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Brief article

Indicators of causal agency in physical interactions: The role of the prior context

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ABSTRACT

The question how agent and patient roles are assigned to causal participants has largely been neglected in the psychological literature on force dynamics. Inspired by the linguistic theory of Dowty (1991), we propose that agency attributions are based on a prototype concept of human intervention. We predicted that the number of criteria a participant in a causal interaction shares with this prototype determines the strength of agency intuitions. We showed in two experiments using versions of Michotte's (1963) launching scenarios that agency intuitions were moderated by manipulations of the context prior to the launching event. Altering features, such as relative movement, sequence of visibility, and self-propelled motion, tended to increase agency attributions to the participant that is normally viewed as patient in the standard scenario.

1. Introduction

In demonstrations of phenomenal causality, subjects are presented with moving colliding objects (Michotte, 1963). For example, in a launching scenario, Object X, a ball, moves towards a resting Object Y, another ball, and touches it. This stops Object X and sets Object Y into motion (see Fig. 1, Condition A, for an illustration) eliciting a causal impression. The strength of the causal impression depends on various parameters, such as the time lag between X stopping and Y starting its movement, or the ratio of pre- and post-movement velocities of the colliding objects (see, e.g., Hubbard, 2013; Scholl & Tremoulet, 2000).

Observers typically describe this kind of launching scenario as a case in which Object X is the causal agent (i.e., "X launched Y") but not that Object Y is the causal agent (i.e., "Y stopped X"; see White, 2006a). This asymmetrical preference seems very natural, but in fact Newtonian physics does not provide us with a reason that can explain why we view object X as primary: the physical force on Object Y exerted by Object X is equal in magnitude (but opposite in direction) to that on Object X exerted by Object Y. Thus, describing the causal interaction as a case of Object Y stopping Object X would be equally justified. But what, then, leads us to make such an asymmetric agency ascription?

Unlike in Newtonian physics, asymmetric ascriptions are natural from the viewpoint of force dynamics, a theoretical framework that has become increasingly popular in recent years for explaining causal reasoning (see Waldmann & Hagmayer, 2013; Wolff & Shepard, 2013, for overviews). Force dynamics was initially developed in linguistics in the context of verb semantics (see Riemer, 2010; Talmy, 1988) and relies on the notion that semantic causatives can be analyzed with respect to the configuration of forces that are attached to the participants in causal interactions (see Wolff, 2007; Wolff, Barbey, & Hausknecht, 2010; Wolff & Song, 2003). Its concepts can be traced back to Aristotle's philosophical treatment of causality

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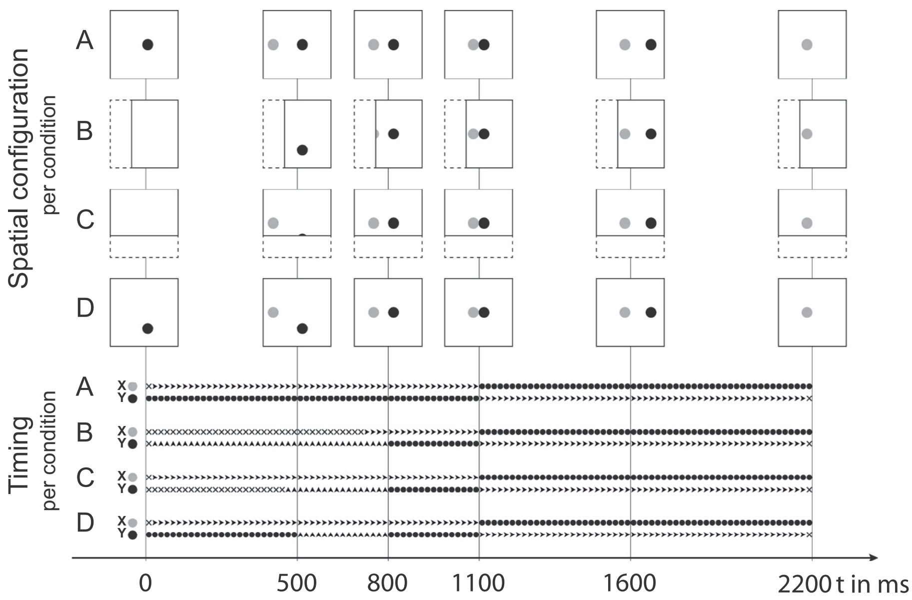

Fig. 1. Illustration of the experimental setup showing the spatial configuration of the balls at significant time points, and the timing and direction of the ball movements in Conditions A to D. Each symbol in the time line represents one frame of 20 ms in length indicating whether the ball is not visible (×), is visible but at rest (●), moves upward (▲) or moves rightward (➤).

(see Gnassounou & Kistler, 2007). Aristotle explained efficient causation as a consequence of the interaction of two entities, an agent and a patient. An agent is, according to Aristotle, a substance operating on another substance, the patient, which is passive with respect to the process of operation. The acting agent who affects the patient therefore has the disposition to act, and the patient has the disposition to be affected by the agent.

In psychological research on force dynamics, the main focus has been on how causal intuitions and semantic ascriptions can be predicted on the basis of configurations of forces attached to agents and patients. In research using verbal instructions, linguistic cues are typically used to signal which of the causal participants is playing the active and which the passive role (see Mayrhofer & Waldmann, in press). However, the question remains how people assign causal roles in perceptual tasks, such as Michottean launching scenarios.

1.1. Current psychological accounts of agency assignments in perceptual tasks

One line of research addressing the question of agency assignment in perceptual scenarios, mainly pursued within developmental psychology, studies the role of features of the involved objects. According to this approach, there are objects, *dispositional agents*, that are more agent-like than others and are therefore more likely to be assigned the agent role in causal interactions (see, e.g., Leslie, 1994; Rakison, 2005, 2006; Saxe, Tzelnic, & Carey, 2007). Features of dispositional agency include human- or animal-like appearance (e.g., eyes, fur) or the presence of dynamic parts. Intuitions in the Michotte task, however, cannot be explained by this account because the moving objects typically do not carry such features.

White (2006b) has focused on kinematic properties to answer the question how observers attribute agency. He hypothesized that in the Michotte task the movement of Object X relative to the resting Object Y in the moment of the causal interaction (i.e., collision) might be the reason for the attributions of agency to Object X (*prior-motion hypothesis*; see also Michotte, 1963). However, White (2012a) recently showed that in other scenarios prior movement is not always the primary criterion for assigning causal agency. In situations in which Object X's direction of movement after contact reverses and Object Y starts moving in Object X's direction after contact, Object Y may be viewed as actively pushing Object X. Similarly, Hubbard and Ruppel (in press) showed that there are Michottean setups in which Object Y does not move at all but is attributed more agency than the moving Object X. The prior-motion hypothesis, therefore, cannot explain all cases of differential attributions of agency. Our main goal, therefore, is to offer a more comprehensive list of context features that are used in the assignment of the agent and patient roles.

1.2. Proto-agency theory

In linguistics, the question of agent role assignment has received substantial attention because of its interaction with grammatical subject roles in causal language. Given that in perceptual scenarios agency assignment is typically measured via a verbal response, linguistic theories, therefore, seem promising candidates for a theory of agency ascription.

According to the linguistic theory of Dowty (1991), agency is not all-or-none but a prototype concept that can be assigned on the basis of a number of criteria. None of these criteria is necessary (hence prototype) but the confidence of the assignment should increase, the more criteria are present. In Dowty's proto-agency theory, the (*proto-*)*agent* features include: (a) volitional involvement in the event or state, (b) participant's capacity of sentience or perception, (c) causing an event or change of state in another participant, (d) movement, and (e) independent existence. The (*proto-*)*patient* features are complementary. When two participants are involved in a scenario, the relative number of proto-agent properties decides about the assignment of roles. Thus, the participant that shares the most features with the proto-agent (and, therefore, the fewest features with the proto-patient) is more likely to be assigned the agent role. If there is an impasse, multiple assignments are possible (see also Hafri, Papafragou, & Trueswell, 2013, for an application of Dowty's, 1991, linguistic theory to static visual displays of interacting humans).

How can Dowty's (1991) linguistic theory be adapted to perceived launching events? At first sight, Dowty's (1991) criteria seem circular for this purpose because in the proto-agent criterion (c) causal asymmetry is listed as one of the features determining agency. However, the definition is only circular if the agent and cause roles are collapsed, as for example in the theory of White (2006a). By contrast, in Dowty's (1991) prototype theory causation is not a necessary feature of agents. In support of this separation, Mayrhofer and Waldmann (in press) presented evidence for the possibility of disentangling causes from agents. In their experiments, subjects were presented with a cover story in which, for example, thoughts of one alien X were transmitted to another alien Y. Thus, the direction of the causal arrow, which expresses the underlying dependency relation, was identical in all conditions (X → Y; that is, the thoughts of X were the cause and the thoughts of Y were the effect). However, by means of verbal instructions it was possible to either characterize the cause alien X as the agent ("X sends its thoughts to Y") or Y as the agent ("Y reads the thoughts of X"). An analogous separation between causes and agents is possible in launching scenarios if causation is understood as referring to the visually conveyed causal process propagated from the event involving Object X onto the temporally subsequent event involving Object Y (see Dowe, 2000, for an overview of causal process theories). The observed asymmetric causal process may be a strong cue to assign agency to Object X, the confidence in this assignment can, however, be weakened when other visible features suggest a different assignment.

We believe that Dowty's (1991) criteria can be generally interpreted as a subset of prototypical features of human interventions. The intervention concept is popular in several accounts of causal reasoning (e.g., Pearl, 2000; White, 2012b; Woodward, 2003). In this literature, interventions are acts that bring about a change in a variable of a causal system of interest and are considered independent of that system. An intervention by a human agent initiating a change in an object has all the features postulated by Dowty (1991) for proto-agents (volition, sentience, causation/change, movement, independent existence). Whereas Dowty's (1991) criteria focus on enduring features of agents and patients and on the moment of the causal interaction, we developed further criteria that capture the role of properties of movements *prior to contact*. This phase of a causal interaction seems less relevant for the understanding of verb semantics (which is Dowty's focus) but important for understanding visual causal perception.

We are going to test the following three proto-agent features that are inspired by properties of human interventions: (1) movement prior to contact (see Dowty, 1991; White, 2006b): because in a human intervention, the agent moves prior to the target objects, we expect that moving objects should tend to be attributed relatively more agency than stationary objects. (2) Sequence of appearance of causal participants: since the prototypical agent intervenes into an existing scenario that is either stationary or changing in a predictable way, the object that enters the observed scene last (prior to the causal interaction of interest) should tend to be attributed relatively more agency than objects that are already part of the scene. To rigorously test this hypothesis, we kept the objective sequence of movements constant, but manipulated the sequence of visibility of fragments of the scene. We hypothesized that the sequence of visibility may be used by subjects as a cue for the objective sequence of events, which should lead to the predicted tendency to attribute relatively more agency to the object made visible last. (3) Movement cues indicating volitional action: when a spontaneously moving object saliently behaves in a manner not obviously explainable by physical knowledge (e.g., self-propelled motion), the object's behavior should be interpreted as a volitional act. This should lead to an increased tendency to assign the agent role to this object (see Csibra, Gergely, Bíró, Koos, & Brockbank, 1999; Muentener & Carey, 2010; Saxe, Tenenbaum, & Carey, 2005).

2. Experiment 1

In our experiments, we employed variants of the standard Michottean launching scenario (see Fig. 1, Condition A, for an illustration), in which a Ball X collides with a Ball Y in the middle of the screen leading to the stopping of X and the movement of Y. Our goal was to test three new criteria of proto-agency by manipulating the prior context of the causal interaction in a way that either Ball X (the pushing ball) or Ball Y (the pushed ball) is more or less seen as agentive while the properties of the causal interaction itself and everything that follows was kept constant across conditions.

As baseline condition (Condition A), we used the standard Michottean launching scenario in which Ball X should clearly be seen as the agent and Ball Y as the patient (see

Table 1
Agency indicators for Ball Y across conditions.

Condition	Agency indicator for Ball Y		
	Movement	Last acting object	Self-propelled movement
A	–	–	–
B	✓	–	–
C	✓	✓	–
D	✓	✓	✓

White 2006a,b). In three further conditions (B, C, and D; see Table 1 for an overview), we manipulated the three proposed agency indicators for Ball Y while holding the properties of Ball X, the properties of the physical interaction itself (i.e., the collision event) and everything that happens afterwards constant (actually, the movement patterns of the balls were the same across conditions, starting 300 ms prior to the collision). Thus, in all conditions Ball Y is at rest in the middle of the screen immediately prior to the collision. When Ball X hits Ball Y, Ball X stops and Ball Y immediately starts moving (with exactly the same speed and direction as Ball X prior to the collision) towards and then beyond the edge of the screen.

In all additional conditions, Ball Y moves from the bottom of the screen towards its collision position where it stops 300 ms prior to the collision (i.e., movement as agency indicator).[1] By hiding either the left margin (Condition B) or bottom margin (Condition C), or by letting Ball Y start a self-propelled movement (Condition D; for details see Section 2.1.2), we added in each condition one additional agency indicator for Ball Y (i.e., movement; relative visibility; self-propelled motion; see Table 1 for an overview). We, therefore, expected an increasing willingness of participants to judge Ball Y as the agent in these scenarios, although the properties of the actual physical contact were identical across conditions. However, given that the movement of Ball X apparently leads to the subsequent movement of Ball Y towards and beyond the edge of the screen, we did not expect a complete reversal of agency assignments. The events around contact represent a strong cue for a causal relation directed from X to Y, which according to Dowty (1991) is one of several possible cues for the agent role. This cue was held constant across all conditions in our experiments.

2.1. Method

2.1.1. Participants

39 Students (27 women; mean age 23.4 years) from the University of Göttingen, Germany, participated as part of a series of various unrelated computer-based experiments for either course credit or €8 per hour.

2.1.2. Material

For each of the four conditions, we constructed a flash movie of 720 × 720 pixels (about 8.8° visual angle) in size that played effectively for 2200 ms and showed a red and a blue ball (each 120 pixels or about 1.5° visual angle in diameter; color assignment to X and Y was counterbalanced, see below). In each movie, Ball X enters the scene from the left side on a horizontal trajectory with constant speed until it reaches the center of the screen (and, therefore, Ball Y) after 1100 ms. Then Ball X stops moving. At the same time (with no time lag), Ball Y starts moving with the same velocity as Ball X towards the right hand side of the screen (and eventually leaves the scene). In Conditions B to D, we only manipulated the first 800 ms of the movies after which the movement patterns of the balls were identical to those in Condition A. The spatial layout of the movies and the timing of the ball movements are depicted in Fig. 1. In Conditions B and C, Ball Y started moving upwards from outside the bottom margin of the scene and stopped at the center of the screen after 800 ms (at the same position as its initial position in Condition A). The underlying movement patterns were identical for both conditions, but we covered either 240 pixels of the screens' left side (Condition B) or its bottom (Condition C).[2] In Condition D, Ball Y was at rest in the lower half of the screen (200 pixels above the bottom margin) and started moving upwards after 500 ms. (Note that from this time point on the shown movement patterns were identical in Conditions B, C, and D.)

For counterbalancing purposes, we additionally generated seven more movies per condition by rotating the scene by 90°, 180°, and 270°, respectively, and by switching colors of the balls yielding 4 × 2 = 8 movies per condition (i.e., 32 movies).

2.1.3. Design and procedure

We presented each subject with all 32 movies in random order (i.e., within-subject design). After having watched a movie, we requested participants to select one of four sentences (presented in randomized order) as the best description of the scene, for example:

1. The red ball launched the blue ball.
2. The blue ball stopped the red ball.
3. The blue ball launched the red ball.
4. The red ball stopped the blue ball.

Note that, depending on color version, only two of the sentences actually described what was seen in the movie. If a subject selected one of the two nonsensical sentences, we coded the answer as an error.

2.1.4. Predictions

We recoded subjects' responses according to the color coding as "X launched Y" vs. "Y stopped X" (plus error) and aggregated the eight color/rotation versions yielding a selection rate for each sentence (per subject). We expected an increasing selection rate for "Y stopped X" and a decreasing selection rate for "X launched Y", respectively, from Conditions A to D because Ball Y shares more and more criteria with a prototypic agent (see Table 1). (Note that both measures are not independent of each other; selection and error rates add up to 1.)

2.2. Results and discussion

Fig. 2 shows the average selection rates for the two relevant scene descriptions across the four agency conditions.

[1] Although the stopping of Object Y was immediate, neither the subjects nor the experimenters perceived the stopping as an abrupt, intentional stopping that violated physical knowledge. People usually assume that moving objects tend to stop eventually due to friction, air resistance or the loss of impetus (see, e.g., Hubbard, 2005, for an overview). These assumptions are obviously consistent with our displays.

[2] Without hiding the margins in Conditions B and C, the objects would have entered the scene simultaneously. To ensure in Condition B that Object X is the one that is visible after Object Y, and to make both conditions as parallel as possible, we covered the left hand side of the screen in Condition B.

In line with previous research, Condition A led to a strong preference for selecting Ball X as the agent (94.9% vs. 3.9%). Moreover, as predicted, the choice of Ball X as agent decreased from Condition A to Condition D, $F_{3,114} = 24.0$, $p < .001$, $\eta^2 = .39$ (all pairwise within-subject comparisons of the conditions are significant, all *ps* < .05). The preference for seeing Ball Y as the agent increased accordingly, $F_{3,114} = 22.9$, $p < .001$, $\eta^2 = .38$ (all pairwise within-subject comparisons of the conditions are significant, all *ps* < .05). The average error rate was 2.6% and did not significantly differ across conditions, $F_{3,114} < 1$.

Experiment 1 clearly demonstrates that agency intuitions are grounded in empirical indicators of agency confirming the proposed proto-agency criteria. However, it could be argued that the forced-choice format compelled people to choose one description even when their intuition was in line with the symmetry assumptions of Newtonian mechanics. Therefore, we planned to replicate the results using a more unrestricted response format in Experiment 2.

3. Experiment 2

To enable subjects to express that they see both alternatives as valid descriptions of the scene, we presented subjects with rating scales that allowed them to judge the appropriateness of the scene descriptions independently.

3.1. Method

3.1.1. Participants, material, and procedure

A new group of 34 students (23 women; mean age 23.4 years) from the University of Göttingen, Germany, participated in this experiment using the same design, the same set of 32 movies, and the same procedure as in Experiment 1. Instead of a forced-choice decision, we presented subjects with two of the sentences (matched to the color version of the movie) and requested them to rate how well each sentence describes the scene using two separate rating scales ranging from 0 ("not appropriate at all") to 10 ("highly appropriate"). Both sentences and rating scales were presented on a single screen (randomized order).

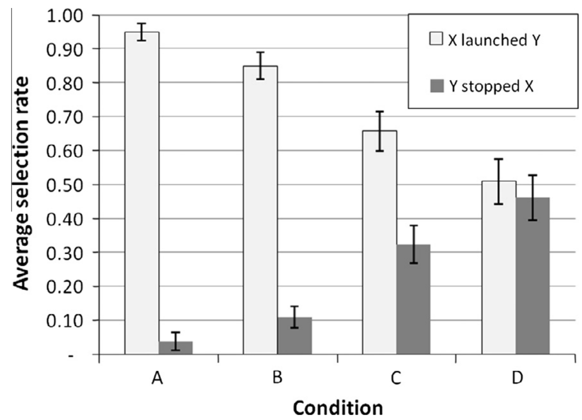

Fig. 2. Results of Experiment 1. (Error bars indicate standard error of the means.)

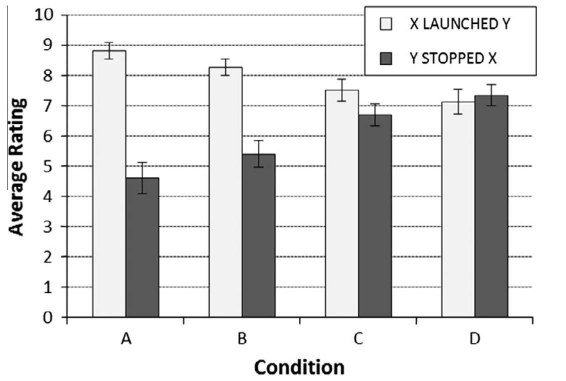

Fig. 3. Results of Experiment 2. (Error bars indicate standard error of the means.)

3.1.2. Design and predictions

We recoded and aggregated the data subject-wise across color/rotation conditions, which yielded a 4 (agency condition: A, B, C, D) × 2 (Ball: X, Y) within-subject design with (agency) ratings as dependent measure. Since we expected decreasing ratings for Ball X and increasing ratings for Ball Y from conditions A to D, we predicted an interaction between the agency factor and the rated ball.

3.2. Results and discussion

As expected, the ratings for Ball X were higher than for Ball Y in Condition A with a decreasing trend for Ball X and an increasing trend for Ball Y from Condition A to Condition D (see Fig. 3). This pattern led to a significant interaction, $F_{3,99} = 23.7$, $p < .001$, $\eta^2 = .42$.[3] Across conditions, Ball X received higher agency ratings than Ball Y, $F_{1,33} = 34.3$, $p < .001$, $\eta^2 = .51$, reflecting the fact that the salient end of the scenes (Ball Y leaving the scene) overall dominated agency intuitions.

Although the difference between agency ratings for Ball X and those for Ball Y is smaller in Condition A compared to Experiment 1, the overall pattern was replicated, which shows that the findings were not restricted to specific response formats.

4. General discussion

Force and dispositional theories of causal reasoning incorporate the distinction between agents and patients as the basis of force configurations predicting causal judgments and semantic intuitions. The assignment of the agent and patient roles, however, has often been treated as self-evident. Inspired by the linguistic theory of Dowty (1991), we proposed that agency is a prototype concept with multiple criteria, none of which is necessary for the role assignments. We adapted this theory to account for physical interactions (e.g., Michottean launching events) focusing in the present research on movement features

[3] As in Experiment 1, all agency conditions differed significantly from each other for Ball X as well as for Ball Y (pairwise within-subject one-tailed *t*-tests, all *ps* < .05).

prior to the collision event. We showed that agency intuitions are moderated by manipulations of the context prior to the launching event. Altering scenario features, such as relative movement, sequence of visibility, and self-propelled motion tended to increase agency attributions to the object that is normally seen as the patient in the standard Michotte scenario (i.e., Object Y).

A unifying principle underlying these agency criteria is the fact that they can be derived from the prototypical case of a human intervention into an otherwise stationary scene. In the present research, we focused on how kinematic features of the objects prior to the collision influence agency intuitions. Obviously other segments of the observed process, for example the moment of contact between objects X and Y and the following events may also influence agency intuitions (see White, 2012a, for an example of the influence of these temporal segments). Thus, further criteria of proto-agency will have to be explored in future research.

Our research adds to the findings demonstrating the influence of context features on causal impressions (e.g., Scholl & Nakayama, 2002) by showing that causal ascriptions are influenced by cues to agency prior to the actual causal interaction. They also seem relevant for accounts that model human inferences in Michottean launching tasks from the perspective of intuitive Newtonian physics (see, e.g., Gerstenberg, Goodman, Lagnado, & Tenenbaum, 2012; Sanborn, Mansinghka, & Griffiths, 2013). Causal asymmetry is at odds with the symmetry assumption inherent in Newtonian mechanics but consistent with Aristotelian physics (see Wolff & Shepard, 2013; White, 2006a). Exploring agency intuitions in launching scenarios may therefore constitute a relevant test case for distinguishing between Newtonian and Aristotelian accounts of intuitive physics.

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