Effect, then when *A* is larger than *B* (and heavier, for objects of equal material) observers should perceive the Launching Effect with relatively high $v(B)/v(A)$ ratios, because this is what it would happen in real physical collisions. For the very same reason, observers should not perceive the Launching Effect with high $v(A)/v(B)$ ratios. In terms of braking and triggering thresholds, we should find a high triggering threshold but a low braking threshold. The opposite should be true when the size of *A* is smaller than the size of *B*: in this case we predict a high braking threshold and a low triggering threshold.

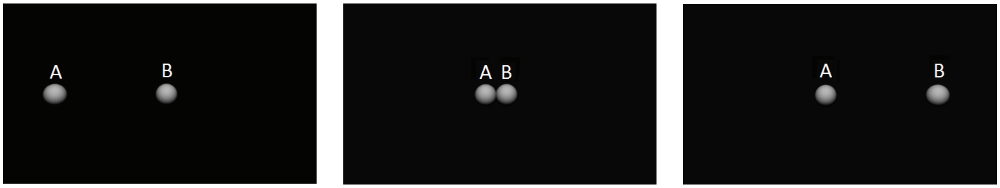

Figure 1: Three frames of an animation sequence used in our experiment (a 3-D version of Michotte's stimuli). Labels "*A*" and "*B*" are added for reference in our discussion.

Participants. Fifteen students of Psychology (aged from 20 to 29, 4 males) participated in the experiment. They all had normal or corrected-to-normal visual abilities, and were paid for the participation.

Stimuli and apparatus. The stimuli were presented on a personal computer equipped with a 37.5 cm × 30 cm screen and a keyboard. Participants sat at a distance of about 50 cm from the screen, the background of which was black. Two smooth, greenish 3-D spheres (created by 3D Studio Max) were presented at middle height of the screen. At the beginning of each animation, one sphere (*A*) appeared close to the left edge of the screen and the other sphere (*B*) in the centre. Then, 170 milliseconds after the appearance of the spheres, *A* began to move horizontally from left to right towards *B*, until making contact with it. At this point, *A* came to a stop, and *B* started moving in the same direction as *A*, until stopping close to the right edge of the screen (see Figure 1). We manipulated the apparent size of *A* and *B*, according to a 3 size *A* (4.2, 8.4, 16.8 cm^3) × 3 size *B* (4.2, 8.4, 16.8 cm^3) factorial design. These sizes (volumes) of the spheres are computed on the diameters of the corresponding images on the screen. The velocity of *A* was kept the same (15.5 cm/s) across the experiment. In each of the nine experimental conditions we manipulated the velocity of *B* for determining the *braking* and *triggering* thresholds (see next paragraph).

Procedure and experimental design. Instructions readable on the screen informed the participants that they would be presented with two colliding spheres, which could represent a collision, e.g., between billiard balls. Participants were asked to pay attention to the post-collision velocity of the initially stationary sphere (*B*), and judge whether its motion was "natural" or "unnatural" compared with the force exerted by the initially moving sphere (*A*). The instructions specified that "unnatural" could have two alternative meanings: first, that the motion of *B* was too slow compared with the force exerted by *A*, as if the motion of *B* was braked by an invisible force; second, that the motion of *B* was too fast compared with the force exerted by *A*, as if the motion of *B* was accelerated by an invisible force. In each trial participants were allowed to view the stimulus as many times as they wanted by pressing "SPACE" on the keyboard and then, when they felt ready to respond, they had to press "N" for the "natural" response, and "Z" for the "unnatural" response. After the instructions, participants were presented with five randomly chosen stimuli to familiarize with the task. They were recommended to rely on their visual impression, not on what they knew from experience or from learning of Physics.

In order to estimate the 50% braking and triggering thresholds we used the standard psychophysical method of "randomly interleaved staircases" with fixed step size (Levitt, 1971). For the estimation of the braking threshold we manipulated the velocity of *B* (the velocity of *A* was fixed at 15.5 cm/s) such that the $v(A)/v(B)$ ratio could take on 11 values from 1 to 3 in steps of 0.2. The threshold was estimated by generating two staircases, one ascending and the other descending. The *ascending staircase* started from the lowest value, corresponding to a velocity ratio of 1, which gave rise to a clear launching impression. Every time the participant responded "natural", the velocity ratio was increased by one step (for instance, from 1 to 1.2, then to 1.4, etc.), until the participant responded "unnatural" (she perceived a braked launch). At that point, the staircase changed its direction, and the velocity ratio was decreased by one step every time the participant responded "unnatural" (for instance, from 2 to 1.8, then to 1.6, etc.). The staircase changed its direction whenever the participant changed her answer, and continued in that direction until the participant changed her answer again. The series of stimuli between two changes of direction is called a "run". Symmetrically, the *descending staircase* started from the highest value, corresponding to a velocity ratio of 3. The velocity ratio was decreased as long as the participant responded "unnatural" (she perceived a braked launch), and the staircase changed its direction when the participant changed her response. Both staircases were terminated after eight runs and the 50% braking threshold was estimated by averaging the midpoints of the last four runs of both staircases (Levitt, 1971, p. 470). For the estimation of the triggering threshold we applied the same procedure, only referring to ratio of velocities $v(B)/v(A)$ (rather than $v(A)/v(B)$).

Both braking and triggering thresholds were estimated in each of the 9 (3 Size A × 3 Size B) experimental conditions. In order to avoid anticipatory effects, the 36 staircases (9 experimental conditions × 2 thresholds × 2 staircases) were randomly interleaved. Participants were allowed to rest as much as they wanted after every 200 trials. The experimental session could last from 35 to 45 minutes.

Results

Parts (i) and (ii) of Figure 2 show the means (over participants) of the braking and triggering individual thresholds, for each condition of our experimental design (i.e., each combination of size of spheres A and B). For graphical illustration and statistical analysis we find it convenient to represent the nine conditions as the levels of one factor (combining variables "size A" and "size B"), which we call "size of the stimuli". The labels of the nine levels of this combined factor are shown on the horizontal axis of parts (i) and (ii) of the figure (see also caption to the figure). Labels "S", "M", and "L" on the abscissa stand for small, medium, and large size of each sphere (4.2, 8.4, 16.8 cm^3) .

Braking threshold. A one-way within subjects ANOVA showed that factor "size of the stimuli" has a significant effect on the braking threshold ($MS_e = 0.852$, $F(8,112) = 6.073$, $p = 1.76 \times 10^{-6}$). As shown in Figure 2.i, the braking threshold tends to be higher when A is smaller than B, and lower when A is larger than B. In other words, with large $v(A)/v(B)$ ratios, observers tend to see more easily a "braked launch" when A is larger than B, whereas they tend to see more easily a "natural launch" when A is smaller than B. This result is in agreement with physical principles, and supports the hypothesis that size of colliding objects does influence perception of the Launching Effect. However, caution is required in interpreting these data. A Tukey's post-hoc test showed that there are only three significant differences between the nine experimental conditions: in condition (L,S) the braking threshold is significantly lower than in conditions (S,L) ($p < 0.05$), (M,L) ($p < 0.05$), and (S,M) ($p < 0.05$). In other words, only extreme differences in size produce significantly different braking thresholds. Note that for the equal-size conditions ((S,S), (M,M), (L,L)), the braking threshold is higher than expected (about 2.5). This means that when A is the same size of B, and $v(A)/v(B)$ ratio is about 2.5, observers still perceive a "natural launch" 50% of the time. Contrary to the results reported by Natsoulas (1961), our results suggest that only very large $v(A)/v(B)$ ratios can produce a vivid Braking Effect. It is thus possible that our manipulations

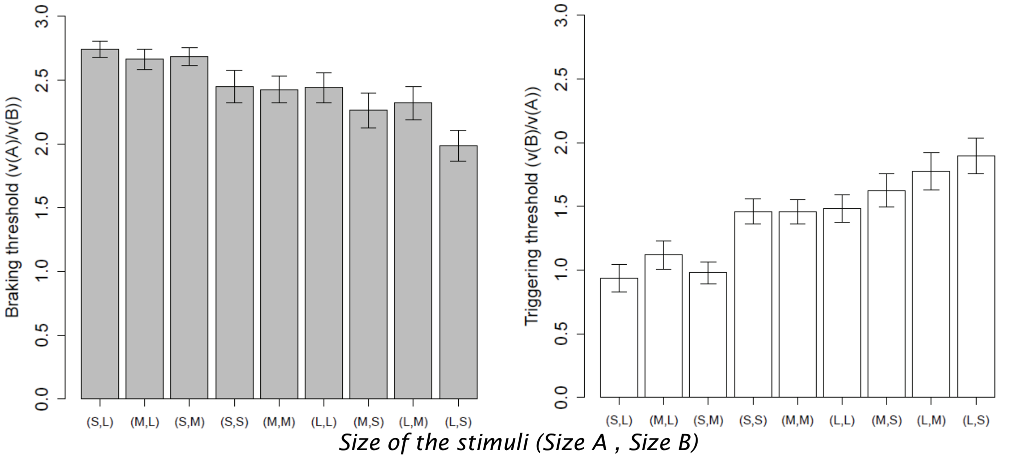

Figure 2. (i) (left): Mean *braking* threshold for each experimental condition. (ii) (right): Mean *triggering* threshold for each experimental condition. Labels "*S*", "*M*", and "*L*" on the abscissa stand for small, medium, and large size of each sphere (4.2, 8.4, 16.8 cm^3). We ordered the nine levels on the abscissa trying to obtain approximately monotone trends.

of velocity ratio were not large enough to produce clear Braking Effects, and that larger manipulations would bring out stronger effects of size on the braking threshold.

Triggering threshold. A one-way within subjects ANOVA showed that factor "size of the stimuli" has a significant effect on the triggering threshold ($MS_e = 1.734$, $F(8,112) = 11.46$, $p = 8.97 \times 10^{-12}$). As shown in Figure 2.ii, the triggering threshold tends to be higher when *A* is larger than *B*, and lower when *A* is smaller than *B*. In other words, with large $v(B)/v(A)$ ratios, observers tend to see more easily a Triggering Effect when *A* is smaller than *B*, whereas they tend to see more easily a "natural launch" when *A* is larger than *B*. Tukey's post-hoc test showed that in all the three conditions where *A* is smaller than *B* ((*S*,*L*), (*M*,*L*), (*S*,*M*)) the triggering threshold is significantly (or marginally) lower compared with the three conditions where *A* is larger than *B* ((*M*,*S*), (*L*,*M*), (*L*,*S*)). These results are in agreement with physical principles, and support the hypothesis that size of the stimuli influence the triggering threshold.

Discussion

The results of our experiment lend support to the hypothesis that size of *A* and *B* influences the perception of the Launching Effect. This evidence was also reported by Michotte (1946) who however classified it as slight and marginal. Our results suggest that this judgment needs revision. Here we remark two interesting results showing that the influence of size on the Launching Effect is not thus negligible: (1) As expected, when the size of *A* is no smaller than the size of *B* and $v(A) = v(B)$, observers report unambiguous Launching Effect (this finding has been replicated several times by different researchers). However, when *A* is small (4.2 cm^3) and *B* is large (16.8 cm^3) the same velocity ratio produces the Triggering Effect about 50% of the time (see Figure 2.ii). (2) As expected, when the size of *A* is no larger than the size of *B* and $v(B) = 2v(A)$, observers report an unambiguous Triggering Effect (this finding too has been replicated several times). However, when *A* is large and *B* is small the same velocity ratio produces the Launching Effect about 50% of the time (see Figure 2.ii).

To sum up, the relations between size (implied mass) and velocity of the colliding objects most favouring visual perception of the Launching Effect appear similar to those governing physical collisions. This lends support to the idea that observers' past experience with collisions may exert some influence on the perception of the launching phenomenon. Such conclusion seems to us to deviate from Michotte's interpretation of the Launching Effect simply in terms of Gestalt principles, and from Scholl and Tremoulet's (2000) conception of the phenomenon as a perceptual module. Our findings are rather in agreement with White's template-matching hypothesis, according to which visual causal impressions result from the matching of stimulus features to features of templates of causal mechanisms (White, 2005, p. 403). Such templates are presumed to be stored in memory, and contain salient features of causal interactions that allow the visual system to recognize causal events. Note that they need not be entirely isomorphic to physical collisions. Actually, in our experiment sphere *A* remained stationary after collision (an extremely unlikely event in real collisions), and nevertheless the Launching Effect was perceived. The results of our experiment suggest that those templates are characterized by a notable common feature: they provide information concerning objects' size.

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