Embodiment in Causal Learning? Effects of Fluency and Body Specificity

Kelly M. Goedert (kelly.goedert@shu.edu)
Department of Psychology, Seton Hall University, 400 South Orange Ave.
South Orange, NJ 07079 USA

Clinton C. Dudley (dudleyc1@mail.montclair.edu)
Department of Computer Science, Montclair State University, 1 Normal Ave
Montclair, NJ 07043 USA

Abstract

The body specificity hypothesis (Casasanto, 2009) predicts an association between positive conceptual information and the side of space associated with the dominant hand. In the current study we investigated whether body specificity may produce states of fluency or disfluency that influence causal learning by inducing intuitive versus analytical processing. Right-handed participants learned about two potential causes of a common outcome in a trial-by-trial contingency learning task. We manipulated the spatial location of the causes (left, right) and the hand participants used to make responses (left, right). Consistent with expected fluency for a strong cause on the right, when using their right hand, participants better-discriminated between strong and weak contingencies for a right-located cause. Eye tracking revealed that this increased accuracy was *not* associated with an increase in overt visual attention. Rather, RT and eye tracking suggest that the body-specificity effects were associated with fluency differences across conditions.

Keywords: causal learning; causal inference; embodiment; eye tracking; body specificity hypothesis; fluency; judgment

Introduction

Systematic and reliable biases emerge from the functional organization of our perception and action systems, affecting high-level cognitive processes such as memory retrieval and problem solving (e.g., Thomas & Llera, 2007). Yet, work in causal inference has largely ignored the embodied reasoner (cf. Wolff, Holmes, & Ritter, 2014).

In using the phrase *embodied*, our intention is *not* to claim that cognition occurs within the body. Rather, we use the phrase to reflect those instances in which higher-level cognitive processes are influenced by seemingly irrelevant stimulus and response characteristics of a task. That is, when cognition is affected by being carried out in a body.

Embodiment may affect cognition in a variety of ways. For example, making goal-directed upward movements with the hands leads to faster retrieval of positive memories, while downward goal-directed movements leads to faster retrieval of negative memories (Casasanto & Dijkstra, 2010). In a Stroop task, placing the response buttons representing conflicting answers farther apart induces faster responding on incongruent trials – i.e., less conflict (Lakens et al. 2011).

While the above examples reflect the influence of irrelevant task demands on cognition, other embodiment effects reflect the nature of the specific body a person inhabits. For example, estimates of both distance and the size of objects are scaled by one's own body (see Proffitt & Linkenauger's, 2013, *phenotypic expression* theory). Of particular relevance here, however, is the *body specificity hypothesis* (Casasanto, 2009). According to body specificity, the fluency of movement associated with a person's dominant hand spatially grounds notions of *positive* or *good* to the dominant side of space. Thus, right-handers implicitly associate *good* with the right side of space and left-handers associate it with the left (Casasanto, 2009). These handedness-based fluency effects may also produce some of the bodily influences on size and distance perception. For example, right-handers perceive their right arm as longer and believe they can reach farther with their right hand versus their left (Linkenauger, et al., 2009).

Embodiment, Fluency, and Judgment

The concept of fluency may be one mechanism for uniting at least some embodiment effects with work in memory, judgment, and decision making. Fluency refers to individuals' subjective perception of the relative ease or difficulty of their own on-going cognitive processing (Oppenheimer, 2008). According to a recent model, fluency serves as a cue to the status of distal events about which individuals do not have direct information (Unkelbach & Greifeneder, 2013). For the phenotypic expression and body specificity effects discussed above, action-based fluency may serve as a cue for perceptual and affective judgments (i.e., embodied fluency; Alter & Oppenheimer, 2009)

What then of fluency's effects? A consistent finding in reasoning and decision making is that individuals in a state of fluency are more likely to engage in faster, intuitive reasoning processes, and those in a state of disfluency in slower, analytic processing – i.e., system 1 versus system 2 (Sloman, 1996), respectively (Alter, Oppenheimer, Epley, & Eyre, 2007; Alter, Oppenheimer, & Epley, 2013; Thompson et al., 2013). In the current study, we used a paradigm in which participants learn about two potential causes of a common outcome to investigate the potential for body specificity to produce states of fluency or disfluency that influence causal learning by inducing intuitive versus analytical processing.

Causal Learning and Cue Competition

Lateralized valence-space associations may be of particular relevance to the situation in which two causes, appearing separately in the left and right sides of space, "compete" for association with the outcome. When simultaneously learning about two causes, participants judge a moderately effective target cause to be less effective when it is learned about in the presence of a highly effective alternative (e.g., Goedert & Spellman, 2005). This general phenomenon is termed *cue competition*, reflecting that cues may compete either for association with the outcome or for attention.

In cue competition, the reduction in the perceived effectiveness of the moderately effective cause is sometimes the product of controlling for alternatives – i.e., holding other causes constant while evaluating the effectiveness of the target (Spellman, 1996). However, participants also reduce their judgments of a moderately effective cause beyond what is expected from controlling for alternatives – i.e., they *discount* a moderately effective target cause when there is a strong alternative (e.g., Goedert & Spellman, 2005).

Current Experiment

We investigated how body-specificity-induced states of fluency or disfluency affect learning about causes of a positive outcome. In this initial investigation, we focused on right-handed individuals because of their greater prevalence. The participants' task was to determine the effectiveness of each of two liquids in causing plants to bloom. They learned about the liquids simultaneously on a trial-by-trial basis. On each trial, one of the liquids appeared on the left of the computer screen and the other on the right, with the plant centrally located. Participants first saw some combination of the liquids applied to the plant (one, neither, or both). They then predicted whether or not the plant would bloom and received feedback. After a series of trials, participants made separate judgments regarding the effectiveness of each of the liquids in causing plant blooming.

Critically, we manipulated the contingencies between each of the causes and blooming such that one cause – the target – was moderately contingent with the outcome. This moderately contingent target cause was learned about in the presence of an alternative that was either strongly related to the outcome (strong alternative) or not related to the outcome (weak alternative). The occurrence of the two causes was independent. Thus, if participants perceived the target to be less effective in the strong than in the weak alternative condition that would be evidence of causal discounting. We varied the location of the target and alternative causes (left, right), which always appeared opposite each other on the computer screen. We also varied the hand participants used to make trial-by-trial predictions (left, right).

Figure 1 depicts the key rationale for our predictions. The body specificity hypothesis predicts that right-handers associate the right side of space with *good*. In the context of learning about causes of a positive outcome (plant blooming), we assumed that "good" would be a strong cause. In particular, we predicted that body-specificity would establish an expectation for a strong cause on the right side of space (first set of shaded boxes in Figure 1). This expectation may be strongest when participants use their right hand, as opposed to their left, for responding. By manipulating the relative locations of the target and alternative causes, we manipulated whether the strong alternative cause appeared on the right versus whether the non-causal alternative or moderately causal target appeared on the right. As seen in Figure 1, when the strong cause appears on the right, this matches the expectation produced by body-specificity and produces a state of fluency, which results in faster responding and causal judgments matching that state (i.e., strong causal judgments for the strong alternative cause). As a result, it may also lead to greater discounting of the target cause. However, when either the weak alternative cause or moderately effective target appear on the right, it is a mismatch to the body-specificity expectation, resulting in a state of disfluency. In turn, this disfluency results in slower responding and more analytic thinking, which we predict will produce more accurate causal judgments.

Figure 1 depicts the events resulting from a strong cause appearing on the right. However, the converse set of predictions may follow from a body-specificity expectation for a weak or non-causal event on the left side of space. When the weak (i.e., non-contingent) alternative is on the left, it matches the body-specificity expectation, which produces a state of fluency, resulting in causal judgments for the alternative that match that state (i.e., causal judgments of zero for the non-contingent).

In addition to causal judgments, we collected participants' response time on the trial-by-trial predictions, as a potential measure of fluency (Oppenheimer, 2008). Finally, we tracked participants' eye movements to assess the potential competing prediction that any embodiment effects we observe are due to shifts in visual attention.

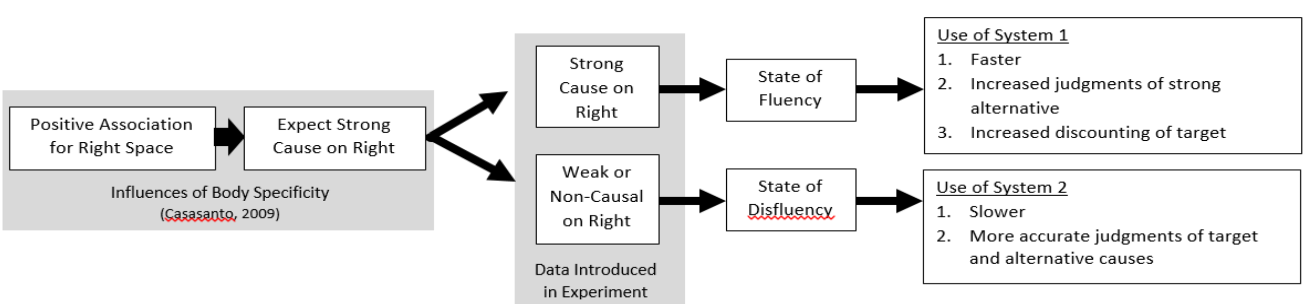

Figure 1: Influences of Body Specificity and fluency interact to create predictions.

Methods

Participants

One hundred twenty-four undergraduate students (88 female) participated. All identified as right-handed on the Revised Edinburgh Handedness Inventory (Dragovic, 2004).

Design

The primary design of the experiment was a 2 (contingency condition: strong alternative, weak alternative) x 2 (alternative location: left, right) x 2 (responding hand: left, right) mixed design with contingency manipulated within-groups and location and responding hand between. We measured objective contingency using the *phi coefficient* (φ). Across contingency conditions, the strength of the target cause was constant (φ = .33), but the strength of the alternative varied: In the strong alternative condition, the contingency between the alternative and the outcome was φ = .67 and in the weak alternative it was φ = 0. Table 1 depicts the frequencies for each type of trial across the conditions. Secondary, within-groups manipulations included learning block (one, two, three) and trial type (target-only, alternative-only, both, none). Finally, because participants responded *yes* and *no* with the same hand using the top and bottom trigger buttons on a game-controller, we counterbalanced the mapping of *yes* and *no* to the top and bottom buttons between-groups.

Table 1: Cell frequencies for contingency conditions.

	Weak Alternative		Strong Alternative	
Target	P	A	P	A
P	6/9	6/9	9/9	3/9
A	3/9	3/9	6/9	0/9

Note. P = present; A = absent. Cell ratios indicate the number of times the outcome occurred over the number of times that combination of causes occurred. Frequencies represent the total number of trials administered across entire experiment.

Procedure

Participants sat 60 cm from the computer screen, with their head and chin stabilized in a chin rest. They held a Logitech game controller in their laps and used either the left or right set of response buttons on the controller. The visual stimuli subtended 16.7° of visual angle.

The participants' task was to determine how effective each of two liquids were in causing plants to bloom. Participants acquired the contingencies depicted in Table 1 across three blocks of 12 trials each. Participants pressed a button to initiate a trial, at which point a cross-hair appeared centrally on the screen until the participant fixated the cross-hair. On each trial participants saw some combination of two colored liquids applied to a plant without a bloom (i.e., one trial from one of the cells of Table 1). They then predicted whether or not the plant would bloom using the top or bottom trigger button of the game controller to indicate *yes* or *no*. This response terminated the prediction screen and initiated feedback (2500ms). Every 12 trials, participants rated how effective each liquid was from -100 (completely inhibits plant blooming) to 100 (completely produces plant blooming). When making these ratings, participants released the Logitech controller and used both hands to type on the keyboard sitting on top of the desk. Each contingency condition was associated with a different set of colored liquids. Prior to starting the contingency acquisition trials, participants first performed training trials to learn the mapping of the *yes* and *no* response to the appropriate top or bottom buttons of the game controller.

Eye-tracking Apparatus and Analysis

We recorded the movements of participants' left and right eyes using a Tobii x120 eye tracker, sampling at 60 Hz. Because eye-movements during feedback are influenced by the accuracy of participants' predictions (Wills, Lavric, Croft & Hodgson, 2007), we focused our analysis on the prediction screens. We created two interest areas (left, right) by dividing the prediction screen in half vertically. Thus, each interest area encompassed either the target or the alternative cause.

Our primary measure of overt visual attention was dwell time in *ms*, which was the sum of all fixations on an interest area for a given trial type. We classified an eye movement as a fixation when the eyes lingered for 50ms or longer. Eye movements with a minimum velocity of 30 degrees per second for 4ms or longer were classified as saccades and screened from the data.

Statistical Analyses

We performed mixed linear modeling (MLM), modeling the full factorial of contingency condition (strong alternative, weak alternative), alternative location (left, right), and responding hand (left, right) as fixed effects, with participants' intercepts as the sole random effect. We only report the fixed effects as those address the research questions of interest.

Preliminary analyses revealed that mapping of the yes/no response to the top and bottom trigger buttons mattered early in learning (block 1), but not later. It is likely that participants were still learning the conceptual mapping for the yes/no response in the first block of trials. While we present analyses for causal judgments across blocks, we focus our interpretation on the final block (block 3), after participants had maximal opportunity to acquire the contingencies, which should also minimize potential extraneous variability from continued learning of the yes/no button mapping.

Results & Discussion

Causal Judgments

Alternative. We turn first to causal judgments of the alternative, for which the predictions depicted in Figure 1 are most relevant because it was either a strong cause (φ = .67) or non-causal (φ = 0) across the contingency conditions. Consistent with our predictions, participants' judgments of the alternative cause varied not only with its objective strength, but also as a function of its location and the responding hand [$F(1, 563) = 6.35$, $p = .012$, for the three-way interaction]. Participants accurately discriminated between the strong and weak alternative conditions across all three learning blocks (all *p*s < .001). However, the size of this effect increased between blocks one and two ($d = 0.69$ for strong vs. weak in block 1, and $d = 1.06$ in blocks 2 and 3).

Figure 2 depicts causal judgments of the alternative in block three. Participants most-accurately differentiated the strong and weak alternative when it appeared on the right side of the computer screen and they used their right hand to respond, $F(1, 107) = 40.3$, $p < .001$, $d = 1.34$. This pattern is consistent with the expectation that with the strong alternative on the right, right-handed participants in a state of fluency would rate it as strongly causal, but in a state of disfluency would more accurately judge the weak alternative as non-causal when it appeared on the right.

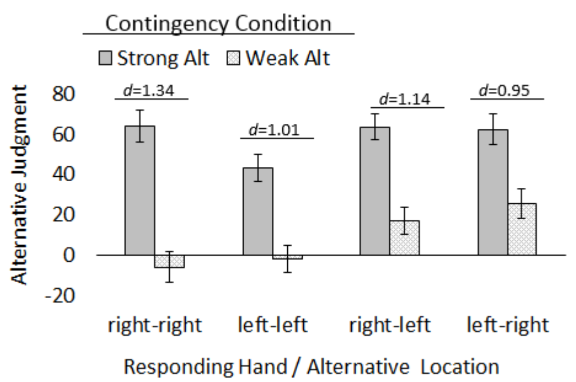

Figure 2: Causal judgments of the alternative in block 3. ± 1 SE.

Conversely, the judgments of participants using their left hand to respond are consistent with the prediction that the weak cause appearing on the left would lead to a state of fluency and subsequent judgment of the alternative as weak (2nd set of bars in Figure 2). Furthermore, participants using their left hand rated the strong alternative as less causal when it appeared on the left vs the right ($p < .05$).

Finally, the pattern of results depicted in Figure 2 suggests that the body-specificity-based expectations hold when there is a match between the responding hand and alternative location (i.e., right-right or left-left), but not when there is a mismatch.

Target. In the same condition in which subjects best-discriminated the alternative, they demonstrated the greatest amount of discounting of the target (Figure 3). Despite equal objective contingencies for the target across the contingency conditions ($\varphi = .33$), they judged the target as less effective with the strong rather than weak alternative, $F(1,107) = 16.82$, $p < .001$, $d = 0.83$, when using their right hand to respond and when the alternative appeared on the right (target on the left). This interaction among contingency condition, responding hand, and alternative location reached significance for causal judgments of the target in block three, $F(1, 107) = 4.72$, $p = .032$. However, the effect of the strong and weak alternatives on judgments of the target was not apparent in blocks one and two (*p*s > .05). This pattern of results, in combination with the observation that participants' accurate discrimination between the alternative strength for strong versus weak conditions was stable by block two, suggests that discounting of the target emerged after – and in response to – recognition of the strong alternative.

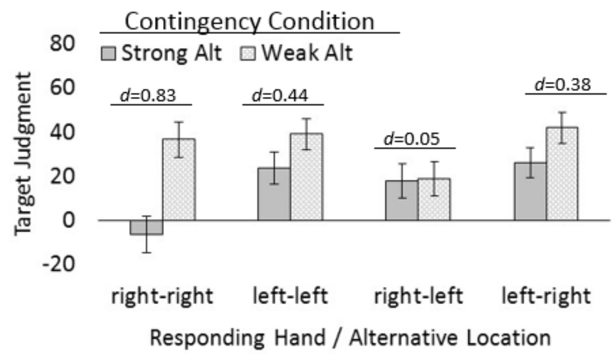

Figure 3: Causal judgments of the target in block 3. ± 1 SE.

Response Time (RT)

Overall, we observed a main effect of block, such that participants' RT decreased across blocks [$F(2, 563) = 11.6$, $p < .001$], as is typical of trial-by-trial causal learning. Block did not, however, interact with any other factors, all *p*s > .13. Therefore, to be consistent with the causal judgments, we focus our interpretation on RT in block 3, which is depicted in Figure 4. Comparing Figures 2 and 4, we see faster RT associated with those instances in which the strong alternative was judged more effective, suggesting a role for fluency.

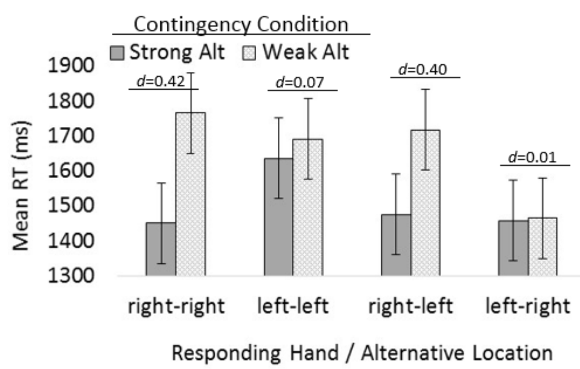

Figure 4: Response time on prediction trials in block 3. ± 1 SE.

More precisely, we predicted fluency effects on RT such that right-handed participants would be in a state of fluency and have faster RT when the strong alternative cause appeared on the right, with the expectation that these effects would be maximal when participants used their right hand. As seen in Figure 4, it was the responding hand, rather than alternative location, that interacted with the contingency condition in determining RT, $F(1, 841) = 5.32$, $p = .021$.

When using their right hand, participants were faster in the strong (M = 1464.3, SD = 725.1) than in the weak alternative (M = 1740.0, SD = 859.2) conditions, p < .001, d = 0.34. This pattern is consistent with a prediction that *right* would induce an expectation for a strong cause and thus induce fluency when that expectation was met. However, when responding with their left hand, there was no difference in participants' response times across contingency conditions (M = 1553.9, SD = 856.9 for the strong and M = 1587.6, SD = 826.2 for the weak alternative).

While no other effects reached significance, the three-way interaction of location, responding hand, and contingency condition was marginal, F(1,118) = 3.09, p = .081. Comparing Figures 2 and 4, we see the same condition that witnessed the greatest differentiation between the strong and weak alternative causes, also witnessed the greatest difference in RT. Also, as seen in Figure 4, there was a general tendency to respond quickly in the strong alternative conditions, except when that strong alternative appeared on the left and participants were responding with their left hands: Participants may have responded more slowly because the strong alternative was inconsistent with the expectation for a weak cause.

To be consistent with the causal judgments, we have focused on RT for block 3. However, if body-specificity induced a state of fluency/disfluency, then effects on RT may be even stronger in block 1. This is indeed what we observe. In block 1, participants using their right hand were faster in the strong (M = 2056.7, SD = 1053.5) vs. weak (M = 2833.2, SD = 1231.1) alternative conditions, d = 0.64 (a larger effect than in block 3). Furthermore, consistent with a violation of expectations, there was a small tendency for participants using their left hand to respond more slowly in the strong (M = 2312.6, SD = 1002.2) vs. weak (M = 2160.7, SD = 1333.8) alternative conditions, d = 0.13.

Dwell Time on Prediction Screens

While RT may serve as an indicator of fluency, RT in this particular paradigm is a product of how much time individuals spend processing both the target and alternative causes. We can tease apart these contributions with the eye tracking data and how long participants spent looking at each of the causes. Average total dwell time to the alternative appears in Figure 5, and that to the target in Figure 6. The eye tracking results do not support the potential competing prediction that embodiment effects result from increased visual attention. Rather, dwell time analyses echoed RT.

Alternative Overall, participants spent more time looking at the alternative when it was on the left (M = 925.7, SD = 558.6) versus right (M = 502.1, SD = 611.9), F(1,118) = 8.12, p = .005, d = 0.69. The analysis also revealed a condition by hand interaction, p = .049, which echoed that observed in RT. When participants used their right hand to respond, they spent less time looking at the alternative when it was strong (M = 641.5, SD = 473.8) than when it was weak (M = 832.1, SD = 794.4). This effect was larger when the stronger alternative was located on the right (d = 0.34) as opposed to the left (d = 0.27). This pattern is consistent with the prediction that responding with the right hand would produce a fluency for the strong alternative, and a relative disfluency for the weak alternative. When participants used their left hands, there was no difference in the dwell time to the alternative in the strong (M = 748.1, SD = 525.1) and weak alternative (M = 790.3, SD = 604.1) conditions, d = 0.07.

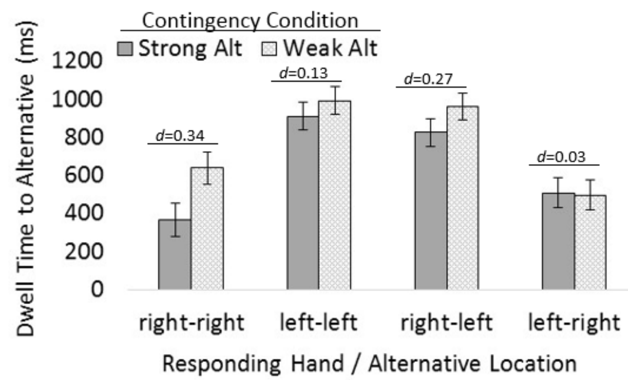

Figure 5: Mean total dwell time to alternative for block 3 prediction trials. ± 1 SE.

Target As with dwell time to the alternative, participants looked at the target more when it appeared on the left versus right, F(1, 118) = 10.35, p = .002. Note that in Figure 6 the x-axis label indicates the alternative location, and the target appeared opposite the alternative. No other effects reached significance.

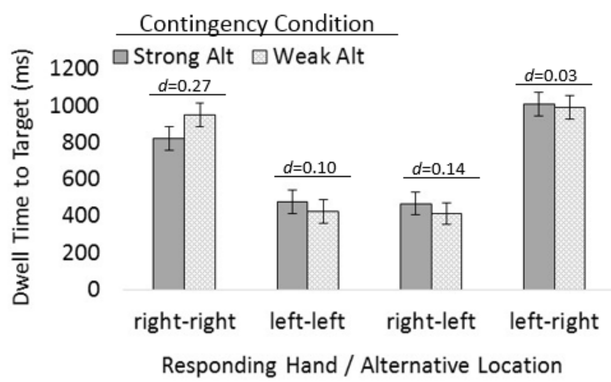

Figure 6: Mean total dwell time to target for block 3 prediction trials. ± 1 SE.

General Discussion

As depicted in Figure 1, we predicted that body-specific associations of the right space and right hand with "good" would produce an expectation for a strong cause on the right to produce a good outcome. Furthermore, we predicted that meeting this expectation would produce a state of fluency, resulting in faster, intuitive responding, while violating this expectation would result in a state of disfluency, resulting in slower, analytical responding. Causal judgments of the alternative are largely consistent with these expectations, but only when the responding hand and alternative location match. Furthermore, the effects are stronger for the right hand and right space than they are for left hand and left space.

A remarkable consistency emerged among participants' judgments of the alternative, those of the target, and the RT and dwell time: Those conditions best-discriminated in causal judgments (right-right) also showed the greatest discrimination in RT and dwell time. Suggestive of a disfluency for the weak alternative on the right, participants spent more time looking at the weak than the strong alternative on the right side of the screen when using their right hand. Eye tracking analyses revealed that these effects were *not* due to an overall increase in visual attention to the right. Indeed, overall, participants spent more time looking at the left than the right side of space, an effect consistent with leftward biases often observed in visuomotor tasks (e.g., Nicholls, Bradshaw & Mattingley, 1999). Rather, the eye tracking and RT analyses are most consistent with a fluency explanation. Participants using the right hand responded quicker in strong relative to weak alternative conditions.

Limitations

This investigation is just a first step in identifying possible embodiment effects, and body specificity effects, on causal learning. Were body specificity mechanisms truly driving the effects observed here, we would expect these effects to reverse in left-handers. We might also expect these effects to reverse for people learning about causes of negative outcomes (e.g., disease). Finally, RT, as used here, is only one potential measure of fluency. Future work could use confidence ratings for the causal judgments to confirm the fluency predictions and RT results.

Conclusion

We provide evidence suggestive of embodiment effects in causal learning. Thus far, these effects are consistent with the prediction of fluency and disfluency resulting from body-specific space-valence associations (Casasanto, 2009). More work is needed to verify this account of the effects and to further understand the underlying mechanisms.

Acknowledgments

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