THINKING & REASONING, 2006, 12 (1), 1–30

Psychology Press
Taylor & Francis Group

Examining the representation of causal knowledge

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Three experiments investigated reasoners' beliefs about causal powers; that is, their beliefs about the capacity of a putative cause to produce a given effect. Covariation-based theories (e.g., Cheng, 1997; Kelley, 1973; Novick & Cheng, 2004) posit that beliefs in causal power are represented in terms of the degree of covariation between the cause and its effect; covariation is defined in terms of the degree to which the effect occurs in the presence of the cause, and fails to occur in the absence of the cause. To test the degree to which beliefs in causal power are reflected in beliefs about covariation information, participants in three experiments rated their beliefs that putative causes have the capacity to produce a given effect (i.e., possess the causal power to produce an effect) as well as their beliefs regarding the degree to which the putative cause and effect covary. A strong positive correlation was discovered between participants' beliefs in causal power and their beliefs that the effect occurs in the presence of the cause. However, no direct relationship was found between participants' beliefs in causal power and their belief that the effect will fail to occur in the absence of the cause. These findings were replicated using both within- (Experiments 1 and 3) and between-subject designs (Experiment 2). In Experiment 3, we extended these analyses to measures of familiarity, imageability, and detailedness of the representation. We found that participants' beliefs in causal power were strongly associated with familiarity, and imageability, but not the perceived detailedness of the cause and effect

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We would like to thank Ron Borowsky, Marc Buehner, Jamie Campbell, David Green, David Lagnado, David Over, and Courtney Stein for comments and helpful suggestions on a previous version of this manuscript. This research was supported by a postgraduate scholarship from the Natural Sciences and Engineering Research Council of Canada (NSERC) awarded to Jonathan Fugelsang, an NSERC discovery grant awarded to Valerie Thompson, and a Dartmouth College research grant awarded to Kevin Dunbar.

http://www.psypress.com/tar DOI: 10.1080/13546780500145678

relationship. These data provide support for a multidimensional account of causal knowledge whereby people's representations of causation include, but are not limited to, the covariation, familiarity, and imageability of cause and effect relationships.

For over 400 years, researchers in a wide variety of disciplines have investigated the ways that people come to know that one event causes another. The predominant view of human causal thinking follows the Humean tradition of radical empiricism (Hume, 1739/1978) wherein all notions of causality are thought to be deduced from observable statistical regularities. Models of causality following this theoretical tradition can be subsumed under the label "Covariation-based models". Covariation-based models (e.g., Cheng, 1997; Cheng & Novick, 1990, 1992; Hilton & Slugoski, 1986; Kelley, 1973; Novick & Cheng, 2004; White, 2002b) are based on the assumption that an event that exhibits a regularity of association with an effect (i.e., covaries with 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. Belief-based representations (i.e., beliefs in causal power) of cause and effect relationships are also proposed to reflect experience with covariation information (Cheng & Lien, 1995; Kelley, 1973; Lien & Cheng, 2000; Young, 1995). Specifically, believable causal candidates are those that are known to covary with the effect; unbelievable candidates are those that are known to show little covariation with the effect. For example, drinking water might not be perceived as possessing the causal power to produce an allergic reaction because in the reasoner's experience drinking water has not been associated with negative physiological symptoms of this kind. Thus, according to such models, beliefs in causal power are assumed to reflect knowledge regarding the degree of covariation between a putative cause and effect.

Knowledge regarding the degree of covariation between a cause and effect is thought to reflect two components: the probability that the effect occurs in the presence of a potential cause [hereafter denoted $P(e|c)$], and the probability that the effect occurs in the absence of a potential cause [hereafter denoted $P(e|\text{-}c)$]. The roles of $P(e|c)$ and $P(e|\text{-}c)$ have featured prominently in contemporary models of causality. For example, Kelley's (1973) ANOVA model, Hilton and Slugoski's (1986) abnormal conditions focus model, Cheng and Novick's (1990, 1992) probabilistic contrast model, and Cheng's power PC theory (Cheng, 1997; Novick & Cheng, 2004) have all delineated a primary role for $P(e|c)$ and $P(e|\text{-}c)$ in human notions of causality. Take, for instance, the probabilistic contrast model (Cheng & Novick, 1990). This model, and its successor the power pc theory (Cheng, 1997), assumes that causal judgements are based in part on the computation of covariation (denoted ΔP_c) constrained by a contextually determined focal set by subtracting the probability of the effect occurring in the absence of a cause [$P(e|\text{-}c)$] from the probability of the effect occurring in the presence of the cause [$P(e|c)$]. If ΔP_c is positive, then the candidate cause (*c*) should be judged to be a facilitatory factor in producing the effect (*e*). If ΔP_c is negative, the potential cause (*c*) should be judged to be an inhibitory factor. Finally, when ΔP_c is zero, the candidate cause (*c*) should be judged as a non-causal factor with respect to the observed effect (*e*).

Research has generally found, however, that people do not weigh $P(e|c)$ and $P(e|\text{-}c)$ equally when judging causal relationships (e.g., Anderson & Sheu, 1995; Downing Sternberg, & Ross, 1985; Klayman & Ha, 1987; Mandel & Lehman, 1998; Over & Green, 2001; Schustack & Sternberg, 1981; White, 2002a, 2002b), even when they are explicitly provided with both sources of information (Wasserman, Dorner, & Kao, 1990). Specifically, in such cases reasoners typically give more weight to the evidence concerning $P(e|c)$ than to $P(e|\text{-}c)$. This *bias* has been observed in both causal and non-causal domains using a variety of task objectives. Similarly, when asked to judge the importance of $P(e|c)$ and $P(e|\text{-}c)$ information, the former is judged more critical than the latter (Wasserman et al., 1990). Based on these findings, recent models have devised modified algorithms that more accurately reflect this unequal weighting of $P(e|c)$ and $P(e|\text{-}c)$ information in judgements of causality (Anderson & Sheu, 1995; Cheng, 1997; Novick & Cheng, 2004; White, 2002b). Perhaps the most widely cited of these models is Cheng's power PC theory (Cheng, 1997; Novick & Cheng, 2004). She proposes that causal strength (denoted p_c) is best served by a function that divides the covariation (ΔP_c) of a given cause and effect relationship by the inverse of the base-rate [$1\text{-}P(e|\text{-}c)$] of that effect, thus buffering the impact that $P(e|\text{-}c)$ has in judgements of causality.

In summary, past research has clearly demonstrated that (1) people's causal judgements are strongly influenced by the degree of covariation between the cause and effect, and (2) people generally display a bias towards evaluating the $P(e|c)$ of a candidate cause more heavily than the $P(e|\text{-}c)$ of a candidate cause. The degree to which such cues to causality also form the basis of the representation of causal knowledge (i.e., one's belief in causal power) is unknown. Support for such representations of causal knowledge would be provided by the degree to which people's *belief* in the capacity of putative causes to produce effects is related to their *belief* in the degree to which they covary. This hypothesis is examined in the present series of experiments by systemically examining the role of $P(e|c)$ and $P(e|\text{-}c)$ in pre-existing representations of beliefs about causal powers.

TERMINOLOGY

Since the reported experiments contain both independent and dependent variables regarding beliefs about causal powers and the covariation of causal candidates, we have adopted the following terminology in order to simplify the dissemination of the findings. In this manuscript we will refer to the independent variables containing these manipulations as BELIEF and COVARIATION manipulations. These manipulations comprise pre-selecting stimuli that vary in terms of one's pre-existing beliefs about the propensity of a given causal candidate to produce a given effect (i.e., BELIEF in the causal power of an object or event) and one's pre-existing knowledge about the degree to which a given potential cause and effect co-occur together (i.e., beliefs about degree to which two variables possess a positive COVARIATION).

The effects of these independent variables will be examined with respect to how they influence participants' ratings of the degree to which they *can* cause a specific outcome (i.e., causal power rating), the degree to which the given effect will occur in the presence of the cause (i.e., $P(e/c)$ rating), and the degree to which the given effect will occur in the absence of the cause (i.e., $P(e/\text{-}c)$ rating). For the purposes of the present investigation, it is of primary interest to examine the degree to which these dependent variables [i.e., ratings of causal powers, $P(e/c)$ and $P(e/\text{-}c)$] correlate with one another. In order to further distinguish the independent and dependent variables, the independent variables (i.e., the pre-selection of stimuli designed to vary orthogonally in terms of BELIEF in causal power and COVARIATION information) will be presented in upper case.

EXPERIMENT 1

The goal of Experiment 1 is to provide a direct test of the relationship between $P(e/c)$ and $P(e/\text{-}c)$ to reasoners' beliefs in causal power. To do this, we presented participants with a series of causal scenarios that depicted putative causes and effects, and simply asked them to rate their believability in terms of causal power, and rate their beliefs in $P(e/c)$ and $P(e/\text{-}c)$ information.

Method

Participants. A total of 60 first-year psychology students from the University of Saskatchewan, with a mean age of 19.0 (range 17–25), completed the study in partial fulfilment of a course requirement.

Materials and procedure. Ten story scenarios were constructed, which depicted an event that had happened and a possible cause for that event. Each scenario was presented with four possible causes. The four causal candidates were designed to vary orthogonally with respect to: (a) the believability of the causal power linking the cause and effect, and (b) the degree to which the cause and effect were believed to covary. Therefore, the presented causal candidates were chosen to be (1) high in BELIEF in causal power, and high in COVARIATION, (2) low in BELIEF in causal power, and high in COVARIATION, (3) high in BELIEF in causal power, and low in COVARIATION, and (4) low in BELIEF in causal power, and low in COVARIATION (see Appendix A for a complete list of stimuli used in Experiment 1).

Participants were first given a brief introductory paragraph, which depicted the event that had happened and a possible cause for that event. Following the introductory paragraph, they were asked to provide three judgements that rated: (1) their a priori beliefs in causal power, (2) their a priori beliefs in the probability that the effect will occur in the presence of the cause [i.e., $P(e|c)$], and (3) their a priori beliefs that the effect will fail to occur in the absence of the cause [i.e., $P(e|\text{-}c)$].

For the causal power rating, participants were asked to indicate whether they believed the causal agent in question *could cause* the given effect. That is, they were not asked to indicate whether the putative cause was actually responsible for the effect, merely whether it had the capacity to do so. Participants made their judgements on an 11-point Likert scale that ranged from 0 (not believable) to 10 (highly believable) with 5 (moderately believable) as the mid-point. For example, for the scenario regarding smoking causing lung cancer, they were given the following scenario:

> Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to smoking.
>
> How believable do you think it is that smoking *can cause* lung cancer?

Participants were then asked to rate how often they thought that the given causal candidate covaried with the given effect in terms of $P(e|c)$ and $P(e|\text{-}c)$. For the judgements of $P(e|c)$, participants were asked to estimate the frequency with which they believed the effect would occur in a sample of 10 events in which the cause was present. Participants were then asked to provide a judgement of $P(e|\text{-}c)$. To do this, participants were asked to estimate the frequency with which they believed the effect would occur in a sample of 10 events in which the cause was absent. For example, for the same scenario regarding smoking causing lung cancer, participants were given the following statement and two questions:

> To determine if there is a relationship between smoking and developing lung cancer, you examine 10 patients who were smoking and 10 patients who were not smoking.
>
> Of the 10 patients who were smoking, how many would you expect to have lung cancer?

> Of the 10 patients who were not smoking, how many would you expect to have lung cancer?

The 40 scenarios (10 effects × 4 different causal candidates) were each presented on a separate page in a different random order for each participant. All participants were tested in small groups of between four and eight people. Instructions were all written, so the experimenter gave only a brief introduction informing participants to complete the questions in the order in which they appeared and to work at their own pace. Participants were encouraged to ask any questions they might have at any time during the experiment.

Results

The results will be presented in two sections. The first section presents the mean analysis of the causal power, *P(e|c)*, and *P(e|-c)* estimates as a function of the manipulations of BELIEF in causal power and COVARIATION. The second section analyses the degree to which participants' judgements of causal power correlate with their judgements of *P(e|c)* and *P(e|-c)*. The alpha level for all statistical tests was set at .01 (two-tailed) unless otherwise stated. Effect size estimates were computed using partial η^2.

Means analysis. Figure 1 presents the mean causal power ratings, *P(e|c)* estimates, and *P(e|-c)* estimates as a function of the level of BELIEF and COVARIATION of the stimuli. The purpose of this first series of analyses is twofold. First, the means analysis serves as a manipulation check to determine the extent to which our stimuli, pre-selected to vary in terms of BELIEF in causal powers and COVARIATION, influence participants' judgements in the predicted manner. In addition, this analysis serves to provide an initial examination of the degree to which these variables influence participants' estimates of *P(e|c)* and *P(e|-c)*.

The omnibus 2 (causal BELIEF manipulation: low and high) × 2 (COVARIATION manipulation: low and high) for the three judgement types [causal power, *P(e|c), P(e|-c)*] ANOVA revealed a main effect of the BELIEF manipulation, $F(1, 53) = 759.55$, $MSE = 1.01$, $\eta^2 = .94$, whereby stimuli that were pre-selected to be highly believable in causal power did indeed result in higher judgements ($M = 5.45$) than stimuli pre-selected to be low in beliefs in causal power ($M = 3.26$). In addition, there was a main effect of the COVARIATION manipulation, $F(1, 53) = 343.79$, $MSE = 0.72$, $\eta^2 = .87$, such that stimuli that were pre-selected to be high in covariation resulted in higher judgements ($M = 4.97$) than stimuli pre-selected to be low in covariation ($M = 3.74$).

As is evident in Figure 1, judgements of causal powers, *P(e|c)*, and *P(e|-c)* are differentially influenced by the BELIEF and COVARIATION stimulus

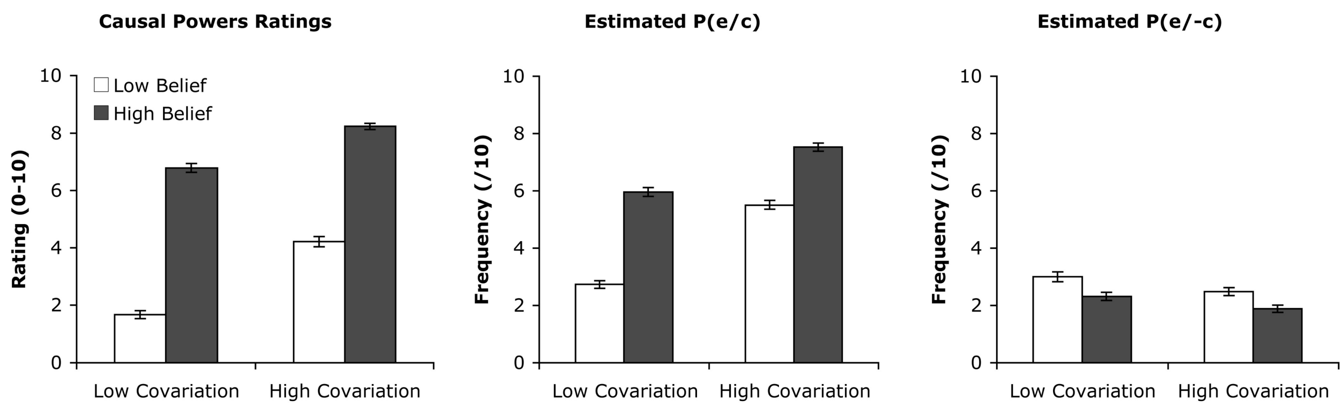

Figure 1. Mean causal power ratings, $P(e/c)$ estimates, and $P(e/\text{-}c)$ estimates as a function of the level of BELIEF (low and high) and COVARIATION (low and high) of the stimuli.

manipulations. This differential effect is further evidenced by the presence of interactions between the judgement type and the BELIEF manipulation, $F(2, 106) = 425.44$, $MSE = 0.86$, $\eta^2 = .89$, and the judgement type and the COVARIATION manipulation $F(2, 106) = 418.76$, $MSE = 0.29$, $\eta^2 = .89$. These interactions are mainly the product of a significantly reduced effect of the BELIEF and COVARIATION manipulations for the *P(e|-c)* estimates (mean BELIEF effect = .62, mean COVARIATION effect = .48) when contrasted with the effect of the BELIEF and COVARIATION manipulations for the causal powers judgements (mean BELIEF effect = 4.53, mean COVARIATION effect = 2.03) and the *P(e|c)* estimates (mean BELIEF effect = 2.61, mean COVARIATION effect = 2.15). Paired *t*-tests comparing the size of the effects of the BELIEF and COVARIATION manipulations for the three judgement types support this interpretation (*smallest* $t = 10.93$, $SE = .17$, $p < .01$). In summary, these analyses revealed that the BELIEF and COVARIATION manipulations successfully influenced participants' judgements in the predicted manner for the causal power ratings and the *P(e|c)* ratings. In addition, these analyses revealed that the BELIEF and COVARIATION manipulations had a larger effect for judgements of causal powers and *P(e|c)* than for *P(e|-c)*, suggesting a minimal relationship between participants' representations of causal power and their judgements regarding the degree to which the effect will fail to occur in the absence of a cause.

Correlational analyses.

The ratings obtained for the individual stimulus items are presented in Appendix B. Table 1 presents the correlations between participants' ratings for their beliefs in causal power, *P(e|c)* and *P(e|-c)*, for the 40 scenarios. In addition, we also include calculations of ΔP, and p_c in order to provide the reader with an estimate of the degree to which these descriptors may provide a better fit to the obtained data. Whereas a reliable positive correlation was discovered between participants' ratings of causal power and their *P(e|c)* ratings, $r(38) = +.83$, $p < .01$, no reliable correlation was observed between participants' ratings of causal power and their *P(e|-c)* ratings, $r(38) = -.20$, $p = .22$, despite adequate power to detect a correlation [$1 - \beta$ for ($r \geqslant .45$) = .80].[1] Thus, when participants perceived that a candidate cause had the capacity to produce a given effect, they also perceived that the probability that the effect would occur in the presence of the cause was high.

[1]The analyses for this experiment and subsequent experiments consist of zero order correlations between the ratings obtained for each of the stimuli. Therefore, the correlational analyses in Experiment 1 and 2 have 38 degrees of freedom (40 items) and Experiment 3 has 18 degrees of freedom (20 items). Note that the stability of these correlations is greatly increased due to the large number of subjects contributing to each data point (60 in Experiment 1, 91 in Experiment 2, and 40 in Experiment 3).

TABLE 1
Correlations between belief in causal power and measures of covariation for Experiment 1

Measure	*1*	*2*	*3*	*4*	*5*
1. Belief	—				
2. P(e/c)	+.83*	—			
3. P(e/-c)	−.20	+.14	—		
4. ΔP	+.88*	+.86*	−.38	—	
5. Power (p_c)	+.90*	+.88*	−.32	+.98*	—

*Correlation is significant at the .01 level.

In contrast, however, beliefs in causal power were unrelated to the perceived probability that the effect would occur in the absence of the candidate cause. Although perceived *P(e/-c)* was not directly linked to causal power, it did show a small residual relationship. A regression analysis demonstrated that *P(e/-c)* information accounted for an additional 10% of the variance in causal power ratings after the effects of *P(e/c)* had been accounted for, $R^2_{change} = .10$, $F(1, 37) = 17.61$, $p < .01$. Therefore, it appears that *P(e/-c)* information can contribute to beliefs in causal power only under conditions in which *P(e/c)* information has already been incorporated into one's internal representation of the cause and effect scenario. Taken together, these data provide support for weighted covariation-based models of causality (e.g., Cheng, 1997; White, 2002b) that assume a greater role of *P(e/c)* than *P(e/-c)* in representations of causal knowledge.[2] Although the non-independence of *P(e/c)* and *P(e/-c)* with ΔP and p_c does not allow a direct comparison using the adopted approach, one can see from Table 1 that these two algorithms do provide the largest correlation with participants' beliefs in causal powers.

EXPERIMENT 2

In Experiment 1, each participant was asked to rate all 40 candidates both in terms of their ratings of perceived causal power and in terms of their ratings of perceived covariation information as measured by the probability of the effect occurring in the presence and absence of the candidate cause. A

[2]When both *P(e/c)* and *P(e/-c)* are regressed on beliefs in a causal power, the obtained standardized beta coefficients suggest that *P(e/c)* provides over two times greater predictive influence of beliefs in causal powers than *P(e/-c)* in Experiment 1 [Causal Beliefs = $.875_{P(e/c)} - .319_{P(e/-c)}$], Experiment 2 [Causal Beliefs = $.685_{P(e/c)} - .327_{P(e/-c)}$], and Experiment 3 [Causal Beliefs = $.789_{P(e/c)} - .388_{P(e/-c)}$].

possible limitation of this approach is that participants' judgements of their beliefs in causal power may influence their judgements of their beliefs in covariation information. To remedy this, participants in Experiment 2 made *either* beliefs in causal power judgements, *or* beliefs in covariation judgements. Otherwise, this experiment was identical to Experiment 1.

Method

Participants. A total of 91 first-year psychology students from the University of Saskatchewan, with a mean age of 19.4 (range 17–41), completed the study in partial fulfilment of a course requirement.

Materials and procedure. The materials and procedure were identical to that of Experiment 1 with the following exceptions. Five causal candidates were changed to better fit the orthogonal presentation of BELIEF in causal power and COVARIATION information. These candidates are presented in Appendix C and denoted with an asterisk in Appendix D.

In addition, the beliefs in causal power and beliefs in covariation judgements were assessed between-subjects, such that one group of participants ($n = 46$) rated their beliefs in causal power of the given scenarios, and a second group of participants ($n = 45$) rated how often they felt that the given causal candidate covaried with the given effect in terms of both $P(e|c)$ and $P(e|\text{-}c)$. Assignment to the causal power rating and the covariation rating group was random. As was the case in Experiment 1, all participants were tested in small groups of between four and eight people.

Results

The ratings obtained for the individual items are presented in Appendix D. As the stimuli used in this experiment were identical (with the exception of five items), we will concentrate our analyses on the observed correlations between the dependent measures.[3] Table 2 presents the correlations between participants' ratings of their beliefs in causal power, $P(e|c)$, $P(e|\text{-}c)$, ΔP, and *pc* for Experiment 2. The data presented in the correlation matrix replicate and extend those observed in Experiment 1 and thus provide support for weighted covariation-based models of causality (e.g., Cheng, 1997; White, 2002b). Specifically, a reliable positive correlation was

[3]The overall pattern of data for the omnibus ANOVA between BELIEF and COVARIATION as a function of the three judgment types was replicated in Experiments 2 and 3. In order to maintain parsimony in the dissemination of the remainder of the findings, these analyses will not be presented. However, the mean pattern of these data can be extrapolated from the raw scores in Appendix D and E.

TABLE 2
Correlations between belief in causal power and measures of covariation for Experiment 2

Measure	*1*	*2*	*3*	*4*	*5*
1. Belief	—				
2. P(e/c)	+.62*	—			
3. P(e/-c)	−.19	+.19	—		
4. ΔP	+.70*	+.87*	−.31	—	
5. Power (p_c)	+.70*	+.91*	−.19	+.98*	—

*Correlation is significant at the .01 level.

discovered between participants' ratings of belief in causal powers and belief in *P(e/c)*, $r(38) = +.62$, $p < .01$. However, no reliable correlation was observed between participants' ratings of belief in a causal power and belief in *P(e/-c)*, $r(38) = -.19$, $p = .24$. In line with Experiment 1, separate regression analyses were performed to see if *P(e/-c)* contributes any unique predictive value of beliefs in causal power once the effects of *P(e/c)* are controlled for. As was found in Experiment 1, *P(e/-c)* accounted for an additional 10% of the belief in causal power variance over and above that predicted by *P(e/c)* alone, $R^2_{change} = .10$, $F(1, 37) = 7.39$, $p = .01$. See footnote 2 for the obtained regression equation with both *P(e/c)* and *P(e/-c)* as predictors of belief in causal power for Experiment 2.

EXPERIMENT 3

In the previous two experiments, we demonstrated that participants' beliefs in causal power are represented more in terms of the perceived *P(e/c)* than of the perceived *P(e/-c)* of the candidate cause under consideration. It is the goal of the third experiment to assess alternative metrics that may contribute to one's belief in causal power in addition to those of *P(e/c)* and *P(e/-c)*. In contrast to proponents of covariation-based models, many researchers claim that causal beliefs can constitute knowledge of causal mechanisms that can be held independently of knowledge of covariation information (Ahn, Kalish, Medin, & Gelman, 1995; Fugelsang & Dunbar, 2005; Fugelsang, Roser, Corballis, Gazzaniga, & Dunbar, 2005; Fugelsang, Stein, Green, & Dunbar, 2004; Fugelsang & Thompson, 2003; Harre & Madden, 1975; Roser, Fugelsang, Dunbar, Corballis & Gazzaniga, in press; Shultz, 1982; Shultz, Fisher, Pratt, & Rulf, 1986; White, 1989, 1995). However, little is known about the actual nature of such alternative representations of mechanism-based causal knowledge. Knowledge of past covariation information, and/or knowledge of mechanism-based cues may be derived and represented from a variety of distinct and interrelated modalities.

Much can be learned about belief-based representations of causal knowledge by extrapolating from research conducted in concept representation (e.g., Medin, Lynch, & Solomon, 2000) and deductive reasoning (e.g., Evans, 2003; Feeney, Evans, & Clibbens, 2000; Johnson-Laird, 1983, 2001). For example, one's belief in causal power may be influenced by how typical or familiar one is with a specific example under consideration (Choi, Nisbett, & Smith, 1997; Kahneman & Tversky, 1996; Ram, 1993; Shafir, Smith, & Osherson, 1990). Furthermore, the extent to which an individual can create a mental image of the interaction between a specific cause and effect may influence the believability of that cause as possessing the necessary mechanism to be responsible for the observed effect (Baird & Fugelsang, 2004; Clement & Falmagne, 1986; De Soto, London, & Handel, 1965; Fugelsang & Dunbar, 2005; Kahneman & Tversky, 1982; Pearson, Logie, & Gilhooly, 1999). For example, research on counterfactual thinking by Kahneman and Tversky (1982) suggests that people may spontaneously run image-based "*if then*" simulations of alternative outcomes when they are presented with various scenarios that do not conform to one's beliefs and expectations (see also Baird & Fugelsang, 2004). As such representations have been shown to play an integral role in knowledge representations in other domains, it is reasonable to assume that these representations may inform one's belief in causal power. Furthermore, the degree to which an individual can create a detailed graphical model of the cause, and the nature of that graphical model, may inform the degree to which they believe that the candidate possesses the causal power to produce the observed effect (Glymour, 2001; Green & McManus, 1995; Green, McManus, & Derrick, 1998). In the following experiment, we provide a first step in this direction by examining the degree to which reasoners' beliefs in causal power are related to (1) familiarity, (2) imageability, and (3) the detailedness of representation. In addition, participants in this experiment were asked to make the same covariation estimates as in the preceding two experiments.

Method

Participants. A total of 40 introductory psychology students from Dartmouth College, with a mean age of 18.8 (range 18–21), completed the study in partial fulfilment of a course requirement.

Materials and procedure. The materials and procedure were identical to that of Experiment 1 with the following exceptions. Due to the increased time required for the additional judgements in this experiment, we opted to use 20 of the 40 stimuli. These stimuli and subsequent ratings appear in Appendix E.

As with Experiments 1 and 2, following the introductory paragraph participants were asked to rate: (1) their a priori beliefs in causal powers, (2) their a priori beliefs in $P(e|c)$, and (3) their a priori beliefs in $P(e|\text{-}c)$.[4] However, due to the subsequent ratings, we changed the causal power rating scale to reflect a 7-point Likert scale ranging from 1 (not believable) to 7 (highly believable) with 4 (moderately believable) as the mid-point. The $P(e|c)$ and $P(e|\text{-}c)$ ratings were identical to those used in Experiments 1 and 2.

Participants were then asked to rate the familiarity of the cause and effect sequence. For these judgements, participants were asked to rate how familiar they were with the specific candidate cause in acting as a precursor to the effect, using a 7-point Likert scale ranging from 1 (not familiar) to 7 (highly familiar) with 4 (moderately familiar) as the mid-point. Participants were then asked to rate the imageability of the cause and effect scenario. For these ratings, participants were asked to rate the degree to which they could create a mental image of the cause actually producing the effect, using a 7-point Likert scale ranging from 1 (not imageable) to 7 (highly imageable) with 4 (moderately imageable) as the mid-point. In order to assess the level of detail of the participants' representation of the candidate cause and subsequent effect, participants were asked to draw a flow chart explicitly depicting how the candidate cause could produce the observed effect. They were instructed to include all factors or events that were involved in the process and how they thought they were inter-related. As was the case in Experiments 1 and 2, all participants were tested in small groups of between four and eight people.

Results

The ratings obtained for the individual items are presented in Appendix E. Table 3 presents the correlations between participants' ratings for their beliefs in causal power, $P(e|c)$, $P(e|\text{-}c)$, ΔP, p_c, familiarity, imageability,

[4]All participants in Experiments 1, 2, and 3 made the judgements regarding $P(e|c)$ before they made the judgements regarding $P(e|\text{-}c)$. However, in order to ensure that the order of the stimulus presentation for $P(e|c)$ and $P(e|\text{-}c)$ did not influence participants' judgements, we ran an additional group of 20 participants with the reverse presentation order [i.e., they made judgements regarding $P(e|\text{-}c)$ before $P(e|c)$]. In addition, we counterbalanced the order of the remaining judgements (familiarity, imageability and belief in causal powers). This new order did not influence the data in any significant way. Specifically, participants' beliefs in causal powers were significantly correlated with their judgements regarding $P(e|c)$, imageability, and familiarity [$r(18)$'s = .68, .98, and .74 respectively], and were not significantly correlated with their judgements regarding $P(e|\text{-}c)$ [$r(18) = -.22$].

TABLE 3
Correlations between belief in causal power, measures of covariation, familiarity, imageability and detailedness for Experiment 3

Measure	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Causal power	—							
2. P(e/c)	+.69*	—						
3. P(e/-c)	+.21	+.19	—					
4. Familiarity	+.73*	+.66*	+.03	—				
5. Imageability	+.98*	+.70*	+.15	+.79*	—			
6. Detailedness	+.11	+.13	+.08	+.37	+.18	—		
7. ΔP	+.77*	+.74*	+.48*	+.57*	+.74*	+.06	—	
8. Power (P_c)	+.82*	+.85*	+.26	+.65*	+.80*	+.07	+.95*	—

*Correlation is significant at the .01 level.

and detailedness for Experiment 3. The data presented in the correlation matrix replicate and extend those observed in Experiments 1 and 2. Specifically, a reliable positive correlation was discovered between participants' judgement of causal powers and *P(e|c)*, $r(18) = +.69$, $p < .01$. This reflected a tendency on behalf of items to elicit increased judgements of *P(e|c)* in line with increased judgements of causal power. However, no reliable correlation was observed between participants' judgements of causal power and their judgements of the *P(e|-c)*, $r(18) = -.21$, $p = .39$. Specifically, as was found in Experiments 1 and 2, participants did not decrease judgements of *P(e|-c)* in line with increased judgements of their belief in causal power. However, consistent with the data observed in Experiments 1 and 2, *P(e|-c)* judgements accounted for an additional 14% of the belief in causal power variance once the effects of *P(e|c)* were controlled for, $R^2_{change} = .14$, $F(1, 17) = 6.50$, $p = .02$. See footnote 2 for the obtained regression equation with both *P(e|c)* and *P(e|-c)* as predictors of belief in causal power for Experiment 3.

Further analyses of the additional ratings revealed reliable positive correlations between participants' judgements of causal power and their familiarity ratings, $r(18) = +.73$, $p < .01$, and imageability ratings $r(18) = +.98$, $p < .01$. However, there was no reliable correlation observed between participants' judgements of causal power and the detailedness of their representation as quantified by the number of factors in their causal diagrams, $r(18) = +.11$, $p = .66$. It should be noted, however, that there was a moderate positive correlation observed between the number of factors in participants' causal diagrams and the rated familiarity of the causal candidates $r(18) = .37$, $p = .11$. This suggests that individuals may possess more detailed representations of causal candidates with which they are more familiar.

In order to further examine the potential relationship between causal powers and the nature of participants' diagrammatic representations, we assessed the degree to which the type of diagram drawn (linear, interactive, or multi-causal) varied as a function of the perceived causal power of the candidate cause. Exemplars of this classification scheme used in this experiment are depicted in Figure 2. The predominant type of diagram drawn was linear (94%), followed by interactive (3%), and multi-causal (3%). That is, participants were much more likely to graphically represent the causal relationships in terms of simple linear functions, $\chi^2(2, N = 40) = 1319.57$, $p < .01$. As can be seen in Table 4, the types of diagrams drawn did not differ as a function of the perceived causal power of the causal candidate, $\chi^2(3, N = 40) < 1.0$, $p > .05$. However, there was a trend for more linear graphical representations to be drawn for causal candidates rated high in causal power (97.4%) compared to those rated low in causal power (90.6%).

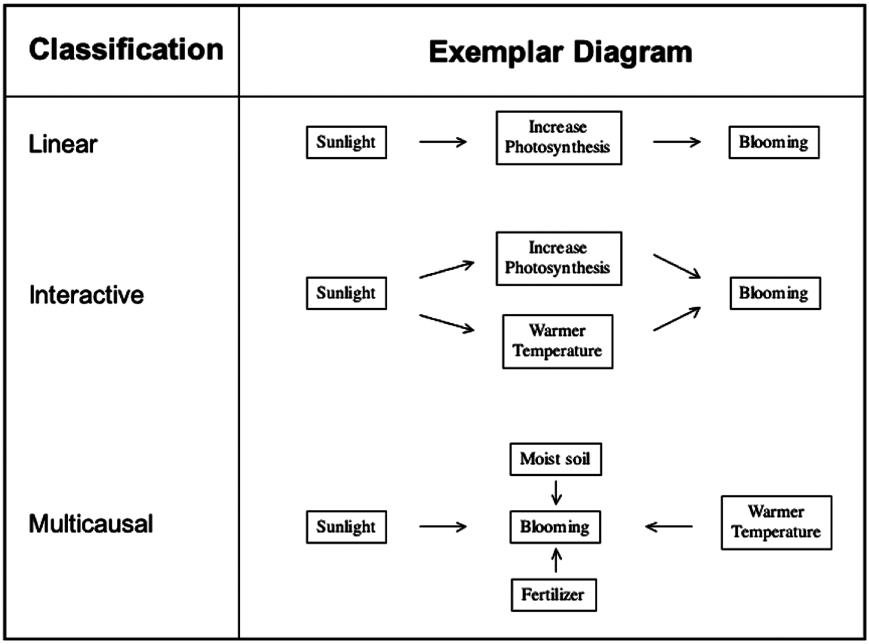

Figure 2. Exemplars of the scheme used in the classification of linear, interactive, or multicausal graphical diagrams.

TABLE 4
Types of diagrams drawn as function of the BELIEF in causal power manipulation

	Diagram classification		
Stimuli type	*Linear*	*Interactive*	*Multicausal*
High causal power/high covariation	97.4%	1.0%	1.5%
High causal power/low covariation	94.4%	2.1%	3.6%
Low causal power/high covariation	94.2%	3.7%	2.1%
Low causal power/low covariation	90.6%	5.8%	3.7%

GENERAL DISCUSSION

We conducted three experiments that set out to investigate how people's beliefs in causality are represented. To do this, we first investigated the relationship between participants' beliefs in causal power and their beliefs in covariation information as measured by both $P(e|c)$ and $P(e|\text{-}c)$. Two main findings emerged. First, we found a reliably positive relationship between participants' belief in causal power and their estimates of *P(e|c)*. However, we found no direct relationship between participants' belief in causal power and their estimates of *P(e|-c)*. This finding was replicated using both within- (Experiments 1 and 3) and between-subjects designs (Experiment 2). These data are inconsistent with normative contingency-based models, as such models propose that *P(e|c)* and *P(e|-c)* contribute equally to judgements of causality, and representations of causal knowledge. However, these findings are consistent with weighted contingency models which propose that people make use of the *P(e|c)* of the candidate cause more than the *P(e|-c)* (e.g., Cheng, 1997; Mandel & Lehman, 1998; Novick & Cheng, 2004; Over & Green, 2001; Schustack & Sternberg, 1981; White, 2002b). Therefore, individuals' incorporation of covariation-based data in their beliefs in causal power may in fact mirror their use of such data when evaluating new evidence (see footnote 2). An important avenue for future research would be to examine the extent to which participants' beliefs about the frequency of causal events vary as a function of the sample size examined. Specifically, the current experiments used relatively small set sizes. That is, participants were asked to make their *P(e|c)* and *P(e|-c)* estimates assuming a relatively small sample size of 10 events. Several studies have demonstrated that set size can have a significant impact on participants' judgements involving causal relationships (e.g., Green & Over, 2000). The degree to which such judgements will vary as a function of parametric manipulations of set size is an important empirical question for future studies to examine.

In Experiment 3, we replicated the dissociation between participants' belief in causal power with *P(e|c)* and *P(e|-c)* in addition to extending our analyses to familiarity, imageability and the level of detail in participants' representations of the causal mechanisms. Concerning first the nature of the diagrams drawn, individuals drew equally complex diagrams (mean of 3.73 factors) for causal candidates that were rated as high versus low in causal power. In addition, the causal diagrams drawn were predominantly linear. These data are consistent with recent work on scientific causal thinking conducted by Dunbar and Fugelsang (2005). Using similar materials, they asked students to generate verbal protocols while they graphically reasoned about causes and effects. They also asked participants to rate each of the links in their causal diagrams in terms of the perceived *probability* of each link occurring in the natural environment. Several interesting findings emerged from the analyses of those data. First, although the complexities of the diagrams were similar (equal number of factors and predominantly linear), the nature of the diagrams differed with respect to the ratings of the *probability* of the links in the diagrams. Specifically, the overall *plausibility* of the graphical causal model was directly related to the *probability* of the weakest link in the causal chain of events. That is, graphical models containing a *plausible* causal mechanism contained highly *probable* links, whereas graphical models containing an *implausible* causal mechanism had at least one link that was rated *improbable*. These data are consistent with research conducted by Green and colleagues (Green & McManus, 1995; Green et al., 1998) who found that people's representations of complex causal relationships are associated with the perceived strength of connections between causal factors and not only the presence or absence of factors (see also Einhorn & Hogarth, 1986, for a similar account of *causal chains*). These findings are also consistent with the work of Keil and colleagues (Keil, 2003; Mills & Keil, 2004; Rozenblit & Keil, 2002) on the "illusion of explanatory depth". They find that people often have a very coarse understanding of the details underlying the causal mechanisms of object and event interactions that occur in the environment.

The imageability data suggest that individuals are better able to generate an internal mental image of the cause and effect relationship for candidates rated as high in causal power (i.e., possessing a plausible causal mechanism) as opposed to candidates rated as low in causal power (i.e., containing an implausible causal mechanism). These data are consistent with theoretical approaches which suggest that complex reasoning can involve the internal manipulation of quasi-pictorial graphical representations (e.g., de Vega, Intons-Peterson, Johnson-Laird, Denis, & Marschark, 1996; Gentner & Stevens, 1983; Johnson-Laird, 1983). In addition, these data extend and provide a behavioural measure of recent functional magnetic resonance imaging work conducted by Fugelsang and Dunbar (2005). They found significantly higher correlated brain activations in the primary visual cortex for causal candidates that contained plausible as opposed to implausible causal mechanisms. Recent research by Kosslyn and his colleagues (Kosslyn, 1994; Kosslyn, Ganis, & Thompson, 2001, 2003; Kosslyn, Thompson, Kim, & Alpert, 1995) has supported the relationship between primary and secondary visual areas with mental imagery. In addition, these data are consistent with recent work on deductive reasoning that underscores the role of visual imagery in complex reasoning tasks (Knauff, Fangmeier, Ruff, & Johnson-Laird, 2003).

The finding that familiarity was related to participants' beliefs in causal power provides further support for the predominant role of $P(e|c)$ but not $P(e|\text{-}c)$ in representations of causal knowledge. Specifically, our data show that believable causal candidates are rated as highly familiar. Familiarity ratings were also strongly associated with $P(e|c)$ but not $P(e|\text{-}c)$ ratings, suggesting that individuals perceive familiar candidate causes to be more often associated with the effect in question.

Taken together, these data highlight the multidimensional nature of causal knowledge whereby people's representations of causation include, but are not limited to, the probability that the cause and effect co-occur, and the familiarity and the imageability of cause and effect relationships. Future research should examine alternative modalities of causal beliefs beyond those used in the current series of experiments. In so doing, one may gather further insight into the ways in which beliefs about the causal mechanism of an object may influence the degree to which people use and evaluate alternative cues to causality, such as covariation-based evidence (e.g., Fugelsang & Thompson, 2003), temporal contiguity (e.g., Buehner & May, 2002), and category membership (e.g., Waldmann, Holyoak, & Fratianne, 1995). In addition, more in-depth analyses of graphical representations of causal models using verbal protocols may prove especially fruitful. Further studies examining the representation and application of causal beliefs from an individual differences perspective may provide a means for examining the multiple facets of causal beliefs to which traditional group analyses may not be sensitive.

Manuscript received 16 January 2004
Revised manuscript received 14 March 2005

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APPENDIX A

Causal scenarios used in Experiment 1

Note: The 40 scenarios used in Experiment 1 are presented on the following pages. Each scenario is preceded by a code (e.g., 11), which denotes the level of the BELIEF and COVARIATION manipulation (1 = high and 0 = low), for each scenario (e.g., Fever, Exam Success, Cancer, etc.). This coding is also used in Appendices B–E.

Fever

11 Imagine you are a school nurse who is trying to determine the cause of a recent outbreak of fevers in children. You have a hypothesis that the fevers may be due contracting the flu virus.

01 Imagine you are a school nurse who is trying to determine the cause of a recent outbreak of fevers in children. You have a hypothesis that the fevers may be due to having chills.

10 Imagine you are a school nurse who is trying to determine the cause of a recent outbreak of fevers in children. You have a hypothesis that the fevers may be due to coming in contact with someone with a cold.

00 Imagine you are a school nurse who is trying to determine the cause of a recent outbreak of fevers in children. You have a hypothesis that the fevers may be due to eating apples.

Exam Success

11 Imagine you are a professor who is trying to determine the cause of students' success in exams. You have a hypothesis that exam success may be due to studying.

01 Imagine you are a professor who is trying to determine the cause of students' success in exams. You have a hypothesis that exam success may be due to success in writing papers.

10 Imagine you are a professor who is trying to determine the cause of students' success in exams. You have a hypothesis that exam success may be due to having a good sleep the night before.

00 Imagine you are a professor who is trying to determine the cause of students' success in exams. You have a hypothesis that exam success may be due to eating cornflakes for breakfast.

Cancer

11 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to exposure to high doses of radiation.

01 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to coughing.

10 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to smoking.

00 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to taking vitamin C supplements.

Drowsiness

11 Imagine you are a counsellor at the University who is trying to determine the cause of drowsiness in a group of students. You have a hypothesis that the drowsiness may be due to taking valium.

01 Imagine you are a counsellor at the University who is trying to determine the cause of drowsiness in a group of students. You have a hypothesis that the drowsiness may be due to having reduced attention.

10 Imagine you are a counsellor at the University who is trying to determine the cause of drowsiness in a group of students. You have a hypothesis that the drowsiness may be due to taking cold medication.

00 Imagine you are a counsellor at the University who is trying to determine the cause of drowsiness in a group of students. You have a hypothesis that the drowsiness may be due to listening to loud music.

Plane Crashes

11 Imagine you are an investigator for the FAA trying to determine the cause of a recent surge of airplane crashes. You have a hypothesis that the airplane crashes may be due to malfunctioning fuel lines.

01 Imagine you are an investigator for the FAA trying to determine the cause of a recent surge of airplane crashes. You have a hypothesis that the airplane crashes may be due to the activation of the black box.

10 Imagine you are an investigator for the FAA trying to determine the cause of a recent surge of airplane crashes. You have a hypothesis that the airplane crashes may be due to pilot illness.

00 Imagine you are an investigator for the FAA trying to determine the cause of a recent surge of airplane crashes. You have a hypothesis that the airplane crashes may be due to the introduction of a new pilot uniform.

Fatigue

11 Imagine you are a doctor who is trying to determine the cause of fatigue in a group of patients. You have a hypothesis that the fatigue may be due to having insomnia.

01 Imagine you are a doctor who is trying to determine the cause of fatigue in a group of patients. You have a hypothesis that the fatigue may be due to anxiety.

10 Imagine you are a doctor who is trying to determine the cause of fatigue in a group of patients. You have a hypothesis that the fatigue may be due to feelings of irritability.

00 Imagine you are a doctor who is trying to determine the cause of fatigue in a group of patients. You have a hypothesis that the fatigue may be due to drinking orange juice.

Red Swollen Eyes

11 Imagine you are an allergist who is trying to determine the cause of red swollen eyes in a group of patients. You have a hypothesis that the red swollen eyes may be due to exposure to tree pollen.

01 Imagine you are an allergist who is trying to determine the cause of red swollen eyes in a group of patients. You have a hypothesis that the red swollen eyes may be due to having a runny nose.

10 Imagine you are an allergist who is trying to determine the cause of red swollen eyes in a group of patients. You have a hypothesis that the red swollen eyes may be due to exposure to smog pollution.

00 Imagine you are an allergist who is trying to determine the cause of red swollen eyes in a group of patients. You have a hypothesis that the red swollen eyes may be due to drinking Evian water.

Slippery Roads

11 Imagine you are researcher for the ministry of transportation who is trying to determine the cause of slippery roads in townships. You have a hypothesis that the slippery roads may be due to ice storms.

01 Imagine you are researcher for the ministry of transportation who is trying to determine the cause of slippery roads in townships. You have a hypothesis that the slippery roads may be due to slippery sidewalks.

10 Imagine you are researcher for the ministry of transportation who is trying to determine the cause of slippery roads in townships. You have a hypothesis that the slippery roads may be due to rainfall.

00 Imagine you are researcher for the ministry of transportation who is trying to determine the cause of slippery roads in townships. You have a hypothesis that the slippery roads may be due to excessive traffic.

Thunderstorms

11 Imagine you are a meteorologist who is trying to determine the cause of thunderstorms. You have a hypothesis that the thunderstorms may be due to a sudden drop in atmospheric pressure.

01 Imagine you are a meteorologist who is trying to determine the cause of thunderstorms. You have a hypothesis that the thunderstorms may be due to a drop in barometer readings.

10 Imagine you are a meteorologist who is trying to determine the cause of thunderstorms. You have a hypothesis that the thunderstorms may be due to dense cloud cover.

00 Imagine you are a meteorologist who is trying to determine the cause of thunderstorms. You have a hypothesis that the thunderstorms may be due to Chinook winds.

Flowers Blooming

11 Imagine you are a horticulturist who is trying to determine the cause of flowers blooming. You have a hypothesis that the flowers blooming may be due the presence of sunlight.

01 Imagine you are a horticulturist who is trying to determine the cause of flowers blooming. You have a hypothesis that the flowers blooming may be due to the presence of bees.

10 Imagine you are a horticulturist who is trying to determine the cause of flowers blooming. You have a hypothesis that the flowers blooming may be due to the presence of fertiliser.

00 Imagine you are a horticulturist who is trying to determine the cause of flowers blooming. You have a hypothesis that the flowers blooming may be due to the plants being planted in red pots.

APPENDIX B

Mean belief in causal power, P(e/c), and P(e/-c) ratings for Experiment 1

Note: The frequency data (e.g., response estimates out of 10) were converted to probabilities in this and subsequent tables in Appendices D and E.

Scenario	*Candidate cause*	*Causal power*	*P(e/c)*	*P(e/-c)*
Cancer00	Taking vitamin c supplements	1.17	.15	.16
Cancer01	Coughing	.78	.24	.16
Cancer10	Smoking	9.58	.74	.14
Cancer11	Exposure to high doses of radiation	6.83	.55	.19
Crash00	New pilot uniforms	.88	.10	.10
Crash01	Black box activations	2.60	.28	.12
Crash10	Pilot illness	4.62	.26	.10
Crash11	Malfunctioning fuel lines	8.68	.75	.12
Drow00	Listening to loud music	1.67	.18	.40
Drow01	Having reduced attention	5.65	.58	.28
Drow10	Taking cold medication	7.97	.70	.27

(*continued overleaf*)

(*continued*)

Scenario	*Candidate cause*	*Causal power*	*P(e/c)*	*P(e/-c)*
Drow11	Taking valium	7.10	.70	.24
Exam00	Eating cornflakes for breakfast	1.58	.42	.53
Exam01	Paper writing success	6.08	.71	.40
Exam10	Good night sleep	7.03	.65	.37
Exam11	Studying	9.50	.84	.21
Eyes00	Drinking Evian water	1.00	.12	.19
Eyes01	Having a runny nose	3.48	.49	.21
Eyes10	Exposure to smog pollution	6.97	.59	.17
Eyes11	Exposure to tree pollen	8.01	.57	.18
Fatig00	Drinking orange juice	.98	.17	.24
Fatig01	Anxiety	6.63	.57	.25
Fatig10	Irritability	4.70	.51	.27
Fatig11	Insomnia	8.38	.83	.23
Fever00	Eating apples	.68	.10	.17
Fever01	Having chills	5.02	.67	.18
Fever10	Contact with someone with a cold	6.15	.48	.15
Fever11	Contracting the flu virus	8.98	.85	.09
Flow00	Red pots	.60	.63	.69
Flow01	Bees	5.12	.74	.48
Flow10	Fertiliser	7.27	.78	.49
Flow11	Sunlight	9.02	.90	.13
Road00	Excessive traffic	3.24	.40	.31
Road01	Slippery sidewalks	1.72	.66	.16
Road10	Rainfall	7.57	.64	.17
Road11	Ice storms	9.41	.94	.21
Thund00	Chinook winds	4.90	.46	.26
Thund01	Drop in barometer readings	5.03	.57	.23
Thund10	Dense cloud cover	5.95	.65	.19
Thund11	Sudden drop in atmospheric pressure	6.72	.65	.23

APPENDIX C

New causal scenarios used in Experiment 2

Cancer

01 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to chronic coughing.

00 Imagine you are a researcher who is trying to determine the cause of lung cancer in a group of patients. You have a hypothesis that the lung cancer may be due to taking iron supplements.

Drowsiness

00 Imagine you are a counsellor at the University who is trying to determine the cause of drowsiness in a group of students. You have a hypothesis that the drowsiness may be due to listening to the radio.

Fatigue

01 Imagine you are a doctor who is trying to determine the cause of fatigue in a group of patients. You have a hypothesis that the fatigue may be due feeling sluggish.

Thunderstorms

00 Imagine you are a meteorologist who is trying to determine the cause of thunderstorms. You have a hypothesis that the thunderstorms may be due to northerly winds.

APPENDIX D

Mean belief in causal power, P(e/c), and P(e/-c) ratings for Experiment 2

Note: Causal candidates that contain an asterisk were new stimuli used in Experiment 2 that were not used in Experiment 1.

Scenario	*Candidate cause*	*Causal power*	*P(e/c)*	*P(e/-c)*
Cancer00	*Taking iron supplements	2.57	.17	.20
Cancer01	*Chronic coughing	1.79	.44	.17
Cancer10	Smoking	9.62	.73	.18
Cancer11	Exposure to high doses of radiation	6.89	.61	.22
Crash00	New pilot uniforms	.450	.07	.08
Crash01	Black box activations	2.04	.52	.16
Crash10	Pilot illness	5.91	.34	.10
Crash11	Malfunctioning fuel lines	8.68	.77	.11
Drow00	*Listening to the radio	2.74	.24	.27
Drow01	Having reduced attention	3.81	.68	.21
Drow10	Taking cold medication	8.70	.68	.26
Drow11	Taking valium	6.68	.72	.28
Exam00	Eating cornflakes for breakfast	1.60	.54	.53
Exam01	Paper writing success	5.55	.73	.38
Exam10	Good night sleep	6.91	.74	.37

(*continued overleaf*)

(continued)

Scenario	*Candidate cause*	*Causal power*	*P(e/c)*	*P(e/-c)*
Exam11	Studying	9.55	.86	.24
Eyes00	Drinking Evian water	.74	.08	.10
Eyes01	Having a runny nose	2.38	.59	.17
Eyes10	Exposure to smog pollution	7.98	.56	.18
Eyes11	Exposure to tree pollen	8.19	.56	.16
Fatig00	Drinking orange juice	.66	.14	.24
Fatig01	*Feeling sluggish	4.13	.86	.18
Fatig10	Irritability	4.04	.60	.27
Fatig11	Insomnia	7.96	.85	.22
Fever00	Eating apples	.66	.07	.10
Fever01	Having chills	3.60	.66	.17
Fever10	Contact with someone with a cold	5.70	.45	.15
Fever11	Contracting the flu virus	8.91	.83	.12
Flow00	Red pots	.23	.75	.72
Flow01	Bees	4.32	.79	.40
Flow10	Fertiliser	7.30	.84	.43
Flow11	Sunlight	8.53	.90	.14
Road00	Excessive traffic	2.66	.29	.39
Road01	Slippery sidewalks	1.15	.91	.18
Road10	Rainfall	8.17	.73	.10
Road11	Ice storms	9.28	.96	.19
Thund00	*Northerly winds	4.43	.43	.26
Thund01	Drop in barometer readings	3.79	.69	.16
Thund10	Dense cloud cover	5.51	.61	.17
Thund11	Sudden drop in atmospheric pressure	6.85	.68	.16

APPENDIX E

Mean belief in causal power, P(e/c), P(e/-c), familiarity, imageability, and detailedness ratings for Experiment 3

Scenario	*Candidate cause*	*CP*	*P(e/c)*	*P(e/-c)*	*Fam*	*Image*	*Detail*
Cancer00	Taking iron supplements	2.70	.19	.15	2.40	2.25	3.53
Cancer01	Chronic coughing	2.20	.33	.14	3.25	2.60	3.71
Cancer10	Smoking	6.67	.66	.11	5.30	6.65	3.97
Cancer11	Exposure to high doses of radiation	5.40	.53	.13	3.82	4.97	3.37
Exam00	Eating cornflakes for breakfast	2.62	.57	.50	4.32	3.55	3.92
Exam01	Paper writing success	4.65	.73	.43	5.25	4.45	3.85
Exam10	Good night sleep	5.45	.69	.43	5.80	5.80	3.87
Exam11	Studying	6.62	.84	.26	6.37	6.65	3.85
Fever00	Eating apples	1.71	.15	.13	4.00	2.51	4.07
Fever01	Having chills	2.67	.65	.11	3.87	2.90	3.79
Fever10	Contact with someone with a cold	5.57	.51	.14	4.67	5.45	4.12
Fever11	Contracting the flu virus	6.60	.85	.11	4.95	6.22	3.65
Flow00	Red pots	1.37	.67	.66	3.47	2.12	3.52
Flow01	Bees	4.85	.82	.46	4.10	4.77	3.42
Flow10	Fertiliser	5.55	.81	.53	4.32	5.50	3.75
Flow11	Sunlight	6.07	.82	.11	4.40	6.15	3.85
Road00	Excessive traffic	2.60	.32	.24	3.60	3.00	3.43
Road01	Slippery sidewalks	1.52	.57	.18	3.80	1.60	3.41
Road10	Rainfall	6.45	.82	.14	5.32	6.45	3.55
Road11	Ice storms	6.75	.93	.18	5.05	6.80	3.45

Note: CP = causal power rating, Fam = familiarity, Image = imageability, Detail = mean number of factors in diagram.