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ORIGINAL PAPER

Phenomenal Causality I: Varieties and Variables

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Abstract The empirical literature on phenomenal causality (i.e., the notion that causality can be perceived) is reviewed. In Part I of this two-part series, different potential types of phenomenal causality (launching, triggering, reaction, tool, entraining, traction, braking, enforced disintegration and bursting, coordinated movement, penetration, expulsion) are described. Stimulus variables (temporal gap, spatial gap, spatial overlap, direction, absolute velocity, velocity ratio, trajectory length, radius of action, size, motion type, modality, animacy) and observer variables (attention, eye movements and fixation, prior experience, intelligence, age, culture, psychopathology) that influence phenomenal causality are reviewed. This provides the necessary background for consideration in Part II (Hubbard, in press) of broader questions regarding properties of phenomenal causality, empirical and theoretical connections of phenomenal causality to other perceptual or cognitive phenomena or processes, and potential mechanisms and models of phenomenal causality.

Keywords Phenomenal causality · Launching effect · Perception of causality · Causal impression · Causal representation · Intentionality · Spatial representation · Michotte

If an observer views a moving object that strikes a stationary target, and that target then immediately begins moving, that observer often has a clear and immediate perception that the subsequent movement of the initially stationary target was caused by contact from the initially moving object. This specific experience is referred to as the *launching effect* (e.g., Michotte 1946/1963); the launching effect is

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the prototypical example of the general notion that causality can be automatically perceived, and this general notion is referred to as *phenomenal causality* (also referred to as *perceived causality*, *causal impression*, and *interaction impression*). Questions regarding how causality is determined are of interest in a variety of domains, and whether observers perceive or reason about causality in different domains has been debated (e.g., Sperber et al. 1995; White 1990, 2009b; Young 1995). Causal perceptions in phenomenal causality are based on physical or mechanical interaction of nonintentional objects (e.g., Schlottmann and Shanks 1992; Scholl and Nakayama 2002; White and Milne 2003; Young et al. 2005) or on action or interaction of stimuli perceived to be animate intentional agents (e.g., Dittrich and Lea 1994; Heider and Simmel 1944; Kanizsa and Vicario 1968; Tremoulet and Feldman 2000). The focus here is primarily on physical and non-intentional interactions of objects, although actions and interactions of animate and intentional agents are also considered.

A consideration of phenomenal causality is of interest for several reasons. First, accurately perceiving or judging causality is critical for successful adaptation to the environment. Second, phenomenal causality is ubiquitous, and interactions of an observer with stimuli in the environment, and observations of stimuli interacting with other stimuli, evoke phenomenal causality. Third, the framework given by Michotte (1946/1963) suggests phenomenal causality arises from a unique mechanism for perception of causality rather than from more general or generic mechanisms of perception, inference, or causal learning. Fourth, investigators subsequent to Michotte proposed additional types of stimuli that they suggested give rise to phenomenal causality, and a compendium of the proposed types of phenomenal causality has not been presented. Fifth, phenomenal causality is evoked even if no causality is actually present; thus, phenomenal causality can be considered an illusion, and like any other illusion, might offer insight into perceptual and cognitive processing. Sixth, there is evidence phenomenal causality might be related to other perceptual or cognitive processes or phenomena. Seventh, the last review of research on phenomenal causality was by Scholl and Tremoulet (2000), and a significant amount of research and theory on phenomenal causality has appeared since that review was published. Eighth, the nature of the connections between cause and effect constrain a critical aspect of the larger epistemology through which the world is viewed.

Phenomenal causality reflects causal perception rather than causal judgment (e.g., see Schlottmann and Shanks 1992). Causal perception involves a direct, rapid, and automatic impression of causality that does not involve explicit inference, whereas causal judgment involves an explicit inference in the absence of any automatic or spontaneous impression of causality. Claims that perception of a specific type of stimulus give rise to a specific type of phenomenal causality must be scrutinized to ensure inference or other judgment could not occur. This can present methodological challenges, as the language used in rating scales and by other tools used to assess the response to a causal stimulus might evoke causal inferences when such inferences would not have otherwise occurred. Even so, a large literature on phenomenal causality has developed in the 50 years since Michotte's seminal research was translated into English and spurred investigation into phenomenal causality. This article is Part I of a two-part series on phenomenal causality, and Part II can be found in Hubbard (in press). Part I provides descriptions of different types of stimuli claimed to give rise to phenomenal causality and reviews variables that influence the type or strength of phenomenal causality. Part II considers broader issues regarding properties of phenomenal causality, examines the relationship of phenomenal causality to other perceptual and cognitive processes and phenomena, and considers mechanisms by which phenomenal causality might be instantiated.

1 Possible Varieties of Phenomenal Causality

Michotte (1946/1963) suggested there were two fundamental types of phenomenal causality, the launching effect and the entraining effect, and that all other examples of phenomenal causality could be reduced to or considered as special cases of the launching effect or the entraining effect. Subsequent researchers suggested the existence of additional types of stimuli that could elicit phenomenal causality but that were not clearly reducible to, or that did not appear to be special cases of, the launching effect or the entraining effect. However, claims regarding some of these additional types of stimuli are based solely on rating scales that might have evoked causal inference or are based on a single report (or a single laboratory), and convergent and independent evidence (e.g., spontaneous reports of phenomenal causality, replication in other laboratories) has not yet been reported. Brief descriptions of each type of stimulus suggested to result in phenomenal causality, and the content of those causal perceptions, are presented in this section, and these include (a) launching, (b) triggering, (c) reaction, (d) tool, (e) entraining, (f) traction, (g) braking, (h) enforced disintegration and bursting, (i) coordinated movement, (j) penetration, and (k) expulsion.

1.1 Launching

The launching effect was first demonstrated by Michotte (1946/1963) and is the most widely-studied type of causal perception (see Fig. 1). In the launching effect, a moving object, referred to as *Object A*, approaches a stationary object, referred to as *Object B*. Object A then contacts Object B, and at the moment of contact, Object A becomes stationary and Object B begins moving. If several parameters are within a set of narrow limits (e.g., the velocity of Object B does not exceed the velocity of Object A, Object B begins moving within 100 ms after contact from Object A, Object B moves in the same direction as did Object A), then observers report a robust perception that movement of Object B was caused by Object A. Although Michotte and subsequent researchers used the terms “Object A” and “Object B”, the more descriptive and intuitive terms “launcher” and “target”, respectively, will be used in this review. Michotte reported the perception of causality in the launching effect occurs rapidly, automatically, and spontaneously, and he reported that even minor changes in the parameters of the display changed or eliminated the causal perception; [1] susceptibility of phenomenal causality to even slight changes in the parameters of the display convinced Michotte that the launching effect reflected

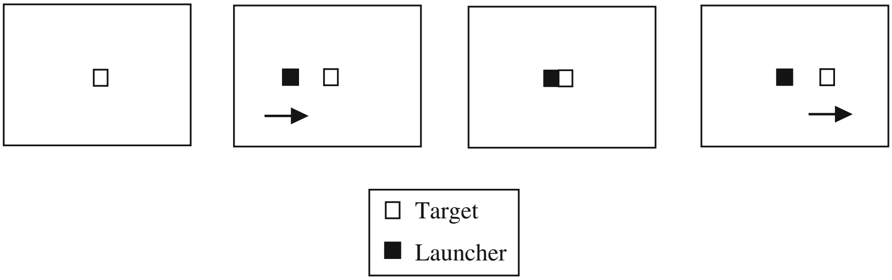

Fig. 1 An illustration of the launching effect. A stationary target is presented. A moving launcher approaches and contacts the target. The launcher becomes stationary, and the target moves in the direction of the previous motion of the launcher. Adapted from Hubbard et al. (2001)

a perception of causality rather than a broader inference regarding causality. Although Michotte treated the launching effect as an all-or-nothing response, subsequent research revealed numerous variables could influence the likelihood and the strength of the launching effect, and these data are discussed below.

1.2 Triggering (Releasing)

In the launching effect, target velocity is typically equal to or slower than launcher velocity, and as noted above, the cause of target motion is attributed to the launcher. However, if spatiotemporal properties of the stimulus are otherwise the same except that target velocity is faster than launcher velocity, a different type of causal perception that Michotte (1946/1963) referred to as the *triggering effect* (also referred to as the *releasing effect*) occurs. In the triggering effect, initiation of target motion is attributed to the launcher, but actual target motion is perceived as more autonomous and self-generated (i.e., as not dependent upon the launcher). Although Michotte suggested the launcher is responsible for initiating target motion in the triggering effect, target motion is not attributed to contact per se from the launcher. Indeed, it is not necessary for the launcher to contact the target in order to produce a triggering effect (e.g., see Thommen et al. 1998). Rather, in the triggering effect the launcher is perceived to release or remove inhibition on target motion, and this allows the target to begin moving of its own accord. Michotte reported a perception of triggering also occurred if a launcher (a) contacted a long rectangular target that then contracted in length or (b) reversed direction and returned to its initial position after contacting a target that then began moving. Unlike in the launching effect, changes in the target attributable to the launcher are not limited to changes in location.

[1] As noted by Scholl and Tremoulet (2000), there have been rigorous criticisms of Michotte's methodology (e.g., Boyle 1960; Joynson 1971), although his methodology has also been acknowledged to reflect the standards of his time (e.g., Montpellier and Nuttin 1973).

1.3 Reaction

In the launching effect and in the triggering effect, target motion usually does not begin before launcher motion stops, and there is usually contact of the launcher and the target prior to target motion. Kanizsa and Vicario (1968) presented a modified launching effect stimulus in which target motion began while the launcher was still moving toward the target (see Fig. 2). Initiation of target motion was attributed to the target (i.e., target motion was perceived as self-generated), but unlike in the triggering effect, if the target began moving while the launcher was moving toward the target, then target motion was perceived to reflect social causality (also referred to as *psychological causality*, *interpersonal causality*, *nonphysical causality*, or *intentionality*) rather than physical or mechanical causality (i.e., the target was perceived as reacting intentionally to flee or avoid the launcher). This type of causal perception was referred to as the *reaction effect* by Thommen et al. (1998) and by Schlottmann and Surian (1999). As in the triggering effect, target velocity in the reaction effect is usually faster than launcher velocity, but the extent to which a faster target velocity is necessary for a reaction effect to occur has not been reported. Target velocity in a reaction effect is overestimated by 20–25 % regardless of launcher velocity (Parovel et al. 2007), and given that target motion in the reaction effect is perceived as self-generated and intentional, overestimation of target velocity is consistent with a perceived intention that the target is trying to move away from the launcher.

1.4 Tool

The likelihood of a launching effect is reduced if a spatial gap separates the final location of the launcher and the initial location of the target (Michotte 1946/1963; Yela 1952; Young and Falmier 2008), but a causal perception in which target motion is attributed to the launcher is more likely if an intermediary object bridges the spatial gap between the final location of the launcher and the initial location of the target (see top panel of Fig. 3). If the temporal gap between when the launcher contacts the intermediary and when the intermediary begins to move and the temporal gap between when the intermediary contacts the target and when the target

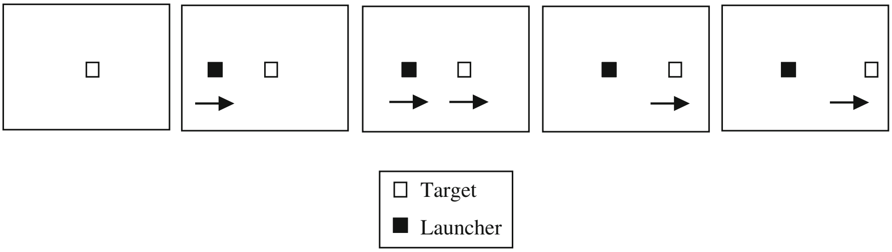

Fig. 2 An illustration of the reaction effect. A stationary target is presented. A moving launcher approaches the target. Before the launcher stops or contacts the target, the target moves away from the launcher (in the same direction of motion as the launcher). Adapted from Kanizsa and Vicario (1968)

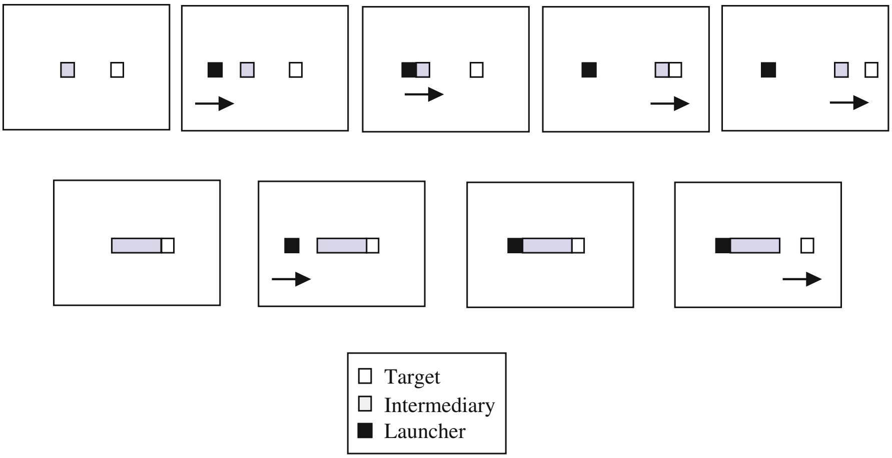

Fig. 3 An illustration of the tool effect. In the *top panel*, a stationary intermediary and a stationary target are spatially separated. The launcher moves toward and contacts the intermediary, and the launcher then becomes stationary. The intermediary then moves toward and contacts the target, and the intermediary then becomes stationary. The target then moves in same direction as previous motion of the launcher. In the *bottom panel*, a stationary intermediary is in contact with a target. The launcher contacts one end of the intermediary, and the target moves away from the other end of the intermediary. Adapted from Hubbard and Favretto (2003)

begins to move are brief, and if target velocity is less than or equal to intermediary velocity which is less than or equal to launcher velocity, then observers report the launcher caused target motion. This causal perception occurs even though the launcher did not contact the target. The intermediary is not perceived to launch the target through its own power (i.e., observers do not perceive successive launchings of the intermediary by the launcher and of the target by the intermediary); rather, observers perceive a single launching of the target by the launcher and in which the intermediary conveyed the influence of the launcher to the target. Michotte (1951/1991b) compared this to a person using a tool to influence another object, and so he referred to this as the *tool effect* [i.e., the intermediary functioned as a tool [e.g., hammer] by which a launcher (e.g., hand) influenced a target (e.g., nail)].[2]

1.5 Entraining

In the launching effect, the launcher stops moving upon contact with the target. If the launcher does not stop moving, but instead continues in the same direction and at the same velocity, a different type of causal perception that Michotte (1946/1963) referred to as the *entraining effect* occurs (see Fig. 4). In the entraining effect, the

[2] Some researchers have referred to a display in which a launcher contacts an intermediary and the target moves away from the opposite end of the intermediary as a launching effect (e.g., Buehner and Humphreys 2010). Although such a display can evoke salient qualities of launching (e.g., initial target motion is attributed to the launcher), it is not a launching effect per se. In the launching effect, the launcher contacts the target and there is no spatial gap (bridged or empty) between the final location of the launcher and the initial location of the target.

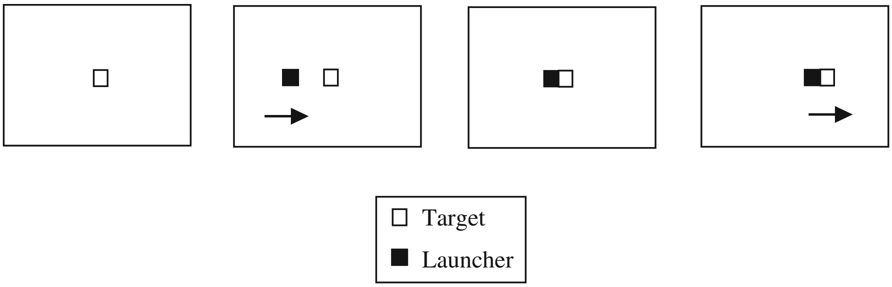

Fig. 4 An illustration of the entraining effect. A stationary target is presented. A moving launcher approaches and contacts the target. The combined launcher and target then move in the direction and at the velocity of the previous motion of the launcher

initially moving object (given that the initially moving object does not "launch" the target, the term "launcher" is not appropriate) approaches the target, and at the moment of contact, the target begins moving in the same direction and at the same velocity as the initially moving object. The trailing edge of the target and the leading edge of the initially moving object remain in contact. Michotte reported observers attribute the initial portion of target motion to the initially moving object and the subsequent portion of target motion to the target; that is, the initial portion of target motion is perceived as passive transport by the initially moving object, but the subsequent portion of target motion is perceived as self-generated by the target. A causal perception of entraining is more likely if the combined initially moving object + target moves at a velocity equal to that of the initially moving object prior to contact. If the combined initially moving object + target moves at a velocity slower than that of the initially moving object prior to contact, the causal perception is that the initially moving object "pushes the target", whereas if the combined initially moving object + target moves at a velocity faster than that of the initially moving object prior to contact, the causal perception is that the initially moving object "carries off" the target (referred to as *abduction* by Weir 1978).

1.6 Traction (Pulling)

Michotte (1946/1963) reported that if an initially moving object passed over a stationary target and that target then began moving (with the leading edge of the target remaining adjacent to the trailing edge of the initially moving object), observers perceived that the initially moving object was towing the target. Michotte referred to this as the *traction effect*, and he considered it to be a special case of the entraining effect in which the cause object (i.e., the initially moving object) was in front of rather than behind the effect object (i.e., the target). A similar effect was observed if the initially moving object contacted the target, reversed direction, and the target then followed the initially moving object. White and Milne (1997) examined a similar causal perception that they referred to as the *pulling impression* (see Fig. 5). On each trial they presented a column of stationary objects, and there were small but distinct spatial gaps between objects. One of the objects began

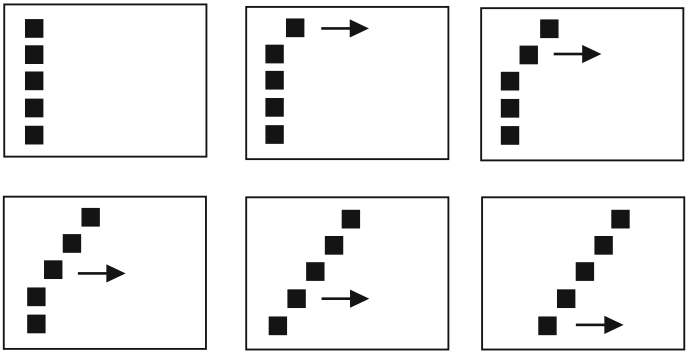

Fig. 5 An illustration of the pulling impression. A column of five stationary targets is presented. The first target begins moving, and after a brief delay, a second target immediately adjacent to the first target begins to move, and after a brief delay, a third target immediately adjacent to the second target begins to move, etc. This continues until all targets are moving in the same direction and at the same velocity. Adapted from White and Milne (1997)

moving at a constant velocity, and after various delays, other objects followed in the same direction and at the same velocity. Unlike in Michotte's demonstration, objects did not contact each other, nor were there visible connections between objects. Participants reported a perception that the initially moving object was pulling the subsequently moving objects. White and Milne reported the pulling impression did not occur if all objects began moving at the same time, and White and Pennington (2003; cited in White 2009b) found the pulling impression was weakened if the objects moved at different velocities or in different directions.

1.7 Braking

Levelt (1962) suggested a causal perception of braking could result from a decrease in the velocity of an object. In Levelt's study, a target moved at a constant velocity over a plain background, and target velocity decreased if the target entered over a different background. If the target vanished before exiting the different background, or if the change in velocity occurred slightly before or slightly after the target began moving over the different background, then observers did not attribute the change in velocity to the different background. However, if the target subsequently exited the different background (i.e., returned to motion against the original background), then observers reported the change in target velocity was due to the target being braked while over the different background. A perception of braking was more likely if the target resumed its previous faster velocity upon exiting the different background, but a perception of braking could occur even if the target remained at the slower velocity after exiting the different background. If the same changes in velocity occurred against a constant background, or if a target increased in velocity upon entering the different background, then perception of braking did not occur. However, it is not clear if "braking" is considered an action the target does to itself (and so the background does not act directly on the target) or if braking is an effect of the background on the target (e.g., providing a change in friction or other resistance to target motion as in representational friction, Hubbard 1995a, b).

1.8 Enforced Disintegration and Bursting

White and Milne (1999) presented stimuli in which an initially moving object collided with a stationary target and either the initially moving object or the stationary target then broke into fragments (see Fig. 6). The velocity ratio between the initially moving object and the resultant fragments varied, and the fragments moved (a) in a variety of directions within a 120-degree arc centered on the direction of motion of the initially moving object, (b) radially outward, or (c) in a variety of directions within a 120-degree arc centered on the direction opposite to motion of the initially moving object. Observers rated whether the fragmented object smashed, popped, or disintegrated of its own accord. Ratings of “smashed” peaked if the velocity of the initially moving object was faster than the velocities of the fragments, and ratings of “popped” peaked if the velocity of the initially moving object was slower than the velocities of the fragments. White and Milne referred to these causal perceptions as *enforced disintegration* and *bursting*, respectively. Conditions that maximized ratings of enforced disintegration (e.g., a wide range of directions of fragment motion) and that maximized ratings of bursting (e.g., velocity of the initially moving object was slower than velocities of the fragments) were different from conditions previously reported to maximize a launching effect, and so

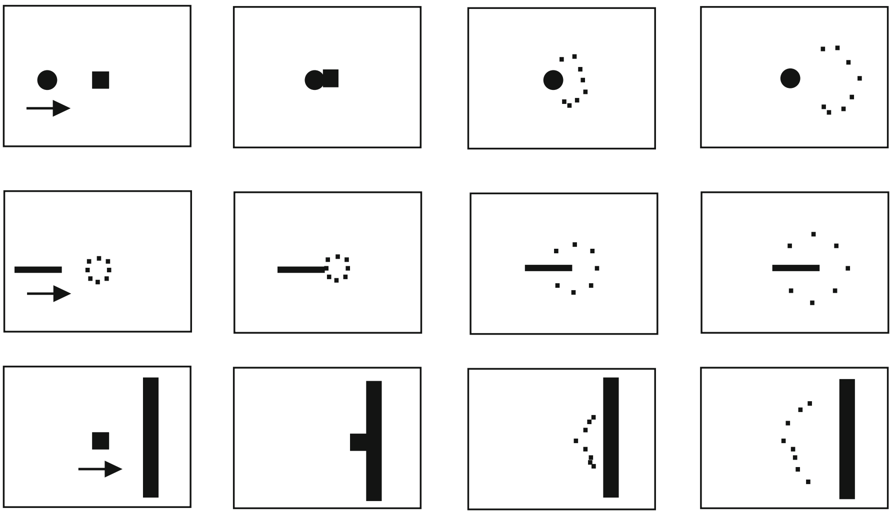

Fig. 6 An illustration of enforced disintegration and bursting. In the *top panel*, a moving object strikes a stationary target that disintegrates into fragments that move in the same direction as the moving object. In the *middle panel*, a moving object strikes a stationary target that disintegrates into fragments that expand radially outward. In the *bottom panel*, a moving object strikes a stationary target, and the moving object disintegrates into fragments that move in the direction opposite to the original moving object. Adapted from White and Milne (1999)

White and Milne suggested enforced disintegration and bursting are distinct from (and not reducible to) the launching effect.

1.9 Coordinated Movement

White (2005) presented a display containing multiple stationary targets and a single launcher (see Fig. 7). If the launcher contacted one of the targets, then all of the targets began moving at the moment of that contact. In a mechanism-consistent condition, the directions of each of the targets were correlated, and the pattern of motions could be attributed to a single underlying mechanism (e.g., a rigid rotating surface in the picture plane to which all of the targets were affixed); in a mechanism-inconsistent condition, the directions of individual target motions were random, and the pattern of motions could not be attributed to a single underlying mechanism. Participants rated whether the launcher caused motions of the other (noncontacted) targets. Ratings were higher in the mechanism-consistent condition than in the mechanism-inconsistent condition, and White suggested this occurred because in the mechanism-consistent condition the visual system could match the pattern of movements to a single potential mechanism. White also suggested the effect of correlated movement of the targets differed from the launching effect because (a) the direction of motion of most of the targets was not the same as the direction of motion of the launcher and (b) there were spatial gaps between the final location of the launcher and the initial location of all but one of the targets. This type of phenomenal causality will be referred to as the *coordinated movement effect*.

1.10 Penetration

White and Milne (2003) presented displays in which a narrow moving object decelerated upon contact with a much larger stationary target (see Fig. 8). The final location of the moving object varied such that the (a) leading section of the moving object was occluded by the near edge of the target and the trailing section of the moving object was visible, (b) entire moving object was occluded by the target, or

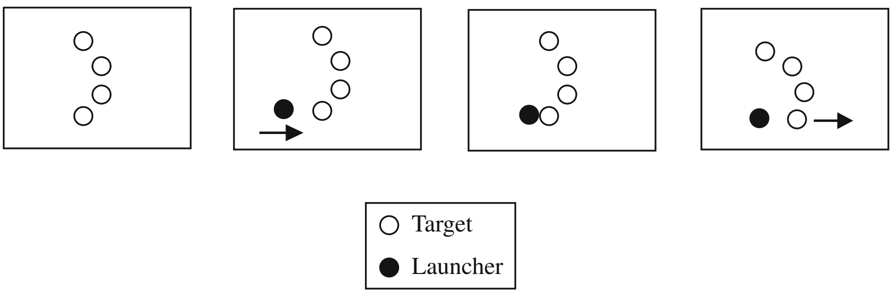

Fig. 7 An illustration of the coordinated movement effect. The launcher contacts one target and all of the targets begin moving. In this example, the directions of the individual targets could be attributed to a rotation of a larger surface or array (i.e., a mechanism consistent stimulus) with the lower targets moving rightward and the upper targets moving leftward). Based on White (2005)

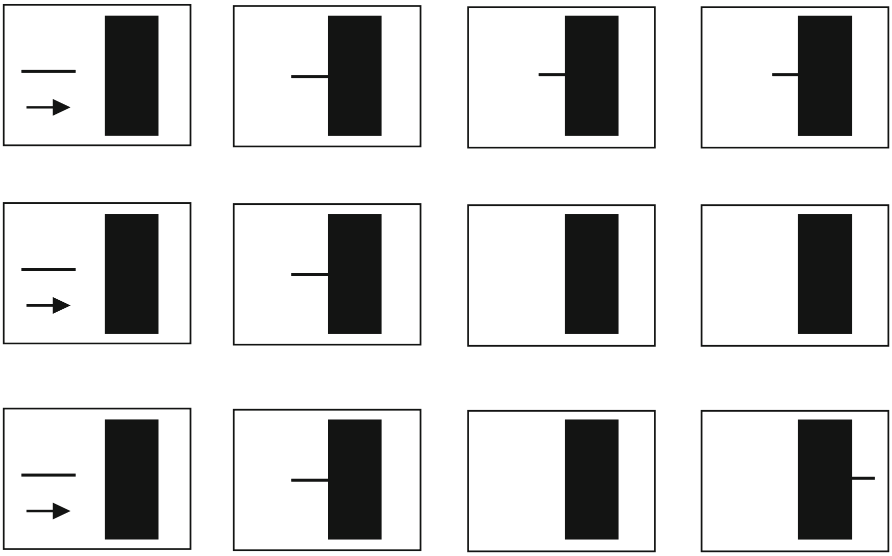

Fig. 8 An illustration of the penetration impression. In the *top panel*, a moving object stops after the leading section is occluded by a larger surface. In the *middle panel*, a moving object stops when it is completely occluded. In the *bottom panel*, a moving object stops when the leading section had emerged from the far side of the occluder but the trailing section remains occluded. Adapted from White and Milne (2003)

(c) trailing section of the moving object was occluded by the target and the leading section of the moving object was visible beyond the far edge of the target. Observers rated whether the moving object passed behind the target, penetrated into or through the target, or passed in front of the target. Ratings suggesting a causal perception that the moving object passed behind the target were more likely with a smaller (or no) deceleration of the moving object upon contact with the target. Ratings suggesting a causal perception of penetration of the target by the moving object (a) increased if smaller lengths of the leading section of the moving object were occluded by the target after the moving object became stationary, (b) increased with larger deceleration of the moving object upon contact with the target, and (c) decreased if the final position of the moving object was fully occluded by the target or if the leading section of the moving object was visible beyond the far edge of the target. White and Milne referred to the causal perception the moving object penetrated the target as the *penetration impression.*

1.11 Expulsion (Launching-by-Expulsion)

Michotte (1946/1963) noted a special case of the launching effect that he suggested reflected a combination of entraining and launching: A launcher moved toward a stationary target, and when the launcher contacted the target, the combined launcher + target continued moving in the same direction as the previous launcher motion. After moving a short distance, the launcher stopped, and the target

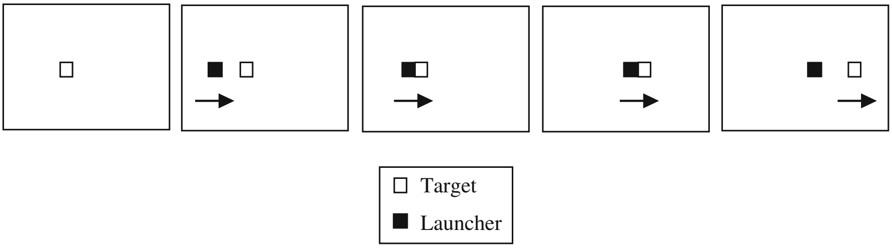

Fig. 9 An illustration of the expulsion effect. A stationary target is presented. A moving launcher approaches and contacts the target. The launcher and target then continue moving in the same direction and at the same velocity as the previous motion of the launcher. The launcher stops, and the target continues moving in the same direction and at the same velocity

continued in motion (see Fig. 9). There was a perception of launching of the target that Michotte referred to as the *expulsion effect* (also referred to as *launching-by-expulsion*). However, if the initial separation of the launcher and target was omitted and the display began with a combined moving launcher + target and the launcher then stopped and the target continued, a causal perception of expulsion was not as likely to occur. Michotte suggested perception of expulsion required the launcher and the target initially be perceived as separate objects. Similarly, if a moving target appeared next to a previously moving launcher (as if expelled from the launcher) at the moment that launcher stopped moving, an expulsion effect was not as likely as if the target was visible as a separate object prior to launching. Causal perception of expulsion was strongest if the temporal gap between when launcher motion stopped and when target motion started (continued) was minimal. Also, Michotte suggested some cases of the expulsion effect involved a perception of propulsion of the target.

2 Variables that Influence Phenomenal Causality

A number of different variables have been suggested or shown to influence phenomenal causality, and these variables can be classified as involving characteristics of the stimulus or characteristics of the observer. The majority of research on phenomenal causality focused on the launching effect, and so this section focuses primarily on variables that influence the launching effect. Data regarding influences of these or other variables on other types of phenomenal causality are noted when such data are available.

2.1 Characteristics of the Stimulus

Michotte (1946/1963) claimed phenomenal causality is based on the kinetic structure of a stimulus, and so it could be predicted that characteristics of the stimulus that influence kinetic structure should influence phenomenal causality and that characteristics of the stimulus that do not influence kinetic structure should not influence phenomenal causality. Characteristics of the stimulus that could potentially influence phenomenal causality and that are discussed in this section include

(a) a temporal gap between when the launcher stops moving and when the target starts moving, (b) a spatial gap between the final location of the launcher and the initial location of the target, (c) a spatial overlap of the final location of the launcher and the initial location of the target, (d) the direction of motion of the launcher and the target, (e) the absolute velocity of the launcher or the target, (f) the velocity ratio of the launcher and the target, (g) the target trajectory length, (h) the radius of action, (i) the size of the launcher and the target, (j) whether motion appears apparent or continuous, (k) whether the launcher and the target are in the same modality or in different modalities, and (l) the implied animacy of the launcher and the target.

2.1.1 Temporal Gap

Michotte (1946/1963) reported the launching effect was strongest if the temporal gap between when the launcher stopped moving and when the target started moving was less than 100 ms, and completely absent if the temporal gap was larger than 150 ms. Schlottmann and Shanks (1992) reported ratings of causality decreased with increases in temporal gap size. Indeed, numerous studies have used a launching effect stimulus with a temporal gap as a noncausal control stimulus (e.g., Desrochers 1999; Fugelsang et al. 2005; Oakes and Cohen 1990; Morris and Peng 1994). Yela (1952) reported the launching effect for a given temporal gap was stronger if the launcher contacted the target than if the launcher did not contact the target. Young et al. (2005) presented an auditory tone during the temporal gap, and increases or decreases in the amplitude of that tone (that were predictive of target motion onset) led to higher ratings of causality than did presenting a tone with a constant amplitude or presenting no tone. Falmier and Young (2008) reported the presence of a temporal gap had a significant impact on ratings of causality, especially if participants had previously completed a task involving prediction of when target motion would begin; this was interpreted as consistent with Schlottmann, Ray, Mitchell, and Demetriou (2006), who reported exposure to multiple events increased sensitivity to differences in the size of a temporal gap or a spatial gap. Powesland (1959) and Brown and Miles (1969) found participants who received exposure to stimuli with a large temporal gap were subsequently more likely to give higher causal ratings to launching effect stimuli that had a smaller temporal gap than were control participants.

Guski and Troje (2003) varied the temporal gap between when the launcher contacted the target and when the target began moving; in some trials, an auditory stimulus (a wood block hit by a drumstick) was presented or the target briefly changed color (described as a "blink" similar in duration to the auditory stimulus) during the temporal gap. Ratings that target motion was caused by "a perceivable event immediately before" (pp. 792) target motion began decreased with increasing temporal gap size. If neither a sound nor a blink was presented, ratings dropped below the midpoint of the rating scale if the temporal gap exceeded 100 ms; if either a sound or a blink was presented, ratings did not drop below the midpoint of the rating scale until the temporal gap exceeded 280 ms, and if both a sound and a blink were presented, ratings did not drop below the midpoint of the rating scale until the temporal gap was nearly 400 ms. In a follow-up experiment, two launching effect stimuli were presented on each trial, and participants judged whether the temporal gap was longer in the first stimulus or in the second stimulus. One stimulus contained a sound within the temporal gap and the other stimulus had a silent temporal gap. Temporal gaps containing a sound were judged as shorter, but the decrease in perceived duration was not enough to account for the effect of sound on ratings in Guski and Troje's prior experiment. Also, Belanger and Desrochers (2001) inserted a temporal gap of 1 second into an entraining effect stimulus (after the initially moving object contacted the target), and such a stimulus was rated as less causal than an entraining effect stimulus without a temporal gap.

2.1.2 Spatial Gap

Michotte (1946/1963) reported the launching effect was strongest if the launcher contacted the target (i.e., if there was no spatial gap between the final location of the launcher and the initial location of the target). Indeed, numerous studies have used a launching effect stimulus with a spatial gap as a noncausal control stimulus (e.g., Cohen and Amsel 1998; Falmier and Young 2008; Leslie 1982; Roser et al. 2005). The notion that a launcher can influence motion of a target even if there is a spatial gap between the final location of the launcher and the initial location of the target is referred to as *launching-at-a-distance* or *causation-at-a-distance*. Yela (1952) reported a launching effect could occur if there was a spatial gap between the launcher and the target, but the likelihood of launching-at-a-distance decreased as spatial gap size increased and decreased more with increases in the temporal gap between when launcher motion stopped and when target motion started. The possibility that motion of a target would be attributed to a launcher that does not directly contact that target (i.e., if there is a spatial gap) can be increased if an intermediary stimulus bridges the spatial gap between the launcher and the target, but the presence of such an intermediary stimulus changes the causal perception from a launching effect to a tool effect. An entraining effect is also less likely to occur if there is a spatial gap between the initially moving object and the target (Belanger and Desrochers 2001).

Young and Falmier (2008) presented a (a) launching effect stimulus or (b) stimulus in which a spatial gap between the final location of the launcher and the initial location of the target was empty, completely filled by an intermediary stimulus (a large cylinder), or partially filled by an intermediary stimulus (a small cylinder or a dashed line orthogonal to the direction of motion) adjacent to the final location of the launcher, centered in the spatial gap, or adjacent to the initial location of the target. In different blocks of trials, participants (a) rated whether the launcher caused target motion or (b) predicted when the target would begin moving. Ratings the launcher caused target motion were highest for launching effect stimuli or if an intermediary stimulus bridged the gap and were lowest if the intermediary stimulus was adjacent to the target or if the gap was empty (i.e., if no intermediary stimulus was presented). Predictions of when the target would begin moving were most accurate for launching effect stimuli and if an intermediary stimulus bridged the gap and least accurate if the intermediary stimulus was adjacent to the target or if the gap was empty (cf. effects of an intermediary on memory for location in the tool effect in Hubbard and Favretto 2003). As will be discussed in more detail below, Young and Falmier suggested the predictability of when target motion would begin and the provision of a conduit for influence of the launcher to be conveyed to the target had independent effects on the launching effect.

The presence of a spatial gap between the final location of the launcher and the initial location of the target has been linked with an increased likelihood of perceiving social or psychological causality rather than mechanical or physical causality. Although inanimate stimuli typically interact through contact, animate stimuli (e.g., people) can influence each other at a distance. As noted earlier, Kanizsa and Vicario (1968) presented a modified launching effect stimulus (later referred to as a *reaction effect* stimulus) in which the target began moving away from the launcher before the launcher reached the initial location of the target or stopped moving, and participants reported a causal perception the target was trying to escape or flee from the launcher (see also Rimé et al. 1985). Schlottmann and Surian (1999) suggested perception of such causation-at-a-distance could promote learning about social interactions of intentional agents and contribute to development of a theory of mind, and they reported evidence consistent with causation-at-a-distance in 9-month old infants and in adults (see also Schlottmann et al. 2009, 2012). Bassili (1976) presented films of moving stimuli (based on Heider and Simmel 1944), and participants' descriptions of those films suggested spatial configuration of stimuli influenced the type of interaction perceived, whereas temporal contingencies between stimuli influenced whether an interaction was perceived.

2.1.3 Spatial Overlap

Scholl and Nakayama (2002) reported if the launcher and the target overlapped completely at the moment launcher motion stopped and target motion started, then that stimulus would be perceived as a noncausal "passing" of one object by the other (and if the launcher and the target were initially different colors, then a color change for both objects also occurred). Scholl and Nakayama (2004) presented a display in which the final launcher location overlapped the initial target location by 60, 80, or 90 %. The launcher and the target were circular shapes of different colors, and participants rated whether motion of the first object caused motion of the second object or whether one object remained stationary and the other object passed over or under that stationary object. If an overlap stimulus was presented in a display that also included a nearby launching effect stimulus, the overlap stimulus was more likely to be rated as causal, but if an overlap stimulus was presented in isolation, the probability such a stimulus would be rated as causal decreased as the amount of overlap increased. The latter pattern is not surprising, as a typical launching effect stimulus involves no overlap. However, Olum (1956) reported 7-year old children were more likely than adults to report a launching effect if the final location of the launcher and the initial location of the target overlapped, and this suggested there might be a developmental component in the processing or importance of the spatial relationship of the launcher and the target.

2.1.4 Direction

Michotte (1946/1963) varied the angle between the direction of motion of the launcher and the direction of motion of the target, and as the angle increased, the likelihood of a launching effect decreased (see also Straube et al. 2011; chasing subtlety in Gao et al. 2009). Similarity of the direction of motion of the launcher and the direction of motion of the target appears necessary for a launching effect. Indeed, displays in which direction of target motion is orthogonal to direction of launcher motion have been used as control noncausal stimuli (Buehner and Humphreys 2010; Hubbard et al. 2001; Young and Sutherland 2009). However, similarity of direction is not sufficient: if a horizontally-moving launcher is vertically offset from a horizontally-moving target, a launching effect does not occur (Michotte 1964/1963). Many studies that presented launching effect stimuli did not explicitly specify the directions of motion; in studies that did, motion was generally horizontal (e.g., Cohen and Oakes 1993; Fugelsang et al. 2005; Scholl and Nakayama 2002) or only left-to-right (e.g., Falmier and Young 2008; Natsoulas 1961; Schlottmann et al. 2002; Young et al. 2005). An examination of effects of launcher direction on the launching effect has not been published; although Scholl and Nakayama (2002) state perception of causality is weaker with non-horizontal motion, they do not provide a citation or evidence for this statement. Studies of braking (Levelt 1962) and of enforced disintegration and bursting (White and Milne 1999) presented left-to-right motion, and effects of direction in other types of phenomenal causality are not known.

2.1.5 Absolute Velocity

Michotte (1946/1963) reported the launching effect was maximized with absolute velocities between 20 and 40 cm/s and that the likelihood of a launching effect was decreased with very low or very high velocities. Yela (1952) presented launcher velocities of 3–30 cm/s (with a constant ratio of launcher velocity to target velocity of 6.7:1) and reported differences in absolute velocities did not influence launching-at-a-distance. Also, increases in launcher velocity increased the radius of action of that launcher (Boyle 1961; Yela 1952; see also De sa Teixeira et al. 2008). In general, and over the range of velocities typically used in studies of the launching effect, decreases in absolute velocity led to weaker causal perceptions. However, and as discussed below, the ratio of launcher velocity and target velocity is usually more influential in determining phenomenal causality than are the absolute velocities of the launcher and the target (e.g., a medium launcher velocity contributes to a launching effect if paired with a slower target velocity but to a triggering effect if paired with a faster target velocity). White and Milne (2003) reported that smaller decreases in the absolute velocity of the moving object weakened ratings of penetration. Interestingly, the causal object in the penetration impression decreased velocity of the effect object, whereas the causal object in the launching effect increased velocity of the effect object; in penetration and in launching, changes in velocity in the direction of the effect of a causal object led to higher ratings of causal perception than did changes in velocity in the direction opposite to the effect of the causal object.

Parovel and Casco (2006; see also Parovel et al. 2007) presented participants with displays of pairs of launching effect stimuli or pairs of triggering effect stimuli, and participants judged whether target velocity in the second member of the pair was faster or slower than target velocity in the first member of the pair. Participants overestimated the velocity needed for the second target to match the velocity of the first target; for launching effect stimuli, overestimation was proportional to target velocity, but for triggering effect stimuli, overestimation was constant across different target velocities. In follow-up experiments, participants were presented with causal displays or with noncausal displays involving (a) succession (the target appeared after the launcher stopped), (b) overlap (the final location of the launcher overlapped the initial location of the target, cf. Scholl and Nakayama 2002), (c) a spatial gap (the final location of the launcher was 1 degree from the initial location of the target), (d) inverse launching (the launcher trajectory was below the target trajectory), or (e) mirror motion (the launcher and the target moved from opposite sides of the display toward the center). Overestimation of target velocity was reduced if causality was not perceived, and Parovel and Casco argued this pattern was consistent with Michotte's notion that perceived causality depends upon continuity of motion.[3]

2.1.6 Velocity Ratio

Michotte (1946/1963) reported the launching effect was strongest if the ratio of launcher velocity and target velocity was 3.6:1, although a launching effect could be obtained with many other velocity ratios. Schlottmann and Anderson (1993) presented launching effect stimuli with velocity ratios of 1:1, 2:1, 4:1 or 8:1. Larger velocity ratios resulted in slightly higher confidence ratings (cf. Boyle 1960, 1961) and higher naturalness ratings (cf. Michotte 1946/1963). However, there were larger effects in individual data than in group-averaged data, and the presence of apparent individual differences does not seem completely consistent with Michotte's (1946/1963) claim nearly all observers spontaneously perceive causality in a launching effect stimulus. Natsoulas (1961) varied the ratio of launcher velocity and target velocity from 1:3 to 3:1, and a launching effect was more likely if launcher velocity was faster than or equal to target velocity. Bowler and Thommen (2000) used velocity ratios of 3:1–9:1 for launching effect stimuli and 1:3–1:9 for releasing effect stimuli, and Parovel and Casco (2006) used velocity ratios of 4:3, 8:3, and 16:3 for launching effect stimuli and 0.5:3, 1:3, and 2:3 for triggering effect stimuli, but neither paper examined effects of velocity ratio within a specific type of causal

[3] Consideration of absolute velocities of the launcher and target might suggest those velocities are represented or processed relatively independently; however, Kerzel et al. (2000) reported reproductions of launcher velocity were influenced by the subsequent target velocity. Such influence occurred for causal displays and noncausal displays, and so was attributed to retroactive interference rather than to any property of perception of causality per se. Even so, it is not clear how a retroactive interference could be responsible for the differences between launching effect display and triggering effect displays found by Parovel and colleagues.

perception. If a stimulus fragmented after a collision, White and Milne (1999) reported ratings of "popped" peaked with a velocity ratio of 1:4, whereas ratings of "smashed" peaked with a velocity ratio of 1.6:1.

2.1.7 Target Trajectory Length

Boyle (1960) examined the influence of target trajectory length and velocity ratio on the launching effect. If launcher velocity was faster than target velocity, then increases in length of the target trajectory slightly decreased the likelihood of a launching effect and did not influence the likelihood of a triggering effect. However, target trajectory length was restricted (from 5 to 40 mm), and Boyle appeared to use the radius of action (see below) as an upper limit for trajectory length. Had such a limit not been imposed, further increases in target trajectory length would have been predicted to change the nature of the phenomenal causality. If launcher velocity was slower than target velocity, then an increase in target trajectory length increased the likelihood of a triggering effect and decreased the likelihood of a launching effect. Also, Boyle reported 50 % of participants were rejected because they did not report appropriate responses to a prototypical launching effect stimulus or to a prototypical triggering stimulus, but such a high percentage does not seem consistent with Michotte's (1946/1963) claim nearly all observers spontaneously perceive causality in a launching effect display (cf. Beasley 1968; Schlottmann et al. 2006; White 1988). Given the lack of spontaneous phenomenal causality in a significant number of Boyle's participants, the generalizability or universality of phenomenal causality might be less than Michotte claimed.

2.1.8 Radius of Action

Michotte (1946/1963) reported a perception the launcher caused target motion was replaced by a different perception if the target traveled a greater distance than what would have been expected given the impact from the launcher. The distance within which target motion was attributed to the launcher was referred to as the *radius of action*. Once the target moved beyond the radius of action, the attribution for the source of target motion changed from the launcher to the target, and the target was perceived to move of its own accord. Michotte suggested the length of the radius of action was determined by a complex function based primarily on target velocity. Yela (1952) had participants note the location at which target motion appeared to change from passive to active, and this was used to delineate the extent of the radius of action. The radius of action if the launcher contacted the target was similar to the radius of action for launching-at-a-distance, and in each case, increases in target velocity resulted in increases in the radius of action. Variability within participants was low, although there was more variability between participants. De sa Teixeira et al. (2008) reported numerical estimates of how far a launched target would travel (i.e., estimates of the radius of action) increased with increases in launcher size and with increases in launcher velocity. An increase in the length of the radius of action with increases in velocity is consistent with the impetus theory of launching discussed in Part II.

Boyle (1961) presented a range of launcher velocities and target velocities (ratios from 1:1 to 10:1). Target trajectory length was increased or decreased until participants judged the target "appeared to go too far for the blow given it" (pp. 223) by the launcher, and this measure provided an estimate of the length of the radius of action. The length of the radius of action was not simply related to target velocity or to velocity ratio of the launcher and the target; with an increase in target velocity, the length of the radius of action increased, but temporal duration within the radius of action decreased. Launcher velocity and the ratio of launcher velocity and target velocity were not significantly related to the length of the radius of action (cf. De sa Teixeira et al. 2008). Umetsu (2008) presented launching effect stimuli in which movement of the target was occluded after contact from the launcher. Participants estimated relative target velocity and distance traveled by the target. The best single predictor of participants' estimates was velocity of the launcher. Umetsu suggested the "power" of a collision in the launching effect was determined by (estimated) velocity of the target after contact from the launcher (cf. De sa Teixeira et al. 2008) and further suggested this was consistent with the idea of the radius of action. The idea of "power" might be related to the perception of force (e.g., White 2009a, 2011a, b, c) discussed in Part II.

2.1.9 Launcher Size and Target Size

Kotovsky and Baillargeon (1998) habituated infants 5.5–6.5 months old to a display in which a medium-sized cylinder rolled down a ramp until it contacted a stationary target at the base of the ramp and that target moved a small distance. For the dishabituation test, the medium-size cylinder was replaced by a small or large cylinder, and after the new cylinder contacted the target, the target moved to the far edge of the display. Infants looked longer if the dishabituation test presented a small cylinder than a large cylinder, and this is consistent with the hypothesis infants' expectations regarding target motion were at least partially dependent upon launcher size (i.e., smaller launchers were expected to result in smaller distances of target motion). De sa Teixeira et al. (2008) had participants estimate the distance a launched target would travel, and they reported increases in expected distance with increases in launcher size. These effects of size do not appear consistent with Michotte's claim the launching effect is not affected by object properties such as size. Natsoulas (1961) varied the ratio of launcher size to target size (see also Natsoulas 1960), and he reported size ratio did not influence the likelihood of a launching effect for adult participants. However, it is possible that differences might have been found if participants rated the strength of launching rather than whether or not launching occurred.

2.1.10 Apparent or Continuous Motion

Gordon et al. (1990) presented participants with launching effect stimuli in which (a) launcher motion was apparent (i.e., the launcher appeared at one location, vanished, and then appeared at another location) and target motion was continuous (i.e., the target passed through all of the intervening locations between the initial location and the final location), (b) launcher motion was continuous and target motion was apparent, or (c) launcher motion was apparent and target motion was apparent. Participants also viewed anchor stimuli consisting of a typical launching effect with continuous motion and in which there was no temporal gap (assigned a value of "10") or a 1 second temporal gap (assigned a value of "0"). Experimental stimuli in which motion of either (but not both) the launcher or the target was apparent were rated 7.0 and 7.9, respectively, and experimental stimuli in which motion of both the launcher and the target was apparent were rated 12.8. The difference between the first two conditions and the latter condition was significant, but if any of these conditions differed from a typical launching effect ("10") was not reported. Hubbard and Ruppel (2012) presented implied motion of a launcher and a target (five presentations of a static launcher and three presentations of a static target, each visible for 250 ms with a 250 ms interstimulus interval between successive presentations, and locations of successive presentations were shifted to imply motion in a consistent direction) and reported ratings consistent with a launching effect.

2.1.11 Modality

Michotte (1946/1963) reported a launching effect occurred if the launcher was a wooden ball and the target was a circle of light. Occurrence of a launching effect if the launcher and the target were from such different dimensions (a) suggests the mechanism underlying the launching effect (and phenomenal causality in general) might be abstract or general rather than dimension- or modality-specific and (b) supports Michotte's claim phenomenal causality depends upon kinetic structure and does not depend upon object properties. Fisher (1962) presented one group of participants with launching effect stimuli in which the launcher and the target were in different modalities and a second group of participants with launching effect stimuli in which the launcher and the target were in the same modality (the specific modalities involved were not identified). Based upon Fisher's discussion, both groups of participants appeared to experience causal perceptions, but statistical analyses and important methodological details were not presented, and so no conclusions can be drawn. Presentation of an auditory stimulus during a temporal gap in a visual launching effect stimulus can increase the likelihood of a causal perception (Guski and Troje 2003; Young et al. 2005). The possibility of a cross-modal mechanism for causal perception is consistent with a contribution of haptic information to visual perception of causality proposed by White (2009a) and with amodal completion of an occluded contact of the launcher and the target in perception of a launching effect demonstrated by Kiritani (1999).

2.1.12 Animacy

Whether stimuli are perceived as animate or inanimate is relevant to an understanding of phenomenal causality for at least two reasons. First, perceived animacy is often confounded with whether social causality or physical causality is perceived; social causality is more likely to be perceived if stimuli are perceived as animate, whereas physical causality is more likely to be perceived if stimuli are perceived as inanimate. Second, many properties of stimulus motion that influence whether a stimulus is perceived to be animate or inanimate are also properties related to phenomenal causality (e.g., whether motion appears self-propelled or caused by another stimulus, whether the trajectory is smooth or irregular, whether contact with another stimulus occurs, whether motion is contingent upon other stimuli; for discussion, see Rakison and Poulin-Dubois 2001).[4] Along these lines, manipulation of implied animacy by varying direction and velocity of motion of a stimulus influences phenomenal causality (e.g., Dittrich and Lea 1994; Gao et al. 2009; Tremoulet and Feldman 2000; but see Gelman et al. 1995), and use of nonrigid motion in which the leading edge of the stimulus extends and then the trailing edge contracts (referred to as "caterpillar" motion by Michotte 1946/1963) is usually rated by adults as more animal-like (i.e., as social rather than physical) and has produced evidence for perception of causality-at-a-distance in infants (Schlottmann and Surian 1999; Schlottmann et al. 2009).

Heider and Simmel (1944) provided the most well-known demonstration that patterns of movement could be spontaneously described in intentional and social terms. Their participants viewed a film consisting of geometric figures (two triangles of different sizes and a circle) that moved around (and entered) an empty rectangle, and participants readily attributed various personality characteristics to the different shapes and described the movements using social and intentional terms suggestive of goals, emotions, and mental states (see also Bassili 1976). Perception of intention in such abstract stimuli is often linked with perception of causality in the launching effect (e.g., see Scholl and Tremoulet 2000), and Michotte (1950/1991a) suggested patterns of motion could provide cues for social perception (see also Scholl and Tremoulet 2000). Patterns of motion in studies of perception of social causality are usually more extended and complex than patterns of motion in studies of perception of physical causality, and this suggests complexity of motion might distinguish animate from inanimate motion (cf. Rakison and Poulin-Dubois 2001). Social and intentional attributions are not limited to single objects, but are also applied to groups of objects (e.g., the "wolfpack effect", Gao et al. 2010), and this suggests "intentional entities" need not be limited to bounded physical objects (see Bloom and Veres 1999).

Springer et al. (1996) presented 3-, 4-, 5-year old children and adults with displays based on Heider and Simmel (1944) stimuli, and although 5-year old children and adults exhibited similar responses, responses of 3-year old and 4-year old children deviated from responses of 5-year old children and adults. Berry and Springer (1993; also Berry et al. 1992) reported disruption of structural elements, but not disruption of dynamic elements, of displays based on Heider and Simmel disrupted descriptions of those displays by 3-, 4-, or 5-year old children. This latter finding is consistent with suggestions the pattern of motion, rather than specific object properties, determines causal responses (cf. Kotovsky and Baillargeon 1998;

[4] The importance of movement patterns in social perception has been demonstrated in literature on biological motion and studied using point-light displays (for review, see Blake and Shiffrar 2007), but consideration of this literature is beyond the scope of this review.

Michotte 1946/1963). Dittrich and Lea (1994) presented displays containing a target and a goal object. Target motion was more likely to be rated as intentional if that motion was toward a goal object, the target moved faster, or a goal object was visible. Tremoulet and Feldman (2000) presented displays in which a target changed velocity and direction within each trial. Ratings of animacy increased with larger changes in direction, larger increases in velocity, and if orientation of the target remained aligned with the trajectory even if the direction of target motion changed (see also Gao et al. 2009; Gao et al. 2010), and Tremoulet and Feldman proposed the existence of a low-level mechanism for perception of intentionality.

Falmier and Young (2008) presented participants with a display of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, (c) launching effect stimulus with a temporal gap, or (d) launching effect stimulus with a spatial gap and a temporal gap. In an inanimate condition, the launcher moved in a straight line as it approached the target. In an animate condition, the launcher was always oriented toward the target but changed direction and velocity as it approached the target (cf. Gao et al. 2009, 2010). In Experiment 1, participants predicted when the target would begin moving and rated whether the launcher caused target motion. Inanimate launching received the highest ratings of causality, and ratings were lowest if both a temporal gap and a spatial gap were present. However, an effect of implied animacy on phenomenal causality occurred only if the rating task was completed prior to beginning the prediction task. In Experiment 2, auditory cues (a mouse squeak for animate targets, a missile sound for inanimate targets) were added to the displays. Attribution of animacy had a stronger impact on causality ratings if it was manipulated with instructions (e.g., to view the stimulus as a mouse or as a missile) than if animacy was manipulated only through presentation of cues (see also Schlottmann et al. 2006). Also, participants more readily rated temporal gap stimuli as causal if the target was perceived as animate.

Schlottmann et al. (2006) presented adult participants with displays of rigid motion or nonrigid (i.e., “caterpillar”) motion, and participants (a) described the stimulus and (b) rated whether the launcher was responsible for target motion, and if so, whether that causality involved physical causality or social causality. Across trials the launcher did or did not contact the target, and the start of target motion was simultaneous with launcher motion, immediately after the launcher stopped moving, or 1.25 second after the launcher stopped moving. Launching effect stimuli and entraining effect stimuli were rated as physically causal, and reaction effect stimuli were rated as socially causal. Ratings of the strength of social causality were generally weaker than ratings of the strength of physical causality. In the absence of contact, nonrigid motion (more likely to be perceived as animate) was more likely to lead to attribution of social causality. On first viewing, nearly 100 % of participants gave physical causal responses for launching effect stimuli and for entraining effect stimuli, and 60 % of participants gave social causality responses for reaction effect stimuli. The lower percentage for social causality responses is consistent with Rimé et al.’s (1985) finding that perception of social causality is weaker and more variable than perception of physical causality. Also, participants were less likely to report perception of causality after multiple viewings, and this suggests a role of learning or experience.

In many studies examining effects of animacy on phenomenal causality, actual animate stimuli were not presented; rather, "animate" stimuli were inanimate depictions of animate objects. An exception was reported by Spelke et al. (1995), who compared effects of animate stimuli and inanimate stimuli in the launching effect in 7-month old infants. In an animate condition, launchers and targets were a man and a woman, respectively, walking at a normal pace. In an inanimate condition, launchers and targets were brightly colored objects 5–6 feet in height and moved from behind by unseen persons walking at a normal pace. In the animate condition and in the inanimate condition, the launcher appeared on the left, moved toward the right and disappeared behind an occluder, and after an appropriate amount of time, the target emerged from behind the right edge of the occluder (cf. Kiritani 1999). After habituation, test displays were shown in which the occluder was removed and the launcher contacted the target or stopped before contacting the target. In the animate condition, there was no difference in looking times between contact displays and no-contact displays, but in the inanimate condition, infants looked longer at no-contact displays. Spelke et al. suggested 7-month old infants reason differently about animate and inanimate objects and appear aware that people are capable of self-generated motion (cf. Cicchino et al. 2011).

2.2 Characteristics of the Observer

Michotte (1946/1963) claimed phenomenal causality is based solely on the kinetic structure of a stimulus, and so it could be predicted that characteristics of the observer should not influence phenomenal causality. Therefore, an effect of any characteristic of the observer on phenomenal causality could potentially be evidence against Michotte's claim, and so whether characteristics of the observer influence phenomenal causality is of considerable theoretical importance. Characteristics of the observer that could potentially influence the launching effect and that are discussed in this section include (a) allocation of attention, (b) eye movements and fixation, (c) prior experience, (d) intelligence, (e) age, (f) culture, and (g) psychopathology.

2.2.1 Allocation of Attention

Choi and Scholl (2004) presented two vertically separated stimuli in a display and cued participants to attend the stimulus in the upper half of the display, the stimulus in the lower half of the display, or to the space between the stimuli. One stimulus was a (full-overlap) noncausal pass stimulus (the launcher approached, overlapped, and moved past a target that remained stationary) and the other stimulus was a partial-overlap stimulus (the final position of the launcher and the initial position of the target partially overlapped). Participants rated causality for the partial-overlap stimulus. If participants attended the partial-overlap stimulus, they were more likely to rate it as causal. If participants attended the space between the stimuli, they were less likely to rate the partial overlap stimulus as causal, and if participants attended the noncausal pass stimulus, they were even less likely to rate the partial-overlap stimulus as causal. In a follow-up experiment, participants rated causality of a partial-overlap stimulus while fixating that stimulus or fixating a peripheral location containing a noncausal pass stimulus or a fixation point. Participants were less likely to rate the partial overlap stimulus as causal if a noncausal pass stimulus was in the periphery but not if a fixation point was in the periphery. In another follow-up experiment, participants fixated a central stimulus and attended a launching effect stimulus or a noncausal pass stimulus in the periphery. The central stimulus was a noncausal pass stimulus, but it was more likely to be rated as causal if the attended stimulus was a launching effect stimulus.

2.2.2 Eye Movements and Fixation

Michotte (1946/1963) asked observers to fixate slightly above or below the point of contact of a launching effect stimulus, and observers reported a perception the launcher moved past a stationary target (cf. noncausal passing in Scholl and Nakayama 2002). Hindmarch (1973) allowed unrestricted viewing of a launching effect stimulus, and perceived causality was more likely if participants fixated the (a) launcher during launcher motion and target during target motion or (b) target during the entire presentation. In a follow-up experiment, participants fixated a small stationary cross slightly above the (a) initial location of the launcher, (b) location of contact of the launcher and the target, or (c) final location of the target. Causal responses were more likely if participants fixated the contact location than if participants fixated the initial location of the launcher or the final location of the target (cf. Choi and Scholl 2004). Hindmarch suggested effects of eye movements were evidence against Michotte's claim perception of causality in the launching effect was not due to experience or intentions of the observer. Yela (1952) noted a launching effect was more likely if participants fixated the launcher or fixated between the launcher and the target. Jansson (1964) reported no differences in initial eye movement patterns as a function of whether participants viewed a launching effect stimulus with an analytic set (i.e., participants reported separate movements and no causal relationship) or a causal set (i.e., participants reported a single movement and a causal relationship). Jansson also reported eye movement patterns changed with repeated presentations as a function of the initial set, although the nature of the changes was not specified.

2.2.3 Prior Experience

Powesland (1959) presented displays of a (a) launching effect stimulus or (b) launching effect stimulus with a temporal gap of up to 300 ms. Prior to viewing experimental displays, some participants viewed displays of launching effect stimuli (that did not contain a temporal gap), and other participants viewed displays of launching effect stimuli that contained a temporal gap of 800 ms. Prior exposure to launching effect stimuli that contained an 800 ms temporal gap increased the threshold of an acceptable temporal gap for perception of causality in experimental displays (i.e., participants were more likely to accept stimuli with larger temporal gaps as causal). Consistent with this, Gruber et al. (1957) presented a bridge stimulus from which a supporting column was removed and the bridge subsequently collapsed. If the bridge collapsed immediately after the column was removed, there was a causal perception that removing the column caused the collapse; however, if there was a temporal gap between when the column was removed and when the bridge collapsed, the likelihood of a causal perception that removing the column caused the collapse was decreased. If trials with an 800 ms temporal gap between when the column was removed and when the bridge collapsed were interpolated within experimental trials, then consistent with Powesland (1959), there was an increase in the temporal threshold for a perception of causality.

Schlottmann et al. (2006) reported exposure to multiple examples of launching effect stimuli and temporal gap stimuli decreased the temporal gap threshold for perception of causality. This pattern appears opposite to that in Powesland (1959) and in Gruber et al. (1957); however, the temporal gap in Schlottmann et al. (1,250 ms) was larger than the temporal gap in Powesland or in Gruber et al. and might have exceeded the maximum bridgeable temporal gap that still allowed a causal perception to occur. Alternatively, presentation of entraining effect stimuli and reaction effect stimuli in addition to launching effect stimuli in Schlottmann et al. might have highlighted the uniqueness of the launching effect and tightened category boundaries for the launching effect (thus decreasing thresholds for temporal deviance from a prototype launching effect). This latter does not seem consistent with Houssiadas (1964), who reported participants were more likely to provide causal responses to launching effect stimuli if those stimuli were viewed before participants viewed a block of noncausal stimuli; however, in the latter case, participants with mental retardation were more likely to give causal responses than were control participants. Along these lines, Houssiadas suggested prior presentation of a block of noncausal stimuli induced a set against causal responding in control participants but not in participants with mental retardation.

Brown and Miles (1969) presented participants with displays of launching effect stimuli, but prior to presentation of experimental displays, each participant viewed one of three sets of launching effect stimuli. In a short set, the temporal gap between when the launcher stopped moving and when the target started moving varied from 60 to 210 ms; in a medium set, the temporal gap varied from 150 to 300 ms, and in a long set, the temporal gap varied from 240 to 390 ms. In subsequent experimental trials, the temporal gap between when the launcher stopped moving and when the target started moving varied from 60 to 390 ms. Participants rated whether each experimental display depicted a causal launching, a delayed launching, or two separate motions. Participants previously exposed to longer temporal gaps gave more causal responses than did participants previously exposed to shorter temporal gaps. This is consistent with findings of Gruber et al. (1957) and Powesland (1959), and in conjunction with findings of Houssiadas (1964) and Schlottmann et al. (2006), is consistent with the hypothesis the temporal gap threshold for perception of causality is increased by prior experience with noncausal stimuli highly similar to causal stimuli (e.g., Brown and Miles 1969; Gruber et al. 1957; Powesland 1959) but decreased by prior experience with noncausal stimuli less similar to causal stimuli (e.g., Houssiadas 1964; Schlottmann et al. 2006).

Young et al. (2005) reported perceived causality could be influenced by prior experience in predicting the moment of target motion onset, and after multiple observations of launching effect stimuli, causality-at-a-distance (i.e., presence of spatial gaps) was more readily accepted and temporal contiguity (i.e., absence of temporal gaps) became more central. Cluster analysis revealed effects of spatial gap size or temporal gap size on ratings of causality differed across groups of participants. Young et al. suggested causal perception (as measured by verbal reports) was not as constant as Michotte (1946/1963) and many subsequent investigators assumed or claimed, and Young et al. suggested differences in verbal reports as a function of experience might occur because of perceptual learning, reassessment of naïve theories of causality, or recalibration of responses on a rating scale (see also Falmier and Young 2008). As noted earlier, Falmier and Young (2008) reported previous experience with prediction of the moment of target motion onset increased sensitivity to temporal gap size and sensitivity to spatial gap size. After experience with prediction, participants' ratings of causality appeared to rely less on motion path complexity and more on spatial or temporal contiguity. The effect of prior experience and the importance of contiguity are consistent with White and Milne's (1997) finding that prior viewing of motion in the opposite direction of a pulling impression stimulus decreased causal perception of pulling.

2.2.4 Intelligence

Houssiadas (1964) presented a display of a (a) launching effect stimulus or (b) noncausal stimulus involving simultaneous appearance and movement of a launcher and an adjacent target. Participants consisted of patients (19–46 years old) institutionalized with mental retardation and whose mean IQ was 59 (SD = 13.6) and a control group of undergraduates (19–27 years old) whose IQs were described as "average" to "bright normal." Participants were more likely to rate launching effect stimuli as causal and to rate stimuli in which a launcher and an adjacent target appeared and moved simultaneously as noncausal, and there was no effect of IQ on ratings. However, spatiotemporal properties of the noncausal stimulus were very different from spatiotemporal properties of the launching effect stimulus, and differences in ratings as a function of IQ might have been found if a noncausal stimulus more similar in spatiotemporal properties had been used (e.g., a launching effect stimulus with a spatial gap or a temporal gap). Nakamura (2006) presented 4- to 6-year old children with launching effect stimuli and with non-launching stimuli and reported differences in intellectual ability did not influence perception of the launching effect. The apparent lack of an effect of mental retardation or of intellectual ability on perception of the launching effect suggests phenomenal causality is a basic property of representation and is consistent with claims of phenomenal causality in infants. Beasley (1968) reported participants who scored high on a group intelligence test were more likely to provide analytic descriptions than causal descriptions of a launching effect stimulus, but this was suggested to reflect training rather than intelligence per se.

2.2.5 Age

Michotte (1946/1963) claimed perception of physical causality is innate, and perhaps as a consequence, much of the developmental research on phenomenal causality focused on whether infants perceived causality in a launching effect display (for additional discussion, see Saxe and Carey 2006; White 1988). One of the challenges in developmental research on phenomenal causality is distinguishing between effects of infants' expectations and effects of infants' potential causal perceptions; infants might expect a target to move after contact from a launcher (and so might look longer at displays in which a target does not move than at displays in which a target does move), but the presence of such an expectation does not demonstrate that such an expectation is based on phenomenal causality or that phenomenal causality must have been present. Rather, what is necessary is to separate information regarding causality from other types of information that could lead to expectations regarding target motion. Even if studies cannot conclusively demonstrate infants perceive causality, examination of infants' responses to launching effect stimuli or to other types of causal displays can be useful in determining whether infants are sensitive to causal information that is presumably necessary for phenomenal causality (as a lack of such sensitivity would be evidence against phenomenal causality). Assessment of phenomenal causality in adults has typically used collection of verbal descriptions and rating scales, but such tools are not available in the study of infants' subjective experience.

Baillargeon et al. (1995) presented 2.5-month old infants with a ramp and a stationary target (a wheeled bug). A cylinder rolled down the ramp, but at the base of the ramp were small stoppers that prevented the cylinder from going further. On some trials, the target was adjacent to the end of the ramp, but on other trials, the target was a short distance from the end of the ramp. The target was immobilized by tiny stoppers on the wheels. Baillargeon et al. reported differences in infants' looking times suggested infants expected the stationary target at the bottom of the ramp to move when contacted by the cylinder. Baillargeon et al. suggested that by 2.5 months of age infants formed an initial causal concept based on whether or not contact between the launcher and the target occurred (see also Kotovsky and Baillargeon 1998). However, even though infants might have an initial concept regarding the importance of contact by 2.5 months, such young infants do not appear sensitive to causal information. Desrochers (1999) habituated infants 3.5 months old to displays of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, or (c) launching effect stimulus with a temporal gap. If infants were sensitive to causal information, there would have been greater dishabituation to a noncausal stimulus for infants habituated to a causal stimulus and greater dishabituation to a causal stimulus for infants habituated to a noncausal stimulus. Dishabituation patterns did not suggest sensitivity to causal information, and infants appeared to dishabituate on the basis of noncausal spatial and temporal properties.

Cohen and Amsel (1998) habituated 4-, 5.5- or 6.25-month old infants to displays of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, or (c) launching effect stimulus with a temporal gap. Infants 6.25 months old dishabituated on the basis of implied causality, but 4-month old infants dishabituated on the basis of whether a single continuous motion was present, and 5.5-month old infants dishabituated on the basis of spatial and temporal features (e.g., presence or absence of a spatial gap or a temporal gap). Cohen and Amsel suggested this pattern indicated a progression in development of sensitivity to causality and that such a progression was evidence against the hypothesis that perception of causality resulted from an innate module (cf. Leslie 1984). Rochat et al. (1997) presented 3-month old infants, 6-month old infants, and adults with displays of moving stimuli (dots) in which (a) one stimulus appeared to pursue another stimulus or (b) stimuli moved independently. Adults and older attentive infants looked more at the display in which stimuli moved independently. Rochat et al. suggested this reflected sensitivity to social causality (but see Springer et al. 1996); more specifically, adults and older attentive infants spent more time looking at the independent display because they already had an explanation (involving social causality) for the pattern in the pursuit display. In Cohen and Amsel and in Rochat et al., sensitivity to causality was not observed in 3-month old infants (cf. Desrochers 1999) but was observed in 6-month old infants.

Rakison and Krogh (2012) suggested previous failures to observe perception of causality in infants younger than 6 months of age were due to use of experimental stimuli that were different from stimuli in causal events with which younger infants were familiar. Rakison and Krogh had infants wear red mittens and interact with green balls. For some infants, mittens and balls were covered with Velcro (to allow infants to move the balls with their hands). Infants then habituated to a display in which a red circle launched a green circle, and after habituation, infants were shown test trials involving causal launching or noncausal stimuli in which the launcher did not contact the target. Infants with experience of moving the green balls (i.e., infants with Velcro-covered mittens and balls) looked longer at test trials that had a different causal relationship than the habituation display, but infants without such experience did not exhibit differential looking times. However, if stimuli in the habituation display and test trials were dissimilar in color from the mittens and balls experienced previously (e.g., blue and yellow rather than red and green), no evidence for causal perception occurred. Rakison and Krogh argued 4.5-month old infants can perceive causality, but only if infants' visual experience matches their previous action experience. Even so, how infants' experience with Velcro-covered mittens and balls (in which balls stuck to their hands) mapped onto the launching effect (in which targets do not stick to launchers) is not entirely clear.

Leslie (1982) habituated infants 13–24 weeks old and infants 27–38 weeks old to films of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, or (c) launching effect stimulus with a temporal gap. A test film then presented a moving launcher that contacted a target that remained stationary or an initially stationary target that began moving without any prior movement of a launcher (thus, in each test film there was only a single movement). There was no effect of age on dishabituation to the test film, and dishabituation was greater for infants habituated to a launching effect stimulus than for infants habituated to a spatial gap stimulus or to a temporal gap stimulus. This was interpreted as (a) suggesting infants perceived stimuli in the launching effect as exhibiting a single continuous motion rather than two separate motions and (b) consistent with a sensitivity to causal structure. Leslie (1984) presented 6.5-month old infants with films of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, (c) launching effect stimulus with a temporal gap, or (d) launching effect stimulus with a spatial gap and a temporal gap. Pairs of habituation and test films in which one film depicted a causal launching effect and the other film depicted a noncausal stimulus resulted in greater dishabituation than did pairs of habituation and test films that did not involve a causal launching effect and a noncausal stimulus (cf. Desrochers 1999).

Leslie and Keeble (1987) examined causal perception in 6-month old infants. They suggested that reversing the temporal order of a display (i.e., reversing the film) could change the causal properties and the spatiotemporal properties of that display. For a launching effect stimulus, the causal direction (i.e., in the initial direction, Object A might appear to launch Object B, but if the film were reversed, Object B might appear to launch Object A; see also Leslie 1984), as well as the spatiotemporal direction, would reverse. However, for a noncausal stimulus, there is no causal direction, and so only spatiotemporal direction would reverse. In other words, reversal of launching effect stimuli reversed the causal relationship as well as spatiotemporal properties, but reversal of noncausal stimuli reversed only spatiotemporal properties; therefore, any differences in responses to reversed causal stimuli and responses to reversed noncausal stimuli would reflect sensitivity to the causal relationship in the launching effect stimulus. Infants habituated to an initial temporal order causal stimulus (a launching effect stimulus) dishabituated more if presented with a reverse temporal order stimulus than did infants habituated to a noncausal stimulus (a launching effect stimulus with a temporal gap). Leslie and Keeble suggested infants can perceive an event as causal, and infants' perception of the launching effect involves more than just encoding of spatiotemporal properties.

Oakes and Cohen (1990) habituated 6- or 10-month old infants to displays of a (a) launching effect stimulus, (b) launching effect stimulus with a temporal gap, or (c) launching effect stimulus with a spatial gap. Ten-month-old infants habituated to a launching effect stimulus dishabituated more to a temporal gap stimulus or a spatial gap stimulus; however, dishabituation of 6-month old infants did not distinguish between causal (i.e., launching) and noncausal (i.e., temporal gap or spatial gap) stimuli. Findings with 6-month old infants initially appeared to conflict with Leslie's (1984) findings, but Oakes (1994) notes Leslie (1984) used simple objects and between-subjects comparisons, whereas Oakes and Cohen (1990) used complex objects and within-subjects comparisons. Cohen and Oakes (1993) presented 10-month-old infants with stimuli similar to Oakes and Cohen (1990). If infants saw the same objects in another display, they dishabituated on the basis of causality; however, if infants saw different objects in another display, they did not dishabituate on the basis of causality (cf. different pairs of colors in Rakison and Krogh 2012). Cohen and Oakes suggested similarity influences causal perception for younger infants, and as infants become better at processing information, causal perception becomes more flexible and causality is perceived in more situations. Such an account is consistent with the apparent perception of causality in younger infants in Leslie (1984) and in Leslie and Keeble (1987).

Oakes (1994) presented 7-month old infants with the same stimuli as in Oakes and Cohen (1990). Infants were habituated to a causal display (launching effect stimulus) or to a noncausal display (a launching effect stimulus with a spatial gap or with a temporal gap), and dishabituation was tested with a causal display or a noncausal display. Consistent with Leslie (1984), infants who had been habituated to causal stimuli dishabituated more to noncausal stimuli than to causal stimuli, and infants who had been habituated to noncausal stimuli dishabituated more to causal stimuli than to noncausal stimuli. A follow-up experiment examined similarity of cause and effect: In addition to temporal gap stimuli and spatial gap stimuli, 7- or 10-month old infants were presented with overlap stimuli in which the launcher contacted the target slightly off-center and the trajectory of the target was 45 degrees from the trajectory of the launcher. Ten-month-old infants habituated to a causal stimulus or to a noncausal stimulus dishabituated more to a noncausal stimulus or to a causal stimulus, respectively, than to a causal stimulus or to a noncausal stimulus, respectively. However, 7-month old infants did not appear to dishabituate on the basis of causality. Oakes concluded 7-month old infants perceived causality on the basis of a similarity of movement as well as on the basis of temporal and spatial similarity, whereas 10-month old infants perceived causality on the basis of temporal and spatial similarity; such a conclusion is consistent with the greater importance of movement per se with younger infants in Cohen and Amsel (1998).

Belanger and Desrochers (2001) replicated findings of Leslie and Keeble (1987) and others that 6-month old infants dishabituated more to reversal of a launching effect stimulus than to reversal of a noncausal (spatial gap or temporal gap) stimulus. In an additional experiment, Belanger and Desrochers habituated 6-month old infants to displays of an (a) entraining effect stimulus, (b) entraining effect stimulus with a spatial gap (between the location of the initially moving object and the location of the target when the target began moving), or (c) entraining effect stimulus with a temporal gap (of 1 second between contact of the initially moving object and the target and when the combined initially moving object + target began moving). Adult participants rated entraining effect stimuli as more causal than spatial gap stimuli or temporal gap stimuli, but infants did not dishabituate on the basis of causality. Interestingly, the spatial gap stimulus was similar to a reaction effect stimulus, but neither adults nor infants appeared to perceive social causality in that stimulus. Regardless, 6-month old infants appeared to perceive the launching effect but not the entraining effect, and Belanger and Desrochers suggest this difference demonstrates perception of causality develops during infancy and does not result from innate or modular processing. Also, different developmental rates of the launching effect and the entraining effect are consistent with the hypothesis that different types of phenomenal causality might involve different mechanisms or different efficiencies/sensitivities in a more general mechanism.

Schlottmann et al. (2012) habituated 4-, 5-, and 6-month old infants to displays of a (a) reaction effect stimulus or (b) reaction effect stimulus with a temporal gap between the launcher and the target. Stimuli exhibited inanimate (rigid) or animate (caterpillar) motion. Six-month old infants dishabituated more to a reversal of the reaction effect stimulus than to a reversal of the temporal gap stimulus, but 4- or

5-month old infants did not appear to dishabituate as a function of causality. The data were consistent with Leslie and Keeble's (1987) finding that 6-month old infants dishabituated more to a reversal of a launching effect stimulus than to a reversal of a noncausal stimulus. Given that Schlottmann et al. found evidence that perception of a reaction effect emerged about the same time as perception of a launching effect, they suggested infants might not initially differentiate between physical and psychological causality; however, Schlottmann et al. also admitted a parallel emergence of two different types of causality cannot be ruled out (cf. Belanger and Desrochers 2001). Whether motion was animate or inanimate did not influence responses, and this is not surprising given that social causality is usually perceived with a reaction effect stimulus. Also, apparent perception of causality in reaction effect stimuli did not correlate with infants' performance on tests of a goal-directed action (Willatts 1999) or goal perception (Woodward 1999), and Schlottmann et al. suggested this might reflect a lack of domain-specificity in perception of causality.

Newman et al. (2008) examined sensitivity to causal information in 7-month old infants. In Experiment 1, infants habituated to a display of a (horizontally moving) launching effect stimulus and a third object vertically aligned with the target and that began moving in the same direction and at the same velocity and time as the target. Dishabituation was tested with a synchronous display in which the launching effect stimulus was replaced with a noncausal pass stimulus or a large offset stimulus in which motion of the third object began 600 ms after the target began moving. Infants dishabituated more to large offset displays than to synchronous displays. In Experiment 2, offset time decreased to 120 ms, and infants looked equally long at synchronous displays and at small offset displays. In Experiment 3, launchers were removed from displays used in Experiment 2, and infants dishabituated more to small offset displays. In Experiment 4, the trajectory of the launcher was vertically offset from the trajectory of the target, and infants dishabituated more to small offset displays. In Experiment 5, infants dishabituated more to noncausal pass stimuli and looked equally long at synchronous displays and at large offset displays. Newman et al. suggested the pattern of results across experiments demonstrated (a) dishabituation was driven by perceived causality rather than by noncausal spatiotemporal properties, and (b) infant perception involves postdictive information integrated over short intervals of time.

Kotovsky and Baillargeon (2000) presented 7.5-month old infants with a ramp and a target near the base of the ramp. There was a vertical barrier aligned with the base of the ramp, and the bottom of the barrier (a) ended above the ramp (and so an object sliding down the ramp would pass beneath the barrier and contact the target) or (b) extended all the way down to the ramp (and so an object sliding down the ramp would be stopped by the barrier before contacting the target). The bottom of the ramp and the nearest edge of the target were then occluded by an opaque barrier, and an object slid down the ramp. If infants had previously viewed the barrier as extending all the way to the ramp, they exhibited greater looking time if the target moved; however, if infants had previously viewed the barrier as not extending all the way to the ramp, they exhibited greater looking time if the target did not move. Such a pattern suggests infants had expectations regarding behavior of the target that were based on whether the object sliding down the ramp could contact the target. The difference between 7-month old infants not perceiving causality in Oakes and 7.5-month old infants perceiving causality in Kotovsky and Baillargeon is consistent with Cohen and Oakes' (1993) suggestions that there is a developmental progression in perception of causality and that causal perception becomes more flexible with increasing age.

Schlottmann and Surian (1999; see also Schlottmann et al. 2009) presented 9-month old infants with displays of a (a) launching effect stimulus with a temporal gap (referred to as a *pause stimulus*) or (b) stimulus in which the target started moving away from the launcher before the launcher contacted the target or stopped moving (referred to as a *reaction stimulus*). Launchers and targets moved by extending their leading edges and then contracting their trailing edges (similar to "caterpillar" motion discussed by Michotte (1946/1963) as more likely to be perceived as animate). Infants and adult controls viewed initial temporal order and reverse temporal order versions of the stimuli. Infants dishabituated more if a reaction stimulus was reversed than if a pause stimulus was reversed, even though initial and reversed versions of each stimulus involved identical spatiotemporal properties. Also, adults were more likely to rate targets as "retaliating" during reversal of reaction stimuli but not during reversal of pause stimuli. Response patterns were consistent with perception of causality-at-a-distance, and coupled with the lack of apparent perception of causality in an entraining effect stimulus with a spatial gap in Belanger and Desrochers (2001), suggests perception of causality-at-a-distance might develop between 6- and 9-months of age. Schlottmann and Surian suggested perception of causation-at-a-distance in infancy could provide a blueprint for development of understanding of psychological (social) causality.

Rakison (2005) noted stimuli that cause an action (i.e., are agents) are usually more dynamic (e.g., have more moving parts) than stimuli that receive an action (i.e., are recipients),[5] and he presented 12-, 14-, and 16-month old infants with launching effect stimuli in which each launcher and each target was composed of a larger red hexagonal body and a smaller green triangle attached to the upper edge of the hexagon. In a dynamic part stimulus, the relative position of the triangle on the hexagon changed (i.e., the triangle slid across the top of the hexagon) as the hexagon moved; in a static part stimulus, the relative position of the triangle on the hexagon did not change as the hexagon moved. Patterns of looking times suggested 16-month old infants associated the dynamic part stimulus with the role of agent and the static part stimulus with the role of recipient, but 12-month old infants did not appear to make such a distinction. Fourteen-month old infants were sensitive to differences between dynamic part stimuli and static part stimuli, but they did not

[5] White (2006) argued the most active (i.e., moving) object is perceived to have the most causal influence (e.g., in the launching effect, the launcher is initially more active than the target, and so the launcher is perceived to have more causal influence). This is consistent with Rakison (2005) findings, but White focuses on differences in activity between different objects rather than within a single object. Even so, although the linkage of "more movement" and "more causal" might be true for many types of causal stimuli, there are exceptions (e.g., an initially stationary target that remains stationary after a launcher contacts that target and fragments is judged as more causal, Hubbard and Ruppel 2012; in the penetration impression, the stationary object is causal in that it stops the forward motion of the initially moving object).

appear to distinguish causal properties of dynamic part stimuli and causal properties of static part stimuli. Rakison suggested 12-month old infants did not encode the relationship between an object's causal role and that object's parts, 14-month old infants encoded differences between parts but did not link these differences to causality, and 16-month old infants encoded the relationships between parts that were linked to causality.

Cicchino et al. (2011) explored infants' perceptions of causal agency and self-propelled motion. As Cicchino et al. point out, causal objects often act upon stimuli that are not self-propelled. Indeed, whether a stimulus is perceived as self-propelled has significant influence on phenomenal causality (e.g., in a launching effect, the target is not perceived as self-propelled, but in a triggering effect or if a launched target moves beyond the radius of action, the target is perceived as self-propelled; see also Hubbard 2012; White 2012a, b). Infants 10 or 14 months old were habituated to a launching effect stimulus. The test stimulus showed (a) an isolated launcher that was stationary and then moved in the same direction as the habituation stimulus (referred to as a *consistent event*) or (b) an isolated target that was stationary and then moved in the same direction as the habituation stimulus (referred to as an *inconsistent event*). Fourteen-month old infants, but not 10-month old infants, looked longer at a subsequent inconsistent event, and Cicchino et al. suggested 14-month old infants inferred that an agent, but not a recipient, in a causal event was self-propelled. If 14-month old infants habituated to a noncausal stimulus, no differences in looking times for consistent events or inconsistent events occurred. If stimuli were reversed (i.e., an isolated launcher or target was the habituation stimulus, and a launching effect was the test stimulus), neither 14- nor 18-month old infants appeared to attribute causal agency to a self-propelled object.

Schlottmann et al. (2002) presented children 3–9 years old with displays of a (a) launching effect stimulus, (b) launching effect stimulus with a spatial gap, or (c) launching effect stimulus with a temporal gap. Stimuli in each display were rigid square shapes or nonrigid caterpillar shapes (that moved by expansion and contraction). After viewing a display, children chose which one of three pictures best matched that display: two balls colliding (for physical causality), a person walking alone (for noncausal motion), or one person chasing another person (for psychological causality). All participants chose the picture of two balls colliding as best matching the launching effect stimulus and the picture of one person chasing another person as best matching the spatial gap stimulus. Many 3- to 5-year old children chose the causal picture for temporal gap stimuli, but choice of the causal picture for temporal gap stimuli decreased in older children. Whether launcher motion was rigid or nonrigid did not influence children's picture choices, although all participants considered nonrigid motion to be more animal-like. Schlottmann et al. suggested some apparent changes in perceived causality might reflect changes in verbal skill rather than changes in causal understanding (see also Thommen et al. 1998), and such a suggestion is consistent with differences in descriptions of Heider and Simmel stimuli by 3-, 4-, and 5-year old children in Springer et al. (1996).

Olum (1956) presented displays of launching effect stimuli (velocity ratio of 1:1) and triggering effect stimuli (velocity ratios of 1:30 and 1:2.33) to 7-year old children and to adults. Participants' descriptions were classified as launching, non-launching, mutual approach, or passing. Children were more likely than adults to give a mutual approach response or a passing response to a launching effect stimulus or a triggering effect stimulus in which target velocity was much faster than was launcher velocity. Olum suggested these patterns resulted from developmental differences in understanding configurations and in processing (segregating) stroboscopic movement. Nakamura (1985) examined ability to segregate movements in a launching effect stimulus in children 6–9 years old. Participants who accurately judged temporal order or velocity differences of the movements within each stimulus, or who could accurately detect if a moving object briefly stopped, were more likely to give a causal response to a launching effect stimulus. Nakamura suggested the ability to segregate movement is an important element of children's ability to perceive causal relationships. However, the emphasis on segregating movements in Olum and in Nakamura is curious in light of Michotte's notion that phenomenal causality involves ampliation (discussed in Part II), as ampliation emphasizes an integration of movements (i.e., extension of a single continuous motion from the launcher to the target) rather than a segregation of movements.

Thommen et al. (1998) considered perception of causality within a framework involving the ability to theorize about intentionality (i.e., within a theory of mind; see also Blakemore et al. 2003; Castelli et al. 2000). Participants included 5-, 6-, 7-, 8-, 10-, and 12-year old children and adults who viewed a (a) launching effect stimulus or (b) reaction effect stimulus in which target velocity was faster than launcher velocity. All participants discriminated between different types of stimuli, but not until at least 7 years of age did participants consistently give specific descriptions based upon contact, and not until 8–10 years of age were attributions involving psychological causes consistently made. Such ages are considerably older than those suggested previously for development of perception of social causality, and Thommen et al. suggest this might reflect language development or an inability for younger children to translate perception into language (see also Schlottmann et al. 2002). Alternatively, development of perception of social causality might be slower or occur later than development of perception of physical causality (cf. Cohen et al. 1998; Schlottmann et al. 2012), and such would be consistent with suggestions of Leslie (1994), Michotte (1946/1963), Schlottmann and Surian (1999), and Wolff (2007, 2008) that development of perception of physical causality precedes or provides a basis for development of social causality.

2.2.6 Culture

Morris and Peng (1994; Morris et al. 1995) presented American participants and Chinese participants with physical causality displays in which launchers and targets were geometric shapes in (a) a launching effect stimulus, (b) an entraining effect stimulus, (c) a launching effect stimulus with a spatial gap, or (d) a launching effect stimulus with a temporal gap. Participants were also presented with social causality displays in which launchers and targets were drawings of fish in which a (a) single fish launched from a group of fish, (b) single fish launched a group of fish, (c) single fish entrained to a group of fish, or (d) group of fish entrained to a single fish. Participants rated whether targets moved because of an internal force or an external force. For physical causality displays, ratings of internal force increased and ratings of external force decreased as displays deviated from conservation of rest, and there were no differences between American participants and Chinese participants (cf. Peng and Knowles 2003). For social causality displays, American participants were more likely to attribute behavior of single fish to internal forces and Chinese participants were more likely to attribute behavior of single fish to external forces; Morris and Peng suggested the difference in perceived social causality was consistent with the individual orientation of American culture and the collective orientation of Chinese culture.

Rimé et al. (1985) presented American, European, or African participants with films of Michotte-like stimuli in which (a) the launcher moved toward the target and stopped upon reaching the target, and after a brief delay, the launcher and target moved away together, (b) the launcher moved toward the target but stopped before reaching the target, the target moved toward the launcher, the launcher backed off, and the target returned to its initial location, (c) the launcher moved toward the target and accelerated as it neared the target, the target moved away, and the launcher and target stopped, (d) the launcher and target were in contact and moved in the same direction, stopped, the launcher moved away from the target, the target followed, the launcher and target stopped, the launcher continued in the same direction and the target moved in the original direction, or (e) the launcher moved toward the target, the target moved toward the launcher, the launcher and target stopped, and the target then moved away from the launcher. Participants rated how well each display depicted each of several emotional concepts, and a principle components analysis revealed five factors (interpreted as corresponding to aggressiveness, fearfulness, kindness, distrust, aversiveness). Characterizations of different patterns of movement by specific emotional attributions and factor profiles were consistent across participants.

2.2.7 *Psychopathology*

Bowler and Thommen (2000) examined perception of physical causality and perception of social causality in children (82–127 months old) who had been diagnosed with autism and in control participants matched for chronological age, verbal age, and IQ. In Experiment 1, participants were presented with displays of a (a) launching effect stimulus (velocity ratios of 3:1–9:1) or (b) reaction effect stimulus (velocity ratios of 1:3–1:9). Participants described the displays. Participants with autism were as able as control participants to discriminate between launching effect stimuli and reaction effect stimuli. In Experiment 2, participants viewed more complex displays (based on Heider and Simmel 1944) designed to simulate motions of animate stimuli. There was no effect of autism on the length of description or in the use of mental state terms and causal statements. Participants with autism differentiated between movement patterns hypothesized to characterize animate objects (social causality) and movement patterns hypothesized to characterize inanimate objects (physical causality) as well as did control participants; however, participants with autism were more likely to place themselves within their descriptions (as if they were one of the moving shapes) and appeared less able to describe the object-directedness of the activity (e.g., if an agent acted on an inanimate stimulus or two animate stimuli interacted, cf. Congiu et al. 2010).

Congiu et al. (2010) compared high-functioning autistic children (average age of 13 years) and control children matched for verbal mental age on the picture task used in Schlottmann et al. (2002). Participants viewed displays of (a) a launching effect stimulus, (b) an entraining effect stimulus, (c) a reaction effect stimulus, or (d) an ambiguous stimulus consisting of simultaneous launcher motion and target motion followed by contact and then launching. Stimuli exhibited rigid or nonrigid motion. Children chose which one of three pictures best matched that stimulus: a boy pushing a cart (for physical causality), a boy chasing a girl (for social causality), or a boy standing still with a girl walking nearby (for noncausal motion). Participants generally chose the appropriate picture; the only difference between autistic participants and control participants occurred with the ambiguous stimulus, with autistic participants choosing the physical causality picture and control participants not exhibiting a consistent picture preference. However, autistic participants and control participants differed in descriptions of nonrigid stimuli, with autistic participants using geometric descriptions (unless otherwise prompted by the experimenter) and control participants using social descriptions. Congiu et al. suggested autistic children are not impaired in perception of causality per se; rather, autistic children are more likely to not perceive animacy, and so are more likely to describe animate stimuli as exhibiting physical causality (also Klin 2000; Ray and Schlottmann 2007).

Tschacher and Kupper (2006) presented adult patients diagnosed with schizophrenia and control participants matched for age and sex with displays in which two stimuli moved toward and past each other. Such displays are perceptually ambiguous, but if an auditory stimulus suggestive of contact is presented at the moment of contact, then (nonclinical) participants are generally biased toward an interpretation that the stimuli bounce off each other (e.g., Sanabria et al. 2004; Sekuler and Sekuler 1999). Bouncing (and the subsequent change in direction of motion) would involve a causal interaction between the object that bounced and the object or surface that was bounced off, and perception of bouncing was suggested by Tschacher and Kupper to be an example of perceived causality.[6] Increases in positive symptoms of schizophrenia were associated with increases in responses indicating perceived bouncing, whereas increases in cognitive symptoms of schizophrenia were associated with decreases in responses indicating perceived bouncing. Such a pattern predicts increases in positive symptoms and increases in cognitive symptoms would result in increases and decreases, respectively, in ratings of causality in the launching effect, but such a study has not been reported. Tschacher and Kupper suggested perception of causality is a preattentive process

[6] Perception of bouncing in the paradigm used by Tschacher and Kupper (2006) is not usually considered as an example of phenomenal causality (e.g., the initial ambiguity of the display seems incongruent with phenomenal causality), and so bouncing was not included in the list of varieties of phenomenal causality discussed earlier. However, and as pointed out in Part II, it is possible additional types of phenomenal causality beyond those discussed here will be documented by future research. Determination of whether perception of bouncing is an example of perceptual causality awaits future investigation.

that could contribute to alterations or deficiencies in any theory of mind held by a patient.

3 Conclusions

If observers view displays containing moving or interacting stimuli, those observers can have immediate and convincing perceptions regarding causal relationships between the stimuli. These perceptions are examples of phenomenal causality, and several different types of phenomenal causality have been proposed. Some types (e.g., the launching effect) have been investigated by multiple laboratories and with multiple methodologies over many years and are well established, whereas other types (e.g., coordinated movement) have been investigated in only a single paper and are in need of replication and validation with convergent measures. A critical feature of phenomenal causality is that causal perception is rapid, automatic, and spontaneous, and researchers have distinguished phenomenal causality from more deliberate and intentional explicit causal judgment. A rapid, automatic, and spontaneous perception or recognition of causality could be adaptive, as it would minimize on-line (real time) attentional demands and facilitate responses consonant with causal principles relevant to a stimulus or set of stimuli. Indeed, an ability to quickly ascertain relevant causal principles to a stimulus or set of stimuli could be crucial for survival. Numerous variables impact phenomenal causality, and data discussed here allowed several conclusions regarding effects of specific variables on specific types of phenomenal causality to be drawn. Part II places these specific findings into a larger context and considers broader properties of phenomenal causality.

Part I focused on individual varieties of phenomenal causality and on effects of individual variables on phenomenal causality, but it should be noted that the nature of phenomenal causality depends upon the overall configuration of stimuli and stimulus variables. Absolute values of stimulus variables (e.g., velocity) are less critical in determining the nature of phenomenal causality of a given stimulus than are the values of those stimulus variables relative to values of other stimulus variables. For example, the ratio between launcher velocity and target velocity determines whether a launching effect or a triggering effect would occur (e.g., a medium launcher velocity can lead to a launching effect if paired with a slower target velocity but a triggering effect if paired with a faster target velocity). Similarly, relative timing of events influences the specific phenomenal causality that is experienced (e.g., onset of target motion can lead to a reaction effect if target motion begins before contact with the launcher and to a launching effect if target motion begins at the moment of contact). Thus, a given absolute value of some stimulus parameter can lead to different types of phenomenal causality as a function of context or configuration. Implications of this finding, as well as consideration of issues regarding phenomenal causality, the relationship of phenomenal causality to other perceptual and cognitive phenomena, and possible mechanisms and models for phenomenal causality, will be considered in Part II.

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