Belief-Based and Covariation-Based Cues Affect Causal Discounting

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Abstract Causal discounting occurs when the perceived efficacy of a putative cause is reduced by the presence of a stronger causal candidate. Previous studies of causal discounting have defined the strength of causal candidates in terms of the degree to which the cause and the effect covary (e.g., Baker, Mercier, Vallee-Tourangeau, Frank, & Pan, 1993). In contrast, in the present study, causal strength was defined in terms of both covariation- and belief-based cues. Seventy-two participants made causality judgments for a fictional causal candidate both in isolation and when paired with either a stronger or a weaker cause. The results demonstrated that the degree to which a causal candidate is discounted depends not only on the degree to which an alternative cause covaries with the effect, but also on whether the alternative is a believable or unbelievable candidate. Indeed, it was observed that a highly believable alternative will produce the discounting effect, even if it is a weaker covariate than the original candidate. These findings suggest the need to incorporate both belief-based and covariation-based cues into models of causal attribution.

Résumé La mise à l'écart de facteurs de causalité se produit quand la valeur subjective de l'un d'eux est atténuée par la présence d'un autre davantage plausible. Des études antérieures ayant porté sur de telles mises à l'écart ont défini la force des causes possibles à partir du degré de covariation entre la cause et l'effet (p. ex., Baker, Mercier, Vallée-Tourangeau, Frank et Pan, 1993). Par contre, dans la présente étude la plausibilité causale a été définie en référence à des indices basés à la fois sur la covariation et sur la croyance. Soixante-douze participants ont posé des jugements sur une cause présumée qui leur était présentée soit isolément, soit appariée à une autre dont la plausibilité était plus forte ou plus faible. Les résultats démontrent que le degré de mise à l'écart dépend non seulement du degré de covariation entre l'autre cause et l'effet, mais aussi du fait que cette autre cause est crédible ou non. En effet, l'analyse révèle que la présentation d'une autre cause hautement crédible entraîne la mise à l'écart même si cette cause constitue une covariable plus faible que la cause originale. Ces résultats suggèrent que les modèles de l'attribution de la causalité devraient inclure des indices basés aussi bien sur la croyance que sur la covariation.

When testing hypotheses about cause and effect relations, one frequently encounters situations in which one must decide which of many competing causal factors are responsible for a single observed effect. When faced with competing causes, individuals will typically judge the degree of causal candidacy for each cause relative to each other, such that stronger causes may reduce the perceived efficacy of weaker causes. This inference process is generally referred to as "discounting" (Baker, Mercier, Vallee-Tourangeau, Franck, & Pan, 1993; Kelley, 1973). The goal of the current paper is to investigate two factors, beliefs and covariation, which may contribute to judgments of causal strength in discounting.

COVARIATION-BASED AND BELIEF-BASED EXPLANATIONS OF CAUSAL STRENGTH

Traditionally, the strength of causal cues has been defined in terms of the degree of covariation between a putative cause and its effect. A commonly used means of measuring the covariation between cause and effect is the delta-p rule: The degree of covariation (and hence causal strength) is determined by assessing the occurrence of an effect when a given cause is both present and absent, using the following equation:

$$\Delta P_i = P(e/i) - P(e/{\sim}i) \qquad (1)$$

In this equation, $P(e/i)$ refers to the probability of the effect occurring in the presence of the cause, and $P(e/{\sim}i)$ refers to the probability of the effect occurring in the absence of the cause (Cheng & Novick, 1990).

Many researchers claim that people and animals are sensitive to the contingency (ΔP_i) between the cause and effect, and use this information as a measure of causal strength (Cheng, 1997; Cheng & Novick, 1990, 1992). Much evidence supports this claim: An event that exhibits a regularity of association with an effect (i.e., covaries with

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that effect) is more likely to be identified as a cause of that effect than is an event that does not exhibit a regularity of association (Cheng & Novick, 1990).

There are, however, several limitations to this approach (see Einhorn & Hogarth, 1986, for a review) that have prompted some researchers to conclude that covariation should be viewed as one of many possible cues to causality, and perhaps not even the primary cue (White, 1992). One such theory is the causal powers theory (Harre & Madden, 1975; White, 1989). This theory emphasizes the role of acquired knowledge in the evaluation of causal hypotheses. Specifically, Harre and Madden posited that causal powers are stable properties of objects whose power to produce an effect is based on the "chemical, physical, or genetic natures of the entities involved" (p. 5). Thus, causal roles are defined conceptually, rather than through empirical associations, such that the assessment of causal hypotheses is proposed to be a matter of seeking some object *believed* to possess the power to produce the effect in question (White, 1989).

LIMITATIONS OF PREVIOUS RESEARCH ON DISCOUNTING

Although it seems very likely that both covariation- and belief-based cues would contribute to the perceived strength of a causal candidate, studies on the discounting effect have focused almost exclusively on covariation-based information (e.g., Baker et al., 1993; Chapman & Robbins, 1990; Dickinson, Shanks, & Evenden, 1984; Shanks, 1986; Wasserman, 1990). In this respect, it is typically observed that the perceived causal efficacy of a candidate is reduced when presented in the context of an alternative cause that covaries more strongly, and that the degree of discounting varies according to the covariation of the alternative (Baker et al., 1993). Although covariation-based researchers often acknowledge the role of prior knowledge, it is typically restricted to prior knowledge of covariation-based information in the form of beliefs about prior probabilities (e.g., Kelley, 1973; Morris & Larrick, 1995).

The goal of the following experiment was to ascertain the extent to which participants' a priori beliefs contribute to the degree of causal discounting, and how those beliefs are combined with covariation-based cues. To do this, participants were presented with multiple causal candidates for a single given effect. Each candidate varied in terms of: (1) the degree to which it covaried with the effect, and (2) the degree to which it was a believable precursor to the observed effect. It was predicted that causal discounting would vary as function of both variables, and as such delimit circumstances where the discounting of a candidate may occur even under conditions in which competing candidates have equal, or even less, predictive strength. Such findings would challenge traditional covariation-based theories, because they argue that the perceived causal efficacy of a candidate is only reduced when presented in the context of an alternative cause that covaries more strongly with the observed effect.

TABLE 1
Mean Believability Ratings (Mean) and Standard Deviations (SD) of the Putative Causes Used in the Experiment.

Scenario	Belief	Putative Causes	Mean	SD
Depleted Fish	High	Insecticides	8.1	1.1
	Neutral	Boronium	6.2	1.3
	Low	Aeration	3.7	2.0
Car Accident	High	Severed Brake Lines	8.0	1.6
	Neutral	Trionic Valves	5.1	1.0
	Low	Broken Radio	2.0	1.6
Productivity Slowdown	High	Illness	7.8	0.8
	Neutral	Extenderometer	5.8	1.5
	Low	New Cafeteria Menu	2.2	1.8
Disease Epidemic	High	Bug Infested Food	8.5	0.8
	Neutral	Tribal Ritual	4.6	1.8
	Low	Possessing Green Eyes	2.1	1.5
Car Start Failure	High	Broken Alternator	8.4	1.2
	Neutral	Polomaric Chamber	5.5	1.4
	Low	Flat Tire	1.4	1.2
Allergic Reaction	High	Eating Peanuts	8.2	0.9
	Neutral	Drinking Water	4.4	2.2
	Low	Homework	1.5	0.8

Method

PARTICIPANTS

Seventy-two students from the University of Saskatchewan summer subject pool completed this study as volunteers.

DESIGN

The experiment employed a 2 x 2 x 3 within-subjects design. There were two levels of the belief manipulation (the alternative cause was either of low or high belief), two evaluation times (the causal efficacy of the candidate cause was evaluated before and after the presentation of the alternative), and three levels of the covariation manipulation (ΔP of the alternative cause was set at .5, .67, and 1).

MATERIALS

Six story scenarios were constructed about the following content areas: depleted fish populations, car accidents, productivity slowdowns, disease epidemics, car starting failures, and allergic reactions. Each scenario presented a relationship between two causes and a single effect. The first cause, hereafter referred to as the *candidate* cause, was always of neutral belief (i.e., it was possible but fictional) and was moderately contingent ($\Delta P_i = .67$) with the effect. For example, in the car accident scenario, the candidate cause was a depressurized trionic valve. The causal efficacy of the candidate cause was evaluated first by itself, and then in the presence of a second cause, hereafter referred to as the *alternative* cause. The alternative cause was either highly believable or highly unbelievable, and was presented at one of three ΔP contingencies ($\Delta P_i = .5, .67,$ or 1). Thus, the alternative cause was either less contingent, the same, or more contingent than the candidate cause. The believability of both the candidate and alternative causes was determined in a previous study in which participants were asked to rate the plausibility of cause and effect relationships in the absence of covariation information. The mean believability ratings for the six causal scenarios, and the low belief, neutral, and high belief candidates used in the present experiment are presented in Table 1.

Covariation information was presented in a discrete format that specified the number of times the effect occurred in the presence of the cause [P(e/i)] and the number of times the effect occurred in the absence of the cause [P(e/~i)]. This presentation format was chosen due to the findings of past research, which have shown that participants typically make more accurate contingency judgments when presented with covariation information in a discrete format, as compared with a continuous format (e.g., Kao & Wassermann, 1993; Ward & Jenkins, 1965). These event frequencies were created such that only the probability of the effect occurring in the presence of the cause [P(e/i)] varied, whereas the probability of the effect occurring in the absence of the cause was held constant at 0 [P(e/~i) = 0)] as illustrated in Table 2. This form of ΔP manipulation was chosen due to the findings of several researchers (e.g., Downing, Sternberg, & Ross, 1985; Schustack & Sternberg, 1981; Wasserman, Dorner, & Kao, 1990) that participants are typically more sensitive to manipulations of the probability of the effect occurring in the presence of the cause [P(e/i)], than the probability of the effect occurring in the absence of the cause [P(e/~i)].

For illustrative purposes, the car accident scenario containing a highly believable and highly contingent alternative cause will be presented in full. Participants were first provided with a brief introductory paragraph explaining the event that had happened, and a possible cause for that event. For example, in the car accident scenario, participants were provided with the following paragraph: "Imagine you are a police officer investigating the possible cause of accidents on the Trans-Canada Highway. You have a hypothesis that the accidents may be due to depressurized trionic valves. To test this theory, you decide to examine 10 cars that had been in accidents and 10 cars that had not been in accidents." At this point, participants were provided with data that specified the number of times the cause (i.e., depressurized trionic valves) co-occurred in a sample of 10 cars that have been involved in accidents, and 10 cars that have not been involved in accidents. Then, participants judged the likelihood that the putative candidate was causally responsible for the observed effect by choosing a number from 0 to 100, where 0 means "definitely not the cause," and 100 means "definitely the cause."

TABLE 2
Event Frequencies Used for the Computation of the ΔP Values Used in the Current Experiment

Frequencies				ΔP Computations			
ie	i~e	~ie	~i~e	P(e/i)	-	P(e/~i)	ΔP
10	10	0	0	10/20	-	0/0	.5
10	5	0	5	10/15	-	0/5	.67
10	0	0	10	10/10	-	0/10	1.0

Note. (ie) represents the number of times the cause and effect co-occurred; (i~e) represents the number of times the cause occurred in the absence of the effect; (~ie) represents the number of times the effect occurred in the absence of the cause; (~i~e) represents the number of times the effect was absent when the cause was absent.

Participants were then provided with evidence about a second potential cause of the same effect. Specifically, in the highly believable car accident scenario, they were provided with the following paragraph: "On the advice of a colleague, you decide to reexamine the cars to look for other potential causes of the car accidents. In particular you have a hypothesis that the car accidents might be due to severed brake lines." Participants were then provided with data that specified the number of times the alternative cause (i.e., severed break lines) co-occurred in a sample of 10 cars that have been involved in accidents, and 10 cars that have not been involved in accidents. Participants were then asked to reassess their initial judgment of the candidate cause (i.e., depressurized trionic valves) and to assess the likelihood of the alternative cause (i.e., severed break lines) using the same 0-100 scale.

Across the six scenarios, levels of ΔP were crossed with belief, such that one problem was presented to each participant in each Belief x ΔP cell. Across participants, the assignment of ΔP and belief conditions were counterbalanced such that believable and unbelievable alternative causes appeared equally often in the three ΔP conditions. The initial judgment of the candidate cause will be referred to as the *pretest* in the results section and the second evaluation of the candidate cause will be referred to

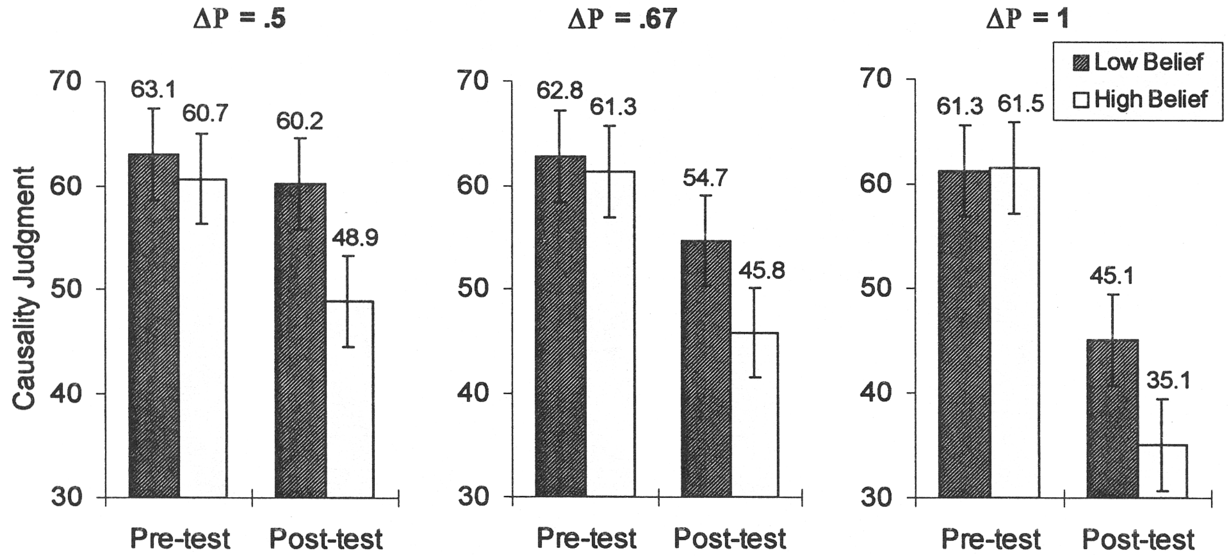

Figure 1. Mean likelihood ratings for the candidate cause (a) when presented alone (pretest), and (b) when presented with the alternative (post-test) of varying believability and ΔP. Error bars depict 95 % confidence intervals calculated using the pooled error term as recommended by Loftus and Masson (1994).

as the *post-test* in the results section. Changes in the ratings of the candidate cause from the pre-test to the post-test reflect the *discounting* effect of the alternative cause.

PROCEDURE

The scenarios appeared in a different random order for each participant, and each was presented on a separate page. The participants were tested after completing an unrelated experiment. Instructions were all written, so the experimenter gave only a brief introduction and informed the participants to complete the questions in the booklet in the order in which they appeared and to work at their own pace. There was no time limit imposed on completing the study. Participants were encouraged to ask any questions regarding the materials at any time during the experiment.

Results

The results section will focus primarily on the discounting effect, that is, the change in ratings of the candidate cause when presented alone and with the alternative. Additional analysis will assess the degree to which beliefs and ΔP influenced judgments of the alternative cause. The alpha level for all statistical tests was .05 (two-tailed) unless otherwise stated. Effect size estimates were computed using partial η^2.

DISCOUNTING EFFECT

Figure 1 presents the mean likelihood ratings for the candidate cause (a) when presented alone (pretest), and (b) when presented with the alternative (post-test) of varying belief and ΔP. Preliminary analysis demonstrated that the pre-test scores were not influenced by the believability or the ΔP of the alternative cause (all *F*s <1). This equality in the pretest ratings means that the discounting effect took place relative to a comparable baseline in all conditions.

The pre- and post-test ratings were analyzed using a 2 x 2 x 3 (Belief x Test x ΔP) repeated measures ANOVA. This analysis revealed significant interactions between belief and test, $F(1,71) = 12.29$, $MSE = 345.60$, $\eta^2 = .15$, as well as between ΔP and test, $F(2,142) = 12.69$, $MSE = 286.36$, $\eta^2 = .15$. Neither the Belief x ΔP nor the three-way interaction were significant (all *F*s <1), suggesting that the effects of belief and ΔP were additive. Tests of simple main effects indicated that likelihood judgments of the candidate cause were influenced by the believability of the alternative cause at the post-test, $F(1, 71) = 15.59$, $MSE = 703.80$, $\eta^2 = .22$, but not at the pretest, $F(1, 71) = .50$, $MSE = 318.0$, $\eta^2 < .01$. Similarly, the likelihood judgments of the candidate cause were influenced by the ΔP of the alternative cause at the post-test, $F(2,142) = 13.0$, $MSE = 608.08$, $\eta^2 = .18$, but not the pretest, $F(2,142) = .09$, $MSE = 215.72$, $\eta^2 < .01$. These analyses indicate that judgments of the candidate cause were influenced by two qualities of the alternative cause, namely, believability and covariation. Likelihood ratings of the candidate cause were lower in the presence of a strong than a weak covariate, and lower in the presence of a highly believable than an unbelievable candidate.

To determine the conditions under which the alternative cause produced a reliable decrease in ratings of the candidate cause (i.e., a discounting effect), paired *t*-tests were computed comparing the pre and post-test ratings. A family-wise level of .05 was set for these six comparisons such that alpha for each individual comparison was set at

.008. All of the belief and ΔP combinations produced reliable discounting (all *t*s > 3.42) except for the low belief/low covariation condition, $t(71) = .95$, $SE = .30$. Of special interest is the high belief/low covariation ($\Delta P_i = .5$) condition. Here, reliable discounting was observed even though the second cause was less contingent than the first cause. In other words, if one defines causal strength strictly in terms of covariation, a weaker cause can reduce judgments of a stronger cause, provided that the cause is believable. Furthermore, reliable discounting occurred even when the candidate and the alternative were of equal contingency ($\Delta P_i = .67$), irrespective of their believability. These findings challenge traditional associative theories (e.g., Baker et al., 1993; Rescorla & Wagner, 1972) because such theories posit that discounting should occur only when cues possess differing contingencies from the effect.

JUDGMENTS FOR THE ALTERNATIVE CAUSE

Figure 2 presents the mean likelihood ratings for the alternative cause as a function of belief and ΔP. The likelihood ratings for the alternative cause were analyzed using a 2 x 3 (Belief x ΔP) repeated measures ANOVA. This analysis revealed a significant main effect of belief, $F(1,71) = 40.77$, $MSE = 1{,}056.67$, $\eta^2 = .37$, where causality judgments for the alternative cause were greater for the believable alternatives ($M = 60.2$) than for the unbelievable alternatives ($M = 40.2$). There was also a main effect of ΔP, $F(2,142) = 50.0$, $MSE = 1{,}004.62$, $\eta^2 = .41$, where causality judgments for the alternative cause increased as a function of increases in ΔP (*M*s = 32.8, 47.8, and 70.0). The Belief x ΔP interaction was not significant ($F < 1$).

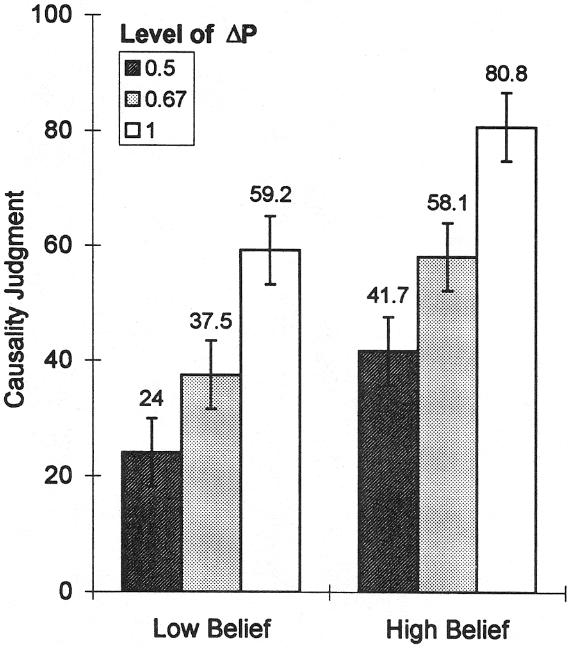

Figure 2. Mean likelihood ratings for the alternative cause as a function of believability and ΔP.

Discussion

The results of this experiment demonstrate that when dealing with multiple potential causes for a single effect, the evaluation of causal strength is not determined solely by its contingency with the observed effect. Rather, judgments of causal strength are strongly influenced by both the covariation and the believability of competing causes. In addition, our results allow us to make inferences regarding how covariation- and belief-based information combine to produce discounting.

First, when dealing with contextually rich materials, it appears that the alternative must be equal to, or exceed, the candidate cause along at least one dimension for discounting to occur. That is, if the alternative is less believable *and* covaries less strongly than the candidate, then it does not reduce the perceived causal efficacy of the candidate cause. However, the presence of either type of cue is sufficient to produce discounting. In other words, if the alternative cause is *either* more plausible *or* covaries more strongly than the candidate, then the perceived causal efficacy of the candidate cause is reduced. Indeed, it appears that a weaker covariate can reduce the perceived causal efficacy of a stronger covariate, provided that it is highly believable. In addition, a moderately contingent alternative can reduce judgments of a moderately contingent candidate, even when the alternative is of low belief. These results suggest that participants are still utilizing covariation evidence to assess the predictive utility of unbelievable covariates, and as such, are using this information to discount the candidate under consideration.

These findings (at least with respect to discounting as a function of ΔP) can be explained in terms of the conditionalizing of one candidate on another. Here, if there exists multiple potential competing causes for a single given effect, it is postulated that individuals tend to evaluate each cause by holding constant the effects of other causes (Spellman, 1996). Therefore, it could be argued that the discounting observed in the current experiment may simply reflect this function. For example, consider the case when the unconditional contingency for the alternative cause was equal to 1, and the unconditional contingency for the candidate cause was equal to .67. If one were to compute the conditional contingency (the influence of the candidate cause independent of the influence of the alternative cause), the resultant conditional ΔP of the candidate cause would equal 0. This is because the candidate cause does not have an influence independent of the alternative cause. That is, when the effect occurs every time the alternative cause is present, [P(e/i) = 1], and never when the alternative cause is absent, [P(e/~i) = 0], any other candidate that has a smaller contingency with the *same* observed effect (i.e., $\Delta P_i < 1$), has a resultant conditional contingency of 0. Therefore, in cases such as these, the candidate cause may possess no independent predictive influence. As such, it could be argued that the observed discounting in this condition could result from the normative application of the conditional ΔP rule. However, a simple rule of conditionalizing cannot fully account for all of the observed data. Specifically, recall that the amount of discounting reliably increased as a function of the believability of the alternative cause. Although several authors do acknowledge the role of knowledge in causal discounting (e.g., Waldmann, 1996), they contend that the conditionalization process will only occur for plausible candidates. That is, if an alternative cause is not perceived as causal, then participants will not conditionalize on it. However, this was not the case in the present experiment: When the alternative cause was perfectly contingent ($\Delta P_i = 1$) and not believable, discounting still occurred.

Finally, our findings indicate that in multiple-cause scenarios, the contribution of ΔP and belief appeared to be additive. Thus, believable candidates produced more discounting than implausible candidates, and strong covariates produced more discounting than weak covariates. This finding is consistent with previous observations that the degree of discounting increases as a function of the covariation of the alternative cause (e.g., Baker et al., 1993). In contrast, when causes are assessed in isolation, the effects of ΔP and belief are consistently over-additive (Fugelsang & Thompson, 2000). This suggests that causal cues, such as ΔP and belief, may be processed differently in multiple- versus single-cause scenarios. For example, when presented with multiple-cause scenarios, participants may form an implicit theory of how the two causal agents interact with each other. One agent may be perceived as inhibiting or enabling the other cause (White, 1995), or the two may be perceived as either additive or redundant. Moreover, the roles that are assigned to each candidate may determine how ΔP and belief information is evaluated, perhaps even causing one of these cues to be overlooked entirely. This raises the interesting possibility that the degree to which the believability and ΔP of the alternative contributes to the discounting of the candidate cause may vary as a function of the causal role assigned to each. In scenarios such as ours, in which the candidate and alternative were presented as mutually exclusive candidates, ΔP and belief appeared to have additive effects; other relationships may be observed when different causal roles are assigned.

The present experiment set out to independently manipulate beliefs and covariation information in an orthogonal design. An implicit assumption of this approach is that beliefs can be represented independently of covariation information, although they may subsume the experience of prior contingencies. An alternative interpretation of what constitutes a belief is that it may be nothing more than knowledge of prior covariation information (e.g., Cheng & Lien, 1995). Although this is a theoretical possibility, Fugelsang and Thompson (2000) outlined several reasons for why it is unlikely. Their arguments stemmed from three basic observations: (a) People form causal attributions in the absence of any covariation information (e.g., Beasly, 1968; Boyle, 1960; Michotte, 1963), (b) people hold positive causal beliefs about things which in actuality do not covary, and (c) people have accurate causal beliefs about many phenomena with which they have not had prior experience and do not, therefore, possess the information needed to compute a covariation estimate. For these reasons, it seems likely that beliefs represent more than just beliefs about covariation information and thus deserve special consideration in models of causal discounting.

Together with previous findings, we can conclude that covariation- and belief-based cues contribute in two ways to the evaluation of a candidate cause. First, the perceived efficacy of the candidate increases as a function of its own plausibility and covariation (see also Fugelsang & Thompson, 2000). Second, the perceived causal efficacy of the candidate decreases as a function of the plausibility and covariation of any alternative that is present. These results indicate that a complete theory of human causality must incorporate the role of acquired beliefs in the assessment of causal strength.

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