AN INFORMATION INTEGRATION APPROACH TO PERCEPTION OF CAUSALITY TROUGH CONTINUOUS BEHAVIOURAL MEASURES

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Abstract

The study of perceptual causality has known a regain in interest from the moment that continuous behavioural measures, and not just perceptual reports, were proposed. As one such measure, representational momentum (RM), was recently applied by T. Hubbard to Michotte's launching paradigm. Among the several open issues regarding the use of RM to gauge perceptual causality there are the following two: 1) how the joint action of dynamic and kinematics variables is captured and integrated in RM; 2) the influence of specific response modalities. In this work "launcher-target" velocities, size of launcher ("implied mass"), gap at the collision, and distance travelled by the target were fully crossed in two information integration tasks, which demanded a localisation response either through a mouse cursor or with a pointer. A significant role of velocity, mass and gap was documented, with mass and velocity combining additively. Integration patterns were shown the same in both response modalities, although "pointing" appears as an advantageous response modality to address RM-attenuation effects.

The finding of a systematic reduction in memory forward displacement (RM) for targets involved in collision settings similar to Michotte's "launching" and "tool" paradigms (Hubbard et al, 2001; Hubbard & Ruppel, 2002; Hubbard & Favretto, 2003), promoted RM as a behavioural measure of causal perception. One major advantage of such a measure over perceptual reports is the circumstance that, by being continuous, it makes possible to address the issue of the integration of contributing factors to causal perception. Many such determinants have been studied in isolation (speed, gap, size, acceleration, shape, elasticity, friction, direction, etc.) but seldom in their joint action. One notable exception is the study by Schlottmann & Anderson (1993), who used continuous ratings of causality and naturalness to establish an integration model of phenomenal causality. Anderson's IIT methodology (Anderson, 1981; 1982; 1996) has actually been offering a powerful framework to the use of continuous response variables across numerous fields.

This work stems from the notion that RM offers new prospects for the use of IIT in the realm of causal perception and naïve physics. As a counterpart, further insights might be gained on the extent to which high-level cognitive processes are reflected in RM, a centre issue of the debate over the very nature of forward displacement bias (Hubbard, 2005; 2006). One particular topic of integration concerns the combined action of mass (as implied by object's size) and speed on RM. Differently from physical momentum, defined as mass times speed, the mass of a horizontally moving object presented in isolation produces no effect on RM (a non-integration result). The situation is different for vertical movements, along the axis of implied gravity, where mass starts acting as implied weight – a force (Hubbard, 1997). This points to the potential usefulness of distinguishing between typical kinematics variables such as speed and more dynamics-associated variables such as “mass”, whose effects on RM might require settings which turn it into a force enabling a specific result. In the present work, the integration of implied mass and velocity is studied in a collisions setting (launching displays) where implied mass can become part of a “force of impact”. The size of a launcher object is manipulated jointly with pairs of “launcher-target” velocities (keeping a constant target/launcher speed ratio of 1/3). Other kinematics and spatial variables commonly considered in studies of launching and in RM studies were also included (gap at collision, target’s travelled distance). In line with IIT methodology, all variables were fully crossed in factorial integration tasks, demanding a localisation response. As a supplementary between-subjects factor, two kinds of localisation response, either indirectly through a mouse cursor, or directly through a pointer, were used.

Method

Subjects

54 under-graduate students at the University of Coimbra were involved in exchange for course credits. All of them had normal or corrected to normal vision, and were unaware of the purposes of the experiment.

Stimuli

A set of avi-type animations (compressed with TechSmith Screen Capture algorithm; rate of 40 frames per second) depicting a 1 cm^2 white square (with a black contour line) at rest near the centre of the screen (the target) which was collided by a moving black square of either 1, 2 or 3 cm^2 (the launcher). The launcher emerged either from the right or from the left edge of the screen and moved towards the target at constant speeds of 9 cm/s, 12 cm/s or 15 cm/s. At a given distance from the target - 9 mm, 6 mm, 3mm or 0 mm - it stopped, upon which the target started moving in the same direction at 1/3 of the launcher’s speed. After travelling for either 1 cm or 2 cm, the target suddenly vanished together with the launcher (see **Fig. 1**). Animations portraying a translating target alone, moving at constant speeds of 3, 4, or 5 cm/s, were also presented. Distances travelled in this “target only” condition were made to exactly match the full course of the “launching” events (launcher travelled distance + target travelled distance). Rightward (LF) and leftward (RL) motions were again equally represented. All animations were created with the program *Interactive Physics 2000*.

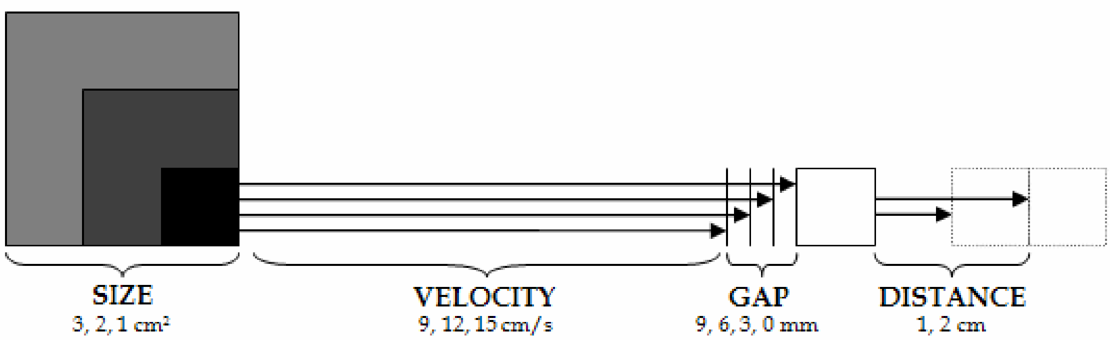

Figure 1 – Schematic representation of the chief “launching” conditions considered in the experiment

Apparatus

The experiment was implemented with Super Lab 4.0. Animations were presented on a dual-core PC with a flat touchscreen LSD monitor, at a refreshing rate of 100 HZ and with screen resolution of 1024 x 768 pixels. Half of the subjects responded by displacing a "plus-sign" cursor controlled by an optical wireless mouse, the other half by directly touching the screen with a Softpoint Pen.

Design and Procedure

The experiment obeyed a full factorial 3 (*velocity* [keeping a constant launcher/target speed ratio of 1/3]) x 3 (*launcher's size*) x 4 (*gap extent*) x 2 (*target's travelled distance*) repeated-measures design, with two replications. Half the subjects used the mouse for responding and the other half the pointer. A supplementary 3(*velocity*) x 2 (*distance*) x 2 (*motion direction*) repeated measures design for the "target only" conditions was also included in the experiment, providing a basis for the calculation of RM reduction in the "launching" conditions. Data analysis was performed through mixed ANOVAs with "response modality" as a between-subjects factor and all remaining variables as within-subjects factors.

Subjects sat at 60 cm from the screen, and were requested to hold a steady attitude. They were asked to attentively observe the randomly presented videos and, the moment these were over, to immediately locate the point where the target had vanished (corresponding to its geometrical centre). Subjects responding with the wireless "mouse" had to displace a "plus-sign" cursor from the centre of the screen, where it appeared, to the desired position. Those responding with the "pointer" simply touched the screen at the last perceived location of the target. Practice trials were given beforehand to ensure good understanding of the instructions and familiarity with the task.

Results

Magnitude of RM was gauged by the difference in pixels between the *x*-coordinate of the target's centre when it vanished, and the *x*-coordinate of the point where the subject remembered seeing it for the last time. *Magnitude of RM reduction* (rRM) corresponds to the differences in RM between launching conditions and equivalent "target alone" conditions. Both these measures were analysed through mixed ANOVAs with response modality as a between-subjects factor. In view of the number of comparisons involved, the significance criterion was set to $\alpha \leq 0.01$.

Figure 2 illustrates the factorial diagrams of *velocity* x *launcher's size* (implied mass) for both RM (leftward graph) and rRM (rightward graph) measures, and also for mouse and pointer responses. Both factors appear to contribute to the final result, judging by the vertical separation of lines and their slanted trends (increasing for RM, mainly decreasing for rRM.). Parallelism in the plots suggests further that they combine additively (or subtractivelly, which is formally the same, in the case of rRM). Since the basis to estimate RM reduction included a matching for velocities, but not for size, the effects of *target's size* in the rRM graph are actually the same as those for RM, simply reversed after being subtracted from a constant. As for velocity, it appears to contribute positively to RM and negatively, for the most, to rRM. Almost identical patterns are obtained from the "mouse" and "pointer" response. From a quantitative standpoint, "pointing" produces lower RM magnitudes but larger RM attenuation, which suggests its particular usefulness as a means to address the effects of causal perception on RM. **Figure 3** illustrates the striking parallel behaviour of every and each factor (effects averaged over all other within-subjects variables) across the two response modalities. Given that each modality actually provides a replication to the other, this finding underlines the robustness of the observed effects, at the same time it enlightens the role of response modality. The already noticed superiority of RM magnitude with the "mouse" response and of RM-reduction with the "pointing" response is again apparent.

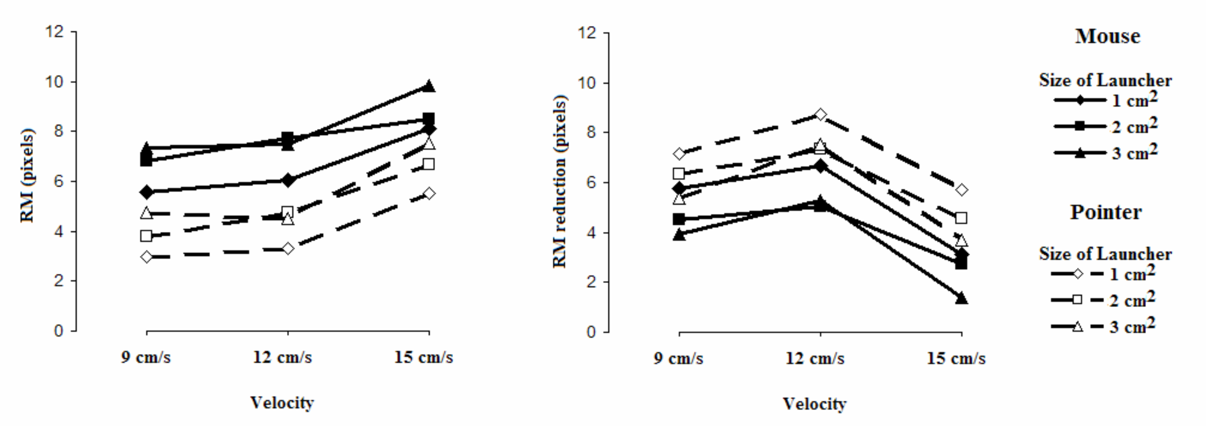

Figure 2 – Factorial plots of "*velocity*" x "*launcher's size*" (curve parameter) for both "mouse" and "pointer" responses. *Left panel*: mean RM on the ordinate. *Right Panel*: mean RM reduction (rRM) on the ordinate.

The outcomes of statistical analysis closely mirrored the ones of graphical analysis. All within-subjects factors had significant main effects on RM magnitude ($p \leq .002$). As for one-way interactions, only *velocity*gap* has proven significant (F(6; 312) = 3.496, p = 0.002), which concurs with the additive combination rule for *velocity* x *size* ("implied mass") suggested from visual inspection. Despite the graphical suggestions of systematic differences between response modalities, the main effect of this between-subjects factor didn't reach significance. Identical statistical patterns were found for rRM.

Discussion

Results illustrate the ability of RM to reflect the joint action of different variables relevant to causal perception. As a particular instance of this, launcher's "implied mass" and velocity exhibited an additive combination rule. Available evidence in the RM literature indicates that, for a single moving object, *size* (standing for "implied mass") has no effect on RM in horizontal movements but does influence RM in vertical movements, where it becomes more of an "implied weight" (Hubbard, 2005; 2006). In our horizontal collision settings, size of the launcher has shown a lawful (even if not normatively correct) effect on RM of the target. As a general suggestion, RM thus appears capable of gauging "implied mass" whenever size is turned into a force (be it "weight" or "impact force") enabling an effect.

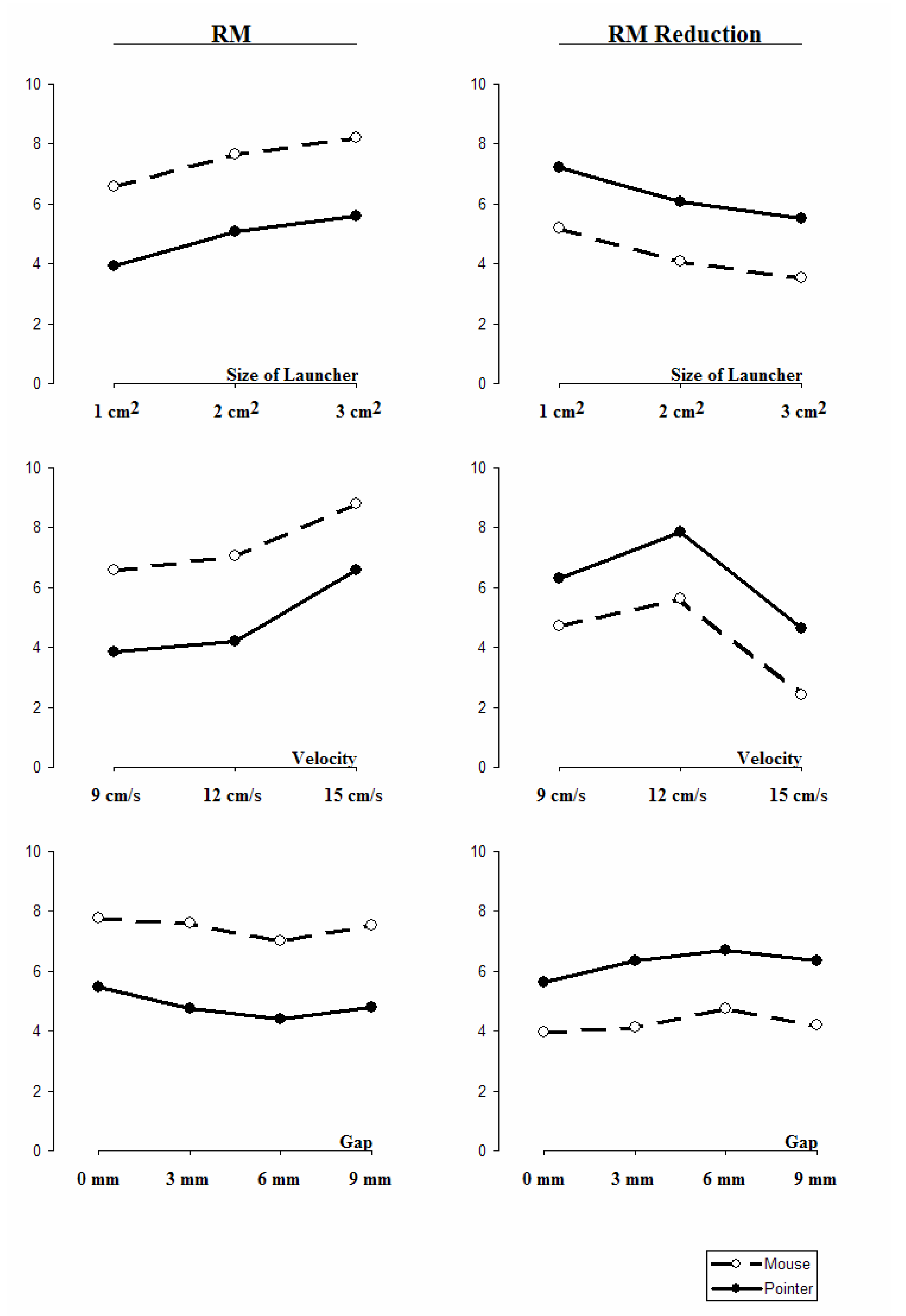

Figure 3 – Factorial plots for *size of launcher* (top row), *velocity* (middle row), and *gap* (bottom row) against mean RM magnitude (left column) and mean RM-reduction (right column), with *response modality* as the curve parameter.

Changes in response modality did not alter the pattern of results. On the quantitative side, consistent trend of higher RM values for mouse responding and higher rRM values for pointing responses was observed, but never reached significance.
Given that "target only" conditions matched for velocity were available, RM and rRM patterns for velocity in the "launching" conditions could be sensibly compared (see middle row on Figure 3). While increased velocities have the effect of increasing RM, they appear to have – overall - a decreasing effect over rRM. This detached and provisional result brings about the issue of a specific logic of RM reduction, independent from the one of RM magnitude: since causal perception appears to express mainly through the former, an interesting prospect for the future would be to address that eventuality, and to unfold any associated rules.

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