Research Report

Discounting and Conditionalization

Dissociable Cognitive Processes in Human Causal Inference

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ABSTRACT—*When people are asked to judge the strengths of two potential causes of an effect, they often demonstrate discounting—devaluing the strength of a target cause when it is judged in the presence of a strong (relative to a weak) alternative cause. Devaluing the target cause sometimes results from conditionalization—holding alternative causes constant while evaluating the target cause. Yet discounting not attributable to conditionalization also occurs. We sought to dissociate conditionalization and discounting (beyond that accounted for by conditionalization) by having subjects perform either a spatial or a verbal working memory task while learning a causal relation. Conditionalization was disrupted by the verbal task but not the spatial task; however, discounting was disrupted by the spatial task but not the verbal task. Conditionalization and discounting are therefore cognitively dissociable processes in human causal inference.*

On a daily basis, humans make causal inferences based on the contingency between events. For instance, to determine whether your new shampoo gives you healthy hair, you compare the state of your hair after using the new shampoo with its state when you were buying the discount brand. Unfortunately, the world rarely provides isolated contingency information; instead, people must make causal inferences given contingency information about multiple potential causes. Is the new shampoo giving you that great shine, or is the new water softener responsible? When determining the cause of an event given information about multiple competing causes, humans both control for alternative causes and discount moderately effective causes in the presence of a highly causal alternative (Goedert & Spellman, 2005). In this article, we demonstrate that these aspects of causal inference rely on dissociable cognitive processes.

CONDITIONALIZATION

When judging a target cause of interest, people often demonstrate a *cue-interaction* effect: The strength of a moderate cause is discounted,[1] or devalued, when judged in the presence of a strong alternative cause (e.g., Baker, Mercier, Vallée-Tourangeau, Frank, & Pan, 1993). Sometimes this devaluing results from holding alternative causes constant (i.e., conditionalization). For example, suppose Figure 1c depicts the outcomes for a patient whose physician has prescribed both a nasal steroid and an antihistamine to treat allergies. One can assess the causal strength of the antihistamine treatment by determining the contingency between antihistamine use and allergy relief (albeit this is not the only way; see De Houwer & Beckers, 2002, for a review). Critical to this assessment are the probabilities of the effect (E) given the presence and the absence of the candidate cause (C). These probabilities are represented as $P(\mathrm{E|C})$ and $P(\mathrm{E|{\sim}C})$, respectively. The change in probability (ΔP) due to the presence of the candidate cause is computed as

$$\Delta P = P(\mathrm{E|C}) - P(\mathrm{E|{\sim}C}).$$

ΔP varies between -1 and $+1$. A nonzero ΔP indicates a statistical relationship between the candidate cause and the effect.

The proportions outside the right-hand side of the table in Figure 1c can be used to calculate the ΔP for antihistamine use and allergy relief. Overall, the patient experienced relief on 24 of the 36 days when she took the antihistamine and on 12 of the 36 days when she did not. Calculating ΔP yields a contingency of .33; the antihistamine appears moderately successful. In this

[1]Kelley introduced two uses of the term discounting: (a) a decrease in confidence that cause X was present when told that cause Y was also present (Kelley, 1972b) and (b) a decrease in the evaluation of the strength of cause X when learned about in the presence of cause Y (Kelley, 1972a). We use the term in accord with this latter usage.

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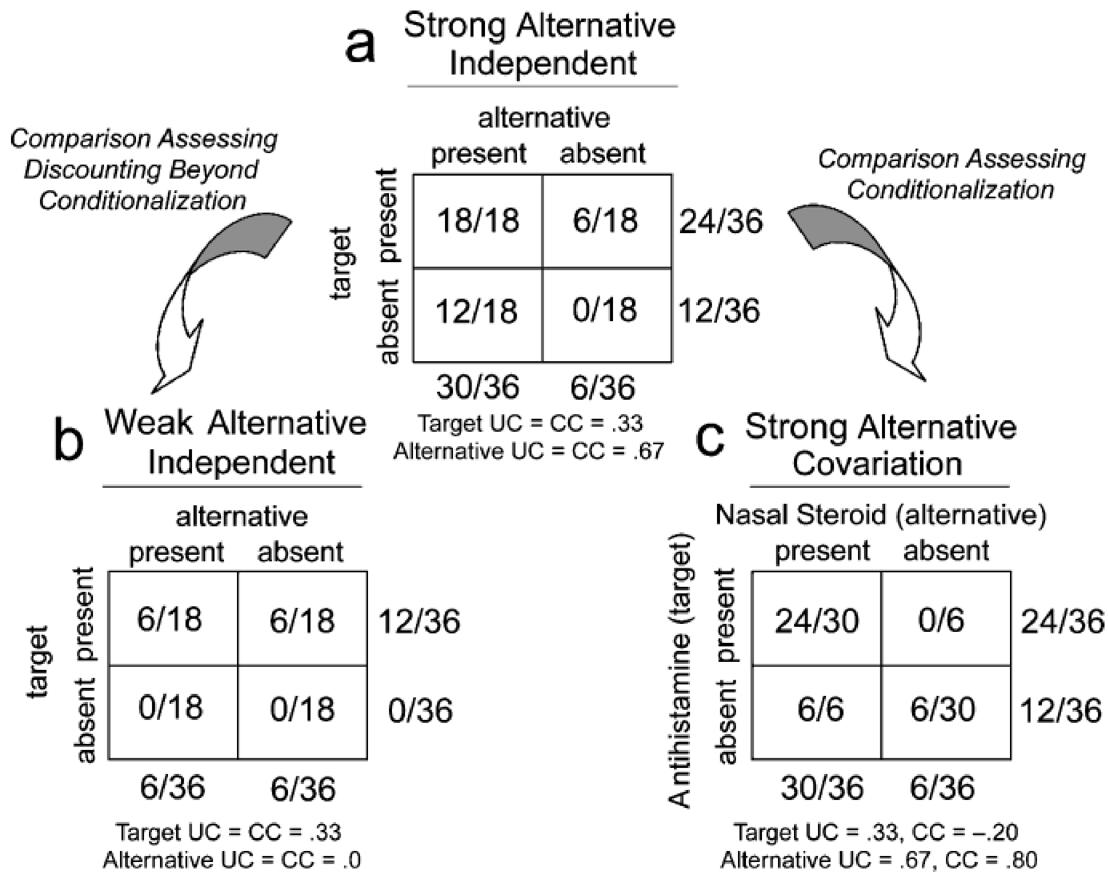

Fig. 1. Event proportions and target and alternative contingencies in the (a) strong-alternative independent (SA-Ind) condition, (b) weak-alternative independent (WA-Ind) condition, and (c) strong-alternative covariation (SA-Cov) condition (showing outcomes associated with use of a nasal steroid and antihistamine to treat an allergy). Proportions in the cells represent the number of times the outcome occurred with that combination (numerator) and the number of times that combination was used (denominator). UC = unconditional contingency; CC = conditional contingency.

instance, we evaluated the effect of the antihistamine without regard to the presence of other causally relevant factors (i.e., the steroid) by calculating the unconditional contingency (UC).

In the case of multiple causes, however, people use the conditional contingency (CC), which takes into account the presence of alternative causes (e.g., Spellman, 1996). To evaluate the success of the antihistamine while controlling for the alternative cause of the steroid, we consider only those days when the steroid was not used and take the difference between the probability of allergy relief when the antihistamine was used and that when it was not.[2] This CC, conditionalized on the absence of the steroid, is −.20. Thus, the antihistamine actually has a negative effect—it only seems to have a positive effect because the occurrence of the antihistamine covaries with that of the steroid.

DISCOUNTING BEYOND CONDITIONALIZATION

Although conditionalization may result in a devaluing of the target cause (because the CC is less than the UC), discounting beyond that which can be explained by conditionalization also occurs. The presence of a strong alternative cause decreases the perceived efficacy of a moderately strong target even when there is no reason to conditionalize on the alternative (e.g., Baker et al., 1993; Busemeyer, Myung, & McDaniel, 1993; Goedert & Spellman, 2005). For example, Figure 1b depicts the frequency information for a moderately contingent target cause (UC = CC = .33) and an alternative that is not contingent (UC = CC = 0). Figure 1a also depicts the frequencies for a moderately contingent target (UC = CC = .33), but in this case, the alternative is strongly contingent with the outcome (UC = CC = .67). In both cases, the occurrence of the target and the occurrence of the alternative are independent of one another (hence, UC = CC for both candidate causes). Yet subjects rate the target less causal when the alternative is strong (Fig. 1a) than when it is weak (Fig. 1b; Goedert & Spellman, 2005).

CONDITIONALIZATION VERSUS DISCOUNTING: THE PRESENT EXPERIMENT

Researchers of contingency learning, causal reasoning, and causal attribution have not been unequivocally clear in differ-

[2]In the current experiment, CCs based on the presence and on the absence of the alternative were equal.

entiating between forms of cue interaction. The term *discounting* is used to refer to both devaluing that can be explained by conditionalization (Vallée-Tourangeau, Baker, & Mercier, 1994; Van Overwalle & Van Rooy, 2001) and devaluing that cannot be so explained (Busemeyer et al., 1993; McClure, 1998); some researchers, however, have claimed that the term discounting should apply only to the latter case (e.g., Gilbert & Malone, 1995).

We investigated whether conditionalization and discounting are distinct cognitive processes by examining whether they are differentially affected by concurrent performance of spatial or verbal working memory tasks. Subjects rated the effectiveness of two potential cures for a disease after encoding the contingencies in a series of trials while performing a working memory task. We assessed discounting that occurs beyond conditionalization by comparing causal judgments in two conditions in which the target's UC and CC were equal (both .33), but in which the strength of the alternative varied (.67 or 0; see Figs. 1a and 1b). If subjects rated the target less causal when the alternative was strong, that would be evidence of discounting. We assessed conditionalization by comparing judgments in two conditions in which there were strong alternatives. In one, the target's UC and CC were equal (both .33); in the other, the target's UC and CC were not equal (UC = .33; CC = −.20; see Figs. 1a and 1c). If subjects rated the target less causal in this latter condition, in which the target and the alternative covaried, that would be evidence of conditionalization.

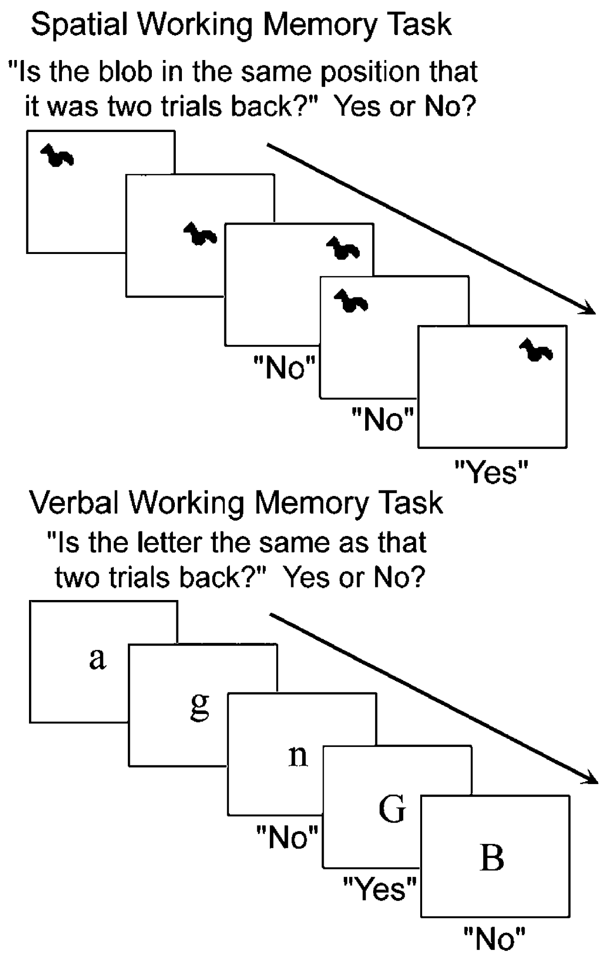

Fig. 2. Depiction of the spatial (top) and verbal (bottom) two-back working memory tasks.

METHOD

Subjects

One hundred thirty-two right-handed undergraduates participated for $6.00 or as a course requirement.

Design

We manipulated two between-subjects factors: working memory task (spatial, verbal) and the contingency between the cause and effect (weak-alternative independent, WA-Ind; strong-alternative independent, SA-Ind; and strong-alternative covarying, SA-Cov). The contingencies appear in Figure 1.

Materials and Procedure

Subjects performed concurrent prediction and working memory tasks after practicing with each task individually. For the prediction task, subjects evaluated two potential cures for a deadly virus by monitoring patient outcomes. Each prediction trial began with a 1,000-ms warning. Subjects then saw a line drawing depicting one of the possible combinations of treatments being administered to a patient. Subjects were asked to indicate within 2,500 ms whether they thought the patient would be cured. They then saw a picture depicting whether the patient was cured (1,000 ms). Seventy-two prediction trials were divided into six identical blocks and then randomized within block.

Subjects also performed one of the two-back working memory tasks in Figure 2 (Jonides et al., 1993; Paulesu, Frith, & Frackowiak, 1993). In the spatial task, a figure appeared in 1 of 8 spatial locations, and the subject determined whether the figure was in the same position as in the trial two trials back. In the verbal task, 1 of 8 letters appeared centrally, and the subject determined whether the letter was the same as that two trials back. There were 16 different verbal stimuli (the lower- and uppercase letters *a*, *e*, *g*, *h*, *k*, *r*, *t*, and *v*). To minimize reliance on the visual representation of the letters, we instructed subjects to make a "yes" response when the letters matched, regardless of case. In both tasks, the stimulus terminated if the subject did not respond within 3,000 ms.

The prediction and working memory tasks were interleaved, such that prior to each prediction trial, subjects saw a working memory stimulus. Because subjects received a break between Blocks 3 and 4, there were 68 working memory trials on which subjects could make a response (the first 2 trials at the outset of

Blocks 1 and 4 had no comparison stimuli that were "two back"). Positive responses were correct on 15 of the 68 trials.

At the midpoint and then after the final trial, subjects rated the effectiveness of each of the potential cures on a scale from −100 to +100 (−100 indicating a total patient killer, +100 indicating a total patient saver, and 0 indicating no effect) and received feedback regarding their accuracy on the working memory task.

RESULTS

Working Memory Performance

Subjects performed above chance on both the spatial and the verbal working memory tasks (means of 56% and 58% correct, respectively; chance = 12.5%). Although the working memory tasks proved difficult, subjects' accuracy did not differ between the two working memory conditions, $F < 1$.

Causal Ratings

Target

Final ratings for the target treatment, which are critical to the assessment of conditionalization and discounting, appear in Figure 3. For purposes of comparison, we have included in the figure data from a very similar study with no concurrent task (Goedert & Spellman, 2005, Experiment 1, which used the same contingencies but a different cover story). In that study, subjects demonstrated significant conditionalization and discounting.

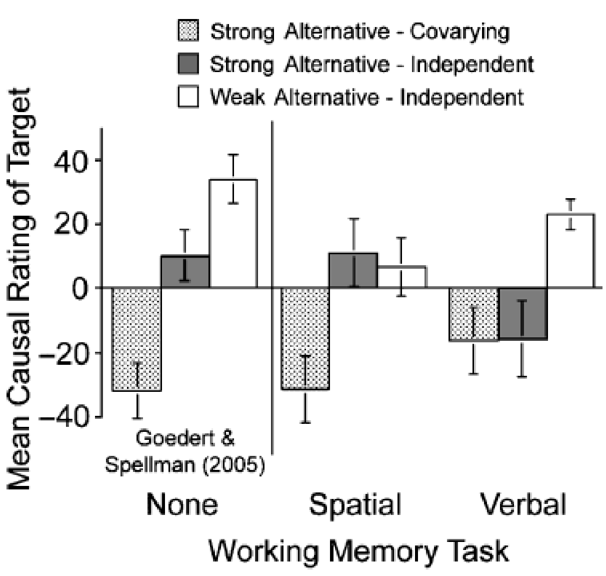

Fig. 3. Causal ratings for the target treatment as a function of working memory task and contingency condition. For comparison purposes, the left-hand panel illustrates data obtained from a previous experiment (Goedert & Spellman, 2005, Experiment 1) in which subjects did not perform a concurrent working memory task. In both the weak-alternative and the strong-alternative independent conditions, the conditional contingency for the target was .33. In the strong-alternative covariation condition, it was −.20. Error bars represent ± 1 *SE*.

In the current study, discounting was eliminated by the spatial task but not the verbal task; conversely, conditionalization was eliminated by the verbal task but not the spatial task. An analysis of variance on the final ratings for the target with working memory task (spatial, verbal) and contingency (SA-Cov, SA-Ind, WA-Ind) as factors yielded an effect of contingency, $F(2, 131) = 7.85$, $MSE = 2{,}171$, $p < .001$, $\eta^2 = .11$; an interaction, $F(2, 131) = 3.17$, $p = .045$, $\eta^2 = .05$; and no main effect of task, $F < 1$. In the spatial conditions, subjects rated the target lower in the SA-Cov (CC = −.20) than in the SA-Ind (CC = .33) condition, $F(1, 44) = 8.16$, $p = .007$, $\eta^2 = .16$, demonstrating conditionalization. However, these subjects did not give different ratings to the target in the SA-Ind and WA-Ind (CC = .33) conditions, $F < 1$, indicating that they did not discount. In the verbal conditions, subjects did not rate the target differently in the SA-Cov and SA-Ind conditions, $F < 1$, indicating that they did not conditionalize. They did, however, give lower ratings to the target in the SA-Ind than in the WA-Ind condition, $F(1, 44) = 9.24$, $p = .004$, $\eta^2 = .17$, demonstrating discounting.

Alternative

Causal ratings of the alternative are not critical to the assessment of discounting, but they do bear on the interpretation of the ratings for the target (e.g., subjects under different memory demands could have differentially attended to the alternative). Also, as the CC for the alternative was different in the SA-Cov and SA-Ind conditions, subjects may have demonstrated conditionalization when evaluating the alternative. An analysis of variance on the final ratings of the alternative yielded an effect of contingency, $F(2, 131) = 36.67$, $MSE = 2{,}298$, $p < .001$, $\eta^2 = .36$, and no other effects. As depicted in Figure 4, ratings of the alternative followed its CC. Subjects rated the alternative higher in the SA-Cov condition (CC = .80) than in the SA-Ind condition (CC = .67), $F(1, 129) = 12.47$, $p = .001$, $\eta^2 = .09$, reflecting conditionalization, and higher in the SA-Ind than in the WA-Ind condition (CC = 0), $F(1, 130) = 77.59$, $p < .001$, $\eta^2 = .37$, reflecting its actual much smaller contingency.

DISCUSSION

Our results suggest that conditionalization and discounting are dissociable cognitive processes, as we found a double dissociation between type of working memory task and type of cue interaction. When subjects rated the target, the verbal working memory task interfered with conditionalization but not discounting. The spatial working memory task, however, interfered with discounting but not conditionalization.

One possible effect of memory demands is to interfere with the encoding of the contingency information overall (e.g., Shaklee & Mims, 1982). In our experiment, the two working memory tasks had different effects on the ratings of the target, but they did not have different effects on the ratings of the alternative. Therefore, differences in the performance of the verbal and spatial groups

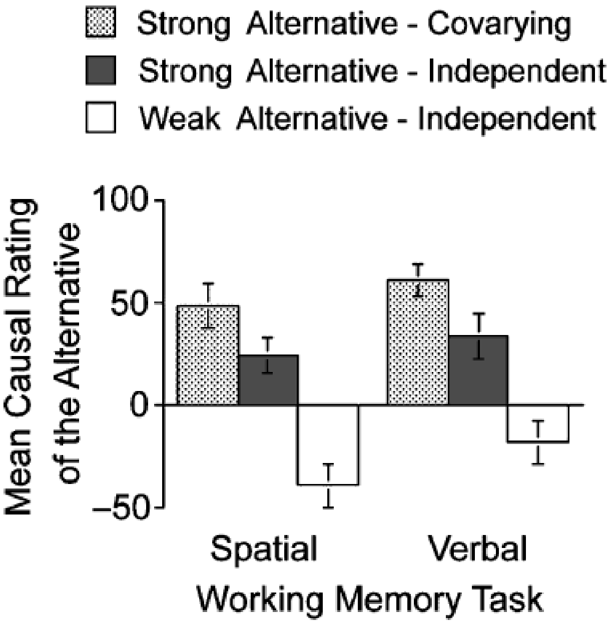

Fig. 4. Causal ratings for the alternative treatment as a function of working memory task and contingency condition. The conditional contingency for the alternative was .80 in the strong-alternative covariation condition, .67 in the strong-alternative independent condition, and 0 in the weak-alternative independent condition. Error bars represent ±1 *SE*.

cannot be attributed to differences in the way those tasks affected the contingency acquisition process per se.

Whereas the verbal working memory group did not conditionalize when evaluating the moderately contingent target, the ratings of the strong alternative indicate that subjects were able to control for a competing cause when evaluating the stronger of the two treatments. This result suggests that subjects in both working memory groups may have preferentially attended to the stronger of the two causes; only when resources were extremely taxed (as was the case for evaluating the target) did the different effects of the working memory tasks emerge.[3]

Current models of contingency learning and causal attribution fail to acknowledge a distinction between different forms of cue interaction (e.g., Cheng, 1997; Denniston, Savastano, & Miller, 2001; Van Overwalle & Van Rooy, 2001). Statistical models of causal reasoning such as the probabilistic contrast model (Cheng & Novick, 1990) or Cheng's (1997) Power PC model do not predict that discounting, outside of conditionalization, will occur. Likewise, traditional associative models (e.g., Rescorla & Wagner, 1972) converge on the predictions of the statistical models when learning is at asymptote. Whereas two associative models, Miller and Matzel's (1988) comparator model and the extended comparator hypothesis (Denniston et al., 2001), both predict discounting, neither model distinguishes conditionalization from other forms of cue interaction. Our results demonstrate that controlling for alternative causes is a process that is distinct from discounting. Such differences must be addressed in future empirical studies and theoretical formulations.

[3]We cannot make a similar assessment of discounting of the alternative as this would require comparison with a strong alternative, and the alternative *was* the strong alternative.

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