What Causal Illusions Might Tell us about the Identification of Causes

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Abstract

According to existing accounts of causation, people rely on a single criterion to identify the cause of an event. The phenomenon of causal illusions raises problems for such views. Causal illusions arise when a particular factor is perceived to be causal despite knowledge indicating otherwise. According to what we will call the Dual-Process Hypothesis of Causal Identification, identifying a cause involves two cognitive processes: 1) an automatic, intuitive process that identifies possible causes on the basis of perceptual cues (spatial and temporal) and 2) a slow, reflective process that identifies possible causes on the basis of causal inference, in particular, a consideration of possible mechanism. Consistent with this hypothesis, we found that in response to a causal illusion shown in a naturalistic setting, people's initial judgments of causation were higher than their ultimate judgments of causation (Experiment 1). Using an online measure of the time-course of people's causal judgments, we found that people initially view animations of causal illusions as causal before concluding that they are non-causal (Experiment 2). Finally, we obtained similar results using a deadline procedure, while also finding that the lower the cognitive reflectiveness (as measured by the CRT), the stronger people's impressions of causation were (Experiment 3). Implications for different classes of theories of causation are discussed.

Keywords: causal reasoning; thinking & reasoning

Introduction

In 1977 New York City experienced a major blackout. Remarkably, some individuals felt, at least momentarily, that the blackout was caused by their own actions. For instance, Sparrow (1999) reports a child who hit a ceiling light fixture with a paddle ball at the exact moment the lights went off, and an opera singer who touched a door just as the power went out. One person exclaimed after plugging in a toaster, "I blew out the whole neighborhood!" (Sparrow, 1999). In situations such as this, people may experience strong feelings of causation while at the same time knowing that such feelings are unwarranted. We will term this experience of causation absent a plausible mechanism a *causal illusion*.

The fact that people can have conflicting judgments about the existence of a causal relationship is consistent with the idea that judgments of causation may be based on two kinds of processes: 1) a fast and intuitive process that identifies potential causes on the basis of perceptual cues, temporal cues in particular, and 2) a slow and reflective process that identifies potential causes on the basis of causal mechanisms, and in particular, how the entities in an event might be spatially arranged in order to allow for the transmission of energy or force (Wolff & Shepard, 2013). According to what we will call the *Dual-Process Hypothesis of Causal Identification*, these two processes occur regularly in people's analyses of everyday events. The two processes may not be easily recognized as distinct processes because in most cases they lead to the same conclusion. In the case of causal illusions, the conclusions of the two processes diverge, and hence their presence is revealed.

The distinction between intuitive and reflective processes is not new. Various forms of this distinction can be found in the perception, reasoning, and social cognition literatures. According to dual-processing theories, System 1 represents the statistical structure of the environment in a sub-symbolic format and involves processes that are implicit, unconscious, and heuristic, while System 2 represents the environment in a symbolic format and involves processes that are explicit, sequential, and rule-based (Sloman, 2015; Evans, 2008; Kahneman, 2003; Stanovich & West, 2000). In the causation literature, the distinction between intuitive and reflective processes is implied in the work of Schlottmann and Shanks (1992), who proposed a distinction between perceived and judged causation. This distinction is also indirectly suggested by the existence of a major partitioning of the causation literature into two areas: research on the perception of causality, which concerns processes that operate independently of background knowledge (e.g., Hubbard, 2013; Michotte, 1963; Rips, 2011; Scholl & Tremoulet, 2000; White, 2006) and research on causal reasoning and learning that involves the use of prior knowledge in the creation of new causal relations (e.g., Ahn et al, 1995; Lien & Cheng, 2000; Goldvarg & Johnson-Laird, 2001; Mayrhofer and Waldmann, 2015; Sloman & Lagnado, 2015; Wolff & Barbey, 2015). Implicit in the causation literature is the view that different kinds of causal reasoning might occur in the intuitive and reflective systems.

According to Sloman (2015) the intuitive system does not represent statistical associations directly, but rather generates such associations though the representation of causal structure. According to Sloman, the intuitive system is capable of making relatively sophisticated distinctions, such as whether an outcome was merely observed or the result of an intervention. In Sloman's (2015) proposal, the reflective system is slower than the intuitive system and capable of exerting some control over the intuitive system, though not completely. When in conflict, people will usually chose the conclusion generated from the reflective system over that generated by the intuitive system. In Sloman's (2015) view, the intuitive system is impressive in how much causal reasoning it is able to perform correctly.

Figure 1: An example causal illusion. A man appears to open elevator doors using only his hands.

We do not necessarily disagree with Sloman's (2015) proposal on how causal reasoning might be instantiated in the intuitive and reflective systems. Like Sloman (2015), we see the intuitive system as able to perform certain types of causal reasoning. Where we may disagree is in the relative level of sophistication of the reasoning in the intuitive system. Causal illusions, we propose, occur in situations in which the intuitive system is getting things wrong, and we speculate that such illusions are relatively common.

To date, however, no studies have directly examined the unique contributions made by the intuitive and reflective systems to the identification of a cause. According to our Dual-Process Hypothesis, the intuitive and reflective systems are expected to come to different conclusions about a cause in situations in which perceptual cues conflict with inferences from background knowledge. In particular, conclusions generated by the intuitive system are expected to occur earlier in the time-course of processing than conclusions generated by the reflective system. This basic prediction was tested in the following three experiments.

Experiment 1: "Jedi Powers"

In Experiment 1, we aimed to establish the phenomenon of causal illusions, and to begin to investigate the time-course of causal identification. In this study participants experienced an unexpected causal illusion on their way to our lab: a man appeared to open an elevator door by merely gesturing with his hands (Figure 1). Importantly, the man made no physical contact with the doors or with any of the buttons in the elevator. Unbeknownst to the participants, the doors were opened by a confederate outside of the elevator pushing the elevator button. Our main prediction was that the intuitive system would lead to feelings of causation that would ultimately be reduced by the reflective system. Participants' impressions of causation were measured in the subsequent interview, which included a short questionnaire.

Methods

Participants. 23 undergraduate participants were recruited for a study on perception and tested in groups of 1-4. One participant was excluded because they personally knew the confederate.

Causal Illusion. Participants were informed that the study would take place in our lab on another floor and followed a research assistant to the building elevator. There, a confederate pretended to re-open the elevator doors using only his hands (see Figure 1). The confederate re-opened the doors a total of three times, and maintained a neutral expression. In reality, the doors were controlled by an unseen confederate; no participants reported discovering the unseen confederate.

Causality Ratings. After the causal illusion, participants completed two sets of written ratings. (A) *Causality Description*: participants answered three questions about their experience: "what do you think you saw?," "please describe how this impression unfolded over time," and "did you think the man caused the elevator doors to open?" (B) *Time-Course Ratings*: participants rated the following statements on a 1-5 Likert scale: "to what extent did you [feel for a moment / ultimately conclude] that the man caused the elevator doors to open?"

Causality Coding. Two raters unfamiliar with the experiment coded participants' written descriptions for two features. (A) *Link Rating*: did the written descriptions mention a link between the man and the doors opening? (B) *Causality Rating*: did the written descriptions attribute causality to the man in causing the doors to open?

Results

Causality Descriptions. If causal illusions are in part causal, participants should spontaneously attribute causality to the Jedi in their causal descriptions. Participants' written descriptions frequently attributed causality to the confederate. Example descriptions were that "A man was controlling the doors of the elevator with his hands," "The man in the elevator kept causing the door to stay open on the wrong floor, like magic," and "A man […] was able to open the doors simply by moving his hands." Coders rated a mean of 87% of written descriptions as causal (inter-rater reliability=89%, kappa=0.33), suggesting that participants spontaneously perceived causal illusions as causal.

Time-Course Ratings. According to the dual-process hypothesis, causal illusions should create a strong *initial* impression of causality, but weaker *subsequent* impression of causality, due to the conflict between intuitive and reflective systems. Participants' time-course ratings supported this account: participants rated a stronger initial than ultimate impression of causality, $t(21)=3.72$, $p<0.01$ (Figure 2). This difference in causality ratings was consistently observed in individual participants. A majority of participants (13/22) rated a stronger initial than ultimate impression of causality, while just 2 participants rated a stronger ultimate than initial impression.

Because the number of participants varied from trial to trial, we conducted an additional analysis to ensure that participants' ratings were not driven by the impressions of other participants. There was no effect of the number of participants on either participants' initial impression of causality, $F(3,18)=1.10$, $p=0.37$, or on their ultimate impression of causality, $F(3,18) < 1$, n.s..

Discussion

There are two main results of Experiment 1. First, the results show that causal illusions give rise to impressions of causality, even in the absence of a possible mechanism. The majority of participants' written descriptions attributed causality to the confederate, and causal illusions received high initial ratings of causality. Second, the results provide initial support for the predictions of the dual-process hypothesis. Causal illusions created a stronger initial than ultimate impression of causality, consistent with a conflict between a fast intuitive system using perceptual cues and a slower reflective system using background knowledge. This effect was consistent across participants and rarely occurred in the other direction.

A limitation of Experiment 1 is that we were only able to measure participants' impressions of causation well after the occurrence of the event, rather than as they actually unfolded in real-time. The results are vulnerable, then, to the possibility that participants really did not have a strong initial impression of causation, but merely attributed this impression after the fact. In Experiment 2, this limitation was addressed through the use of a real-time measure of participants' impressions of causation.

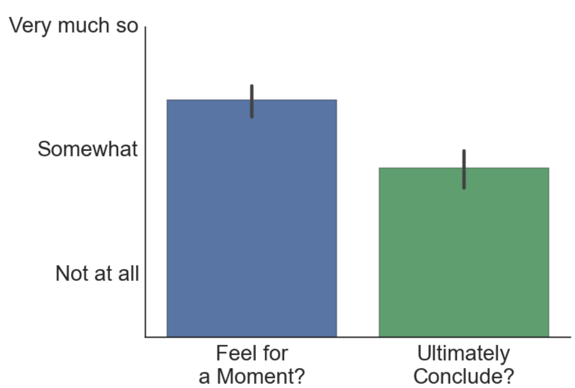

Figure 2: Participants rated a stronger initial than subsequent impression of causality when experiencing causal illusions. Error bars +/- 1 SEM.

Experiment 2: Time Course

In Experiment 2, participants viewed three kinds of events: causal, non-causal, and causal illusions (see Figure 3A). The temporal unfolding of the three kinds of events was exactly the same, except for the position of the causer in the scene. For example, in one set of animations, participants saw a record begin to turn. In the causal version, the hand made physical contact with the record. In the non-causal version of the event, the hand did not move. In the causal illusion version of the event, the hand moved, but did not make physical contact with the record. The experiment included six different sets of animations. As participants watched an animation, they indicated the degree to which they felt the event was causal or non-causal by how far they turned a dial to the right (causal) or left (non-causal) (see Figure 3D). Participants could change how far they turned the response dial at any point during the presentation of the animation. The dual-process hypothesis predicts that for the causal event, participants should move and keep the dial in the cause direction. For the non-causal event, participants should move and keep the dial in the non-causal direction. Critically, for the causal illusions, the dual-process hypothesis predicts that participants should *initially* move the response dial to cause, but *later* move the response dial to non-cause.

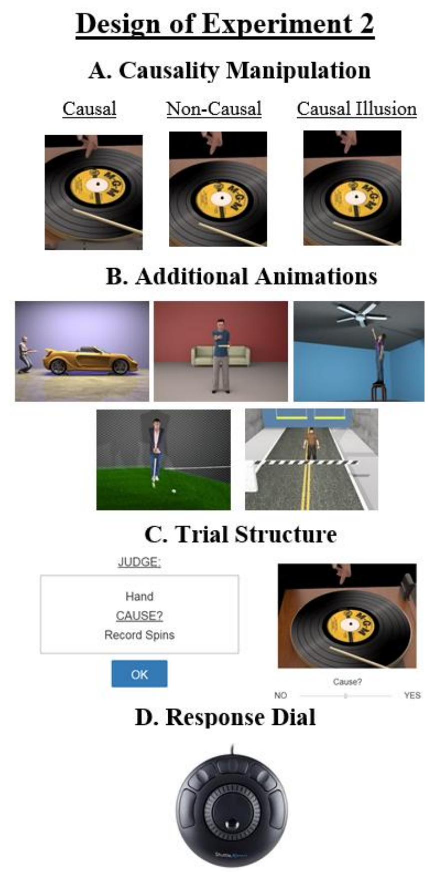

Figure 3**:** Experimental design for Experiment 2.

Methods

Participants. 60 adult participants were tested individually in the lab. 3 participants were excluded for failing to respond to at least 2 animations.

Animations. Animations were constructed using 3D Studio MAX animation software and rendered in Mental Ray or VRAY to increase realism. Six experimental animations were created (Figure 3A,B); each animation had a causal, non-causal, and causal illusion variant. All animations were

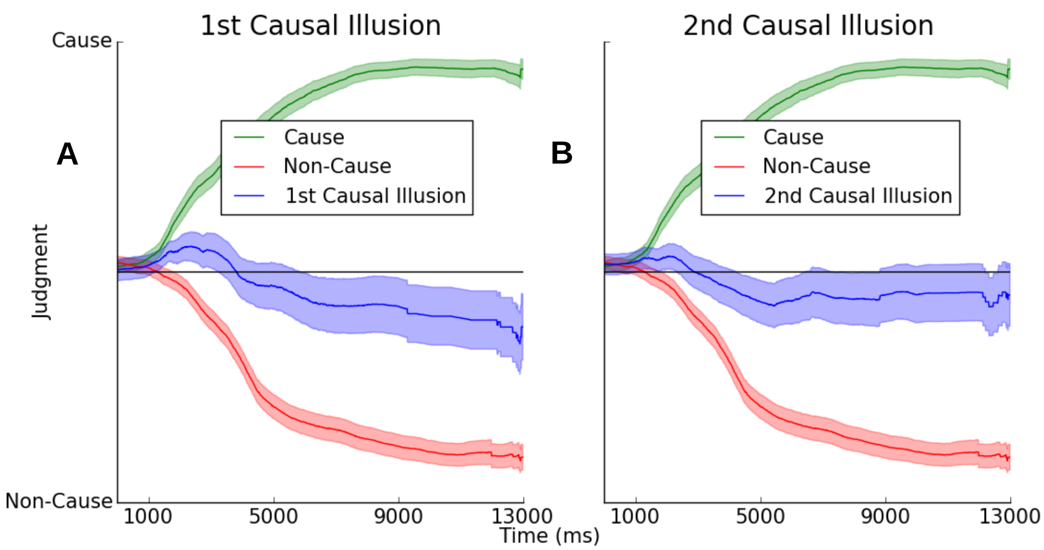

Figure 4: The average decision function for causal, non-causal, and causal illusion animations (shading +/- 1 SEM). Causal illusions are plotted separately for the 1st and 2nd causal illusions in Figure 4A and 4B, respectively.

matched at the single-frame level for duration (7s) and for when the resulting effect occurred (4s). Animations were displayed at a rate of 30 frames/s. An additional 5s of a still first frame was added to the beginning of the animations to allow participants to orient to the scene. 6s of a still last frame was also added to the end of the animation to allow the causal impression additional time to unfold. Six practice animations were created with clear cases of causation and non-causation to allow participants to become comfortable with the procedures in the experiment.

Trial Structure. The experiment was conducted on lab computers using a javascript application. Participants first completed 6 practice trials with clear causal or non-causal animations. Before the animation played, one of the objects in the scenes was named. Participants were instructed to evaluate the causality with respect to this object (see Figure 3C). Participants then viewed the animation, and were instructed to use a response dial to judge causality in real time. Participants responded "yes" or "no" by moving the dial right and left, respectively. Dial position was recorded as a continuous variable from +15 (yes) to -15 (no) every 10 ms. Participants were instructed that the position of the dial should always reflect their current opinion of whether a particular event was caused by the named object.

Data Analysis. Data analysis was conducted using custom Python scripts. For each participant, we averaged the responses to causal, non-causal, and causal illusion animations separately to create a single average decision for each animation type. We considered only data recorded at or after the time the effect occurred, resulting in 3 separate 13s-long decision functions, 1 for each animation type, with position recorded every 10 ms.

Results

The average decision function for each type of animation is shown in Figure 4. Significance tests were conducted by binning decisions at the group level using 100 ms bins, and testing whether the mean of that bin (which could range from +15 to -15) differed from 0 (i.e., no decision), using single-sample t-tests, $\alpha=0.05$, 2-tailed.

As expected, causal animations were quickly judged as causal, with decisions differing significantly from 0 beginning 800 ms after the effect occurred. Non-causal animations were quickly judged as non-causal, with decisions differing significantly from 0 beginning 1,200 ms after the effect occurred. Critically, the predictions of the dual-process hypothesis were also supported for the causal illusions, provided the analyses are restricted to only the first causal illusion participants saw. In particular, for the 1st causal illusion, as seen in Figure 4A, causal illusions were *initially* judged as causal 1,160 ms after the effect occurred, and then later judged noncausal at 12,700 ms after the effect occurred. The results from all of the causal illusions show a similar pattern, but are not significantly different from 0. The results suggest that participants viewed the animations in a more reflective manner once they saw one of the causal illusions. In particular, participants may have been able to use remembered knowledge about the 1st causal illusion to suppress the causal impression of the 2nd causal illusion. This result is consistent with the dual-process hypothesis, since prior inferences may have had a chance to interact with perceptually-based judgments.

Discussion

The main predictions of the dual-process hypothesis were supported. For causal illusions, but not for clear causes or non-causes, participants made two opposite decisions over the course of the single trial. Participants initially judged the 1st causal illusion to be causal, but subsequently judged it to be non-causal. In addition to providing evidence for the existence two kinds of processes, the results from this experiment provide some indication about when in time the two kinds of causal processes take place. In particular, it appears that the results of the intuitive process become available at around about 1000 ms, whereas the results from the reflective process might not be felt until 1300 ms. With these temporal benchmarks in place, we can test the dual-process hypothesis using a standard methods for examining the temporal time-line of processing, as demonstrated in the next experiment.

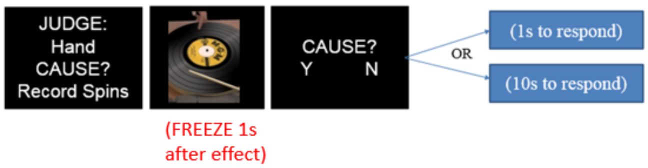

Figure 5: The deadline procedure in Experiment 3. Participants made a yes/no decision about causation under either a short or long response deadline.

Experiment 3: Thinking Styles

Experiment 3 had two aims. First, we sought to provide converging evidence for the existence of multiple processes in the interpretation of causal events using a deadline methodology, as well as by examining whether people's impressions of causation might depend on their cognitive reflectivity.

As in the previous experiment, participants viewed causal, non-causal, and causal illusion animations. In the current experiments, however, participants were prompted to make a yes/no decision about causation after either a short or long response deadline (Figure 5). The dual-process hypothesis predicts that participants will be more likely to judge causal illusions as causal under a short than long response deadline.

In addition to completing a deadline procedure, participants also completed a measure of reflective thinking style, specifically the Cognitive Reflection Test (CRT7; Toplak et al, 2014). If heuristic processes are responsible for the impression that causal illusions are causal, than participants higher in cognitive reflectiveness may be less susceptible to causal illusions.

Methods

Participants. 51 adult participants were tested individually in the lab.

Stimuli. Stimuli were the animations used in Experiment 2, as well as 4 new animations for a total of 10 different animations, each with a causal, non-causal, and causal illusion variant. The new animations were added to ensure results are not specific to items from Experiment 2.

Deadline procedure. The deadline procedure is outlined in Figure 5. Participants were first prompted which events to judge. Participants were then presented with an animation with the same time-course as in Experiment 2, except that the animation terminated 1s after the effect occurred. Participants then used the left and right arrow keys arrow keys to judge (yes/no) whether the first event caused the second event. Half of participants (*short-deadline* group) had 1s to respond; half of participants (*long-deadline* group) had 10s to respond. Response deadline was manipulated between participants because of possible order effects discovered in Experiment 2. All participants saw each of 30 animations twice in random order for a total of 60 trials.

Individual Differences Measures. After the deadline task, participants completed other tasks in our lab, and then completed the revised 7-item version of the Cognitive Reflection Test (CRT-7; Toplak et al, 2014).

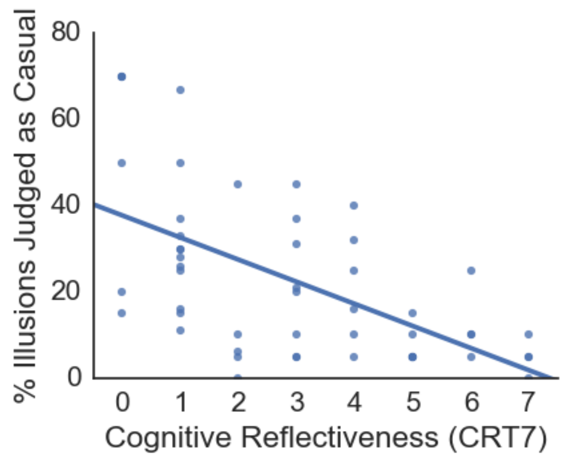

Figure 6: Participants high in cognitive reflectiveness were less likely to endorse causal illusions as causal.

Results

Just as predicted by the dual-process hypothesis, ratings of causation were higher for causal illusions when the deadline was short (M = 25.0%) than long (M = 18.2%), $t(9) = 3.76$, $p < 0.01$. In contrast, ratings of causation did not differ between the two deadlines for the animations showing clear cases of causation, $t(9) = 1.33$, $p = 0.215$, or non-causation, $t(9) = 0.27$, $p = 0.793$.

An analysis of participants' individual differences provided further support for the dual-process hypothesis. In these analyses, we correlated participants' CRT7 scores with the percent of times participants judged causal illusions as causal. As shown in Figure 6, cognitive reflectiveness correlated negatively with ratings of causation, $r(50) = -0.579$, $p < 0.001$. The effect was specific to causal illusions: cognitive reflectiveness was unrelated to judgments of causation in response to the causal, $r(50) = 0.03$, $p = 0.036$, and non-causal stimuli, $r(50) = -0.247$, $p = 0.081$. This pattern of results suggests that cognitive reflectiveness is a strong predictor of resistance to causal illusions.

General Discussion

In a series of three experiments, the predictions of the dual-process hypothesis were supported. In Experiment 1, we documented the phenomenon of causal illusions outside the lab. We showed that participants had a strong initial impression of causation, but a weaker ultimate impression of causation, supporting the claim that two cognitive processes are involved in causal reasoning. In Experiment 2, we replicated this dual pattern of response using a novel online measure of decision-making. Additionally, we showed an order effect, where participants were most susceptible to causal illusions for the very first illusion viewed. Finally, in Experiment 3, we demonstrated the same dual pattern of response using a deadline procedure. Additionally, we showed individual differences in susceptibility to causal illusions, where individuals high in reflective thinking were less susceptible to causal illusions.

An alternative interpretation of our results is that the intuitive process really processes dependency, not perceptual cues (Cheng, 1993). On this account, participants may judge a contingency between sub-events in a causal illusion: that the effect is more likely to occur after rather than before the causer moves. However, this interpretation does not easily account for our finding that the impression of causation declines over time for causal illusions (Experiments 1 and 2). With repeated presentations of a causal illusion, contingency should remain constant or increase; however, participants' judgments of causation decreased with repeated presentations.

The results have implications for theories of causal identification. As noted by Sloman and Lagnado (2015) and Copley and Wolff (2014), theories of how people identify causes fall into two categories: 1) Dependency theories which characterize causal relations with respect to statistical, logical, or counterfactual dependency relations, and 2) Process theories which characterize causal relations with respect to the notions transmission and force. The results reported in this paper might be viewed as problematic for all of these theories, because these theories define causation with respect to only one process. On the other hand, the results from this paper might be viewed as an opportunity. It may be that the different processes implies in this paper point to the need for multiple theories of causation. As suggested by Sloman (2015) dependency theories might be well suited for explain intuitive processing, whereas as suggested by Wolff and Shepard (2013), process theories might be well suited for reflective processes used in the identification of a mechanism that allows for the transmission of energy or force. An examination of the time-course of the processing of dependency relations and of forces may provide some resolution to the feasibility of a pluralistic theory of causation.

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References

Ahn, W., Kalish, C.., Medin, D., & Gelman, S. (1995). The role of covariation versus mechanism information in causal attribution. *Cognition, 54*, 299–352.

Cheng, P. (1993) Separating causal laws from causal facts: pressing the limits of statistical relevance. In D. Medin (Ed.), *The psychology of learning and motivation* (pp. 215-264). San Diego, CA: Academic Press.

Copley, B. & Wolff, P. (2014). Theories of causation can and should inform linguistic theory. In. B. Copley, F. Martin, & N. Duffield (Eds.), *Causation in grammatical structures* (pp. 11-56). Oxford: Oxford UP.

Evans, J. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology*, *59*, 255-278.

Goldvarg, E. & Johnson-Laird, P. (2001). Naïve causality: a mental model theory of causal meaning and reasoning. *Cognitive Science*, *25*(4), 565-610.

Hubbard, T. (2013). Phenomenal causality I: varieties and variables. *Axiomathes*, *23*, 1-42.

Kahneman, D. (2003). A perspective on judgment and choice. *American Psychologist, 58*, 697 – 720.

Lien, Y., & Cheng, P. (2000). Distinguishing genuine from spurious causes: a coherence hypothesis. *Cognitive Psychology*, *40*, 87 – 137.

Mayrhofer, R. & Waldmann, M. (2015). Sufficiency and necessity assumptions in causal structure induction. *Cognitive Science*. Advance online publication.

Michotte, A. (1963). New York: Basic Books.

Rips, L. J. (2011). Causation from perception. *Perspectives on Psychological Science, 6*, 77–97.

Schlottmann, A. & Shanks, D. (1992). Evidence for a distinction between judged and perceived causality. *Quarterly JEP*, *44A*, 321-342.

Scholl, B. & Tremoulet, T. (2000). Perceptual Causality and Animacy. *TICS*, *4*(8), 299-309.

Sloman, S. (2015). Two systems of reasoning, an update. In J. Sherman, B. Gawronski, & Y Trope (Eds.), *Dual process theories of the social mind*. Guilford Press.

Sloman, S. & Lagnado, D. (2015). Causality in thought. *Annual Review of Psychology*, *66*, 223-247.

Sparrow, J. (1999). The blackout history project. Retrieved from http://sloan.stanford.edu/SloanConference/papers/.

Stanovich, K. & West, R. (2000). Individual differences in reasoning: implications for the rationality debate. *Behavioral Brain Sciences, 23,* 645–726.

Toplak, M., West, R., & Stanovich, K. (2014). Assessing miserly information processing: an expansion of the CRT. *Thinking & Reasoning*, *20*(2), 147-168.

White, P. (2006). The role of activity in visual impressions of causality. *Acta Psychologica, 123*, 166–185.

Wolff, P., & Barbey, A. (2015). Causal reasoning with forces. *Frontiers in Human Neuroscience, 9*.

Wolff, P., & Shepard, J. (2013). Causation, touch, and the perception of force. *Psychology of Learning and Motivation, 58*, 167 – 202.