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Causal reports: Context-dependent contributions of intuitive physics and visual impressions of launching

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ABSTRACT

Everyday causal reports appear to be based on a blend of perceptual and cognitive processes. Causality can sometimes be perceived automatically through low-level visual processing of stimuli, but it can also be inferred on the basis of an intuitive understanding of the physical mechanism that underlies an observable event. We investigated how visual impressions of launching and the intuitive physics of collisions contribute to the formation of explicit causal responses. In Experiment 1, participants observed collisions between realistic objects differing in apparent material and hence implied mass, whereas in Experiment 2, participants observed collisions between abstract, non-material objects. The results of Experiment 1 showed that ratings of causality were mainly driven by the intuitive physics of collisions, whereas the results of Experiment 2 provide some support to the hypothesis that ratings of causality were mainly driven by visual impressions of launching. These results suggest that stimulus factors and experimental design factors − such as the realism of the stimuli and the variation in the implied mass of the colliding objects − may determine the relative contributions of perceptual and post-perceptual cognitive processes to explicit causal responses. A revised version of the impetus transmission heuristic provides a satisfactory explanation for these results, whereas the hypothesis that causal responses and intuitive physics are based on the internalization of physical laws does not.

1. Introduction

In one of Michotte's (1963) seminal experiments on the perception of causality, observers were presented with two small, horizontally aligned squares; at a point in time one square (*A*) started moving towards the other (*B*). When *A* made contact with *B*, *B* started moving with the same velocity as *A*, whilst *A* came to a halt (see Fig. 1). The vast majority of observers described this scene by saying that *A* "launched" or "kicked" *B*—that is, that the motion of *A* had *caused* the motion of *B*. This phenomenon was called the *launching effect*. Through a series of ingenious experimental demonstrations, Michotte (1963) showed that the launching effect is a genuinely visual phenomenon, because the necessary and sufficient conditions for its occurrence all relate to the perceptual properties of the scene. That is, the effect occurs when the *perceived* scene satisfies certain requirements; for example, two distinct objects must be present and their motions must exhibit perceptual continuity. In contrast, Michotte showed that the launching phenomenon was not related to either observer's *knowledge* of collisions or the degree of consistency between the simulated collisions and the physical laws of collisions: observers reported visual impressions of launching even when relationships between the physical motions of *A* and *B* were inconsistent with physical laws of collisions. More recently, Michotte's Gestalt-theoretic account of the perception of causality has been reinterpreted in terms of *modularity*. In other words, the launching effect is conceived of as the result of a visual module which is impervious to learning, past experience, and high-level cognitive processes (Leslie & Keeble, 1987; Scholl & Tremoulet, 2000; cf. Rips, 2011).

Michotte's ideas contrast markedly with the empiricist approach to causal relations. The empiricist philosopher David Hume argued (Hume, 1977) that causality cannot be directly perceived and that subjective impressions of causality stem from acquired knowledge about the relationship between separate motions that are characterized by spatiotemporal contiguity. Shortly after the publication of Michotte's work, the empiricist account of perceived causality was supported by research emphasizing the roles of learning (Brown & Miles, 1969; Gruber, Fink, & Damm, 1957; Powesland, 1959) and individual differences (Beasley, 1968; Boyle, 1960; Gemelli & Cappellini, 1959) in the perception of causality. Although the value of Michotte's studies is widely acknowledged in contemporary vision research (see Wagemans, van Lier, & Scholl, 2006), there is as yet no consensus on the relative contributions of low-level visual processes and learning and past

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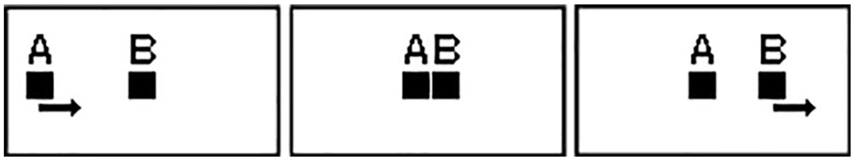

Fig. 1. Three frames of a Michottean collision. The letters *A* and *B* and arrows were added to indicate which objects are moving in the three stages of the collision event.

experience to perceived causality (see Hubbard, 2013a, 2013b). This lack of consensus is partly due to a methodological problem. Most research in this domain has been conducted using explicit measures, for example by asking participants to rate the extent to which the motion of *B* appears to be *caused* by the motion of *A*. However, in the words of Choi and Scholl (2006, p. 93) "explicit reports are always sensitive in principle to extra-perceptual factors, and one of the most serious concerns is that verbal reports reflect not only what subjects are *seeing* but also their higher-level interpretations and judgments." In other words, learning and past experience might be relevant to explicit reports of causality – and hence to the explicit post-perceptual processing of the stimuli – rather than to perceived causality per se.

In order to bypass the seemingly inescapable problem of the contribution of explicit post-perceptual processing to *explicit* reports of causality, researchers have recently focused on *implicit* measures of causal perception. For instance, it has been shown that perception of the launching effect implies a distortion of the perceived distance between *A* and *B* (Buehner & Humphreys, 2010; Scholl & Nakayama, 2004) and a modification of the perceived trajectory of the apparent motion of *A* (Kim, Feldman, & Singh, 2013). Moors, Wagemans, and de-Wit (2017) showed that visual stimuli that normally elicit a launching effect enter awareness faster than similar stimuli that do not elicit a causal impression. Rolfs, Dambacher, and Cavanagh (2013) showed that the launching effect was subject to specific retinotopic visual adaptation. These studies highlighted behavioral consequences of the visual perception of launching that emerge despite the lack of explicit reference to causality in the experimental instructions, and so they suggest that causal perception stems from automatic, low-level visual processing of Michottean collisions (i.e., collisions like that depicted in Fig. 1).[1] Further support for this claim has been provided by neurophysiological and neuroimaging studies showing that distinct brain regions are involved in causal perception and causal reasoning (Fonlupt, 2003; Roser, Fugelsang, Dunbar, Corballis, & Gazzaniga, 2005; cf. Straube & Chatterjee, 2010).

1.1. A connection between causal reports and impetus transmission?

Implicit measures allow researchers to explore genuine visual impressions of causality independently from the influence of explicit post-perceptual causal reasoning. Nevertheless, everyday causal reports appear to be based on a blend of perceptual and cognitive processes (Schlottmann, 2000, 2001; Schlottmann & Anderson, 1993). Our explicit responses about the possible existence of a causal relationship between two events are likely to be driven not only by our immediate visual impressions, but also by what we *know* about the events. According to *physicalist models* of causal cognition, causal inferences are based on analogies with the physical world; in other words, events are believed to be causally related if there is a plausible physical *mechanism* to explain such a relationship (Bullock, Gelman, & Baillargeon, 1982; Schlottmann, 1999; Schultz, Fisher, Pratt, & Rulf, 1986; Wolff, 2007). In this context, the term "mechanism" refers to people's intuitive understanding of a physical event, which may not correspond with the relevant physical laws (e.g., diSessa, 1993; McCloskey, 1983). The *property transmission* hypothesis (White, 2009a) reflects a physicalist account of causal cognition: causal inferences are drawn when some property is implicitly or explicitly believed to be transmitted from one object to another. In the case of interactions between physical objects, a cause-effect relationship is inferred from the transmission of some physical quantity (e.g., velocity, energy, force) from the agent object (or cause object) to the patient object (or effect object).

Research in the field of intuitive physics has shown that people understand interactions between physical objects – including collisions – in terms of *transmission of impetus* (Clement, 1982; diSessa, 1993; Halloun & Hestenes, 1985; McCloskey, 1983). For instance, people intuitively understand a Michottean collision such as that depicted in Fig. 1 as an agent (i.e., object *A*) transmitting impetus to a patient (i.e., object *B*), which *resists* the transmission of impetus to a certain degree (Hubbard, 2013c; Hubbard & Ruppel, 2002; White, 2009a). As a consequence, *A* is perceived to exert a force on *B*, whereas *B* is perceived to exert a small or null force on *A* (White, 2007, 2009b). Incidentally, this is at odds with the symmetry of forces implied by Newton's Third Law, which states that the force that *A* exerts on *B* is equal and opposite to the force that *B* exerts on *A*. Hubbard (2013c, p. 642) speculated that "perhaps observers experience impressions of causality when viewing launching effect displays not because they directly perceive causality, but because behavior of the mover [object *A*] and target [object *B*] in launching effect displays match an impetus heuristic used when predicting outcomes of collision events" (see also Hubbard & Ruppel, 2002). This hypothesis appears to dismiss the possibility of direct visual impressions of causality, but to do so would be at odds with recent findings supporting the existence of such low-level visual impressions (e.g., Buehner & Humphreys, 2010; Kim et al., 2013; Moors et al., 2017; Rolfs et al., 2013; Scholl & Nakayama, 2004). A hypothesis compatible with these recent findings is that visual impressions of launching are impervious to the impetus transmission heuristic because they result from a visual module (Leslie & Keeble, 1987; Scholl & Tremoulet, 2000; see also Firestone & Scholl, 2016); however, *explicit* reports of causality would be primarily driven by high-level interpretations of the stimuli based on the impetus transmission heuristic, rather than by visual impressions of launching. The hypothesis that we set out to test in this study is that explicit reports of causality are primarily driven by people's intuitive understanding of the physics of collision, rather than by genuine visual impressions. This is consistent with the idea that explicit causal responses are based more on an intuitive understanding of the physical situation (i.e., on high-level cognitive processes) than on low-level perceptual cues (Schlottmann, 2000, 2001).

We tested the hypothesis in two distinct stimulus conditions: in Experiment 1, we presented participants with simulated collisions involving depictions of realistic spheres differing in implied masses, whereas in Experiment 2, we presented participants with simulated collisions involving depictions of non-material spheres. We speculated that explicit reports of causality could be primarily driven by people's intuitive understanding of the physics of collision when the stimuli are sufficiently similar to real life physical collisions (Experiment 1), because this is the domain to which intuitive physics of collisions normally applies. We also speculated that, when the stimuli lack the material properties of real life objects as in Experiment 2, participants' responses could be driven by a different source of information, namely visual impressions of launching.

The intuitive understanding of collisions and the explicit reports of causality are two distinct constructs that should be measured

[1] Within the frame of the "representational momentum" paradigm, Hubbard suggested that the remembered vanishing location of *B* also constitutes an indirect measure of perceptual causality (see Hubbard, 2013c; Hubbard & Ruppel, 2002). This claim, however, has been called into question by Choi and Scholl (2006).