Suppositions, Conditionals and Causal Claims

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1. Introduction

Over several years we have been interested in how people understand and test conditional assertions (for example see Feeney & Handley, 2000; Handley & Feeney, 2004, 2007). One of us has been involved in the development of the suppositional theory of conditionals (see Evans, Over & Handley, 2005), and in this chapter we will describe how the methods that have been used to test this theory can be turned to examining the processes involved when people think about the causal relation that holds between events in the world. The suppositional theory holds that to understand a conditional one temporarily adds the antecedent to one's store of beliefs and evaluates the consequences. At the core of the theory is the idea that understanding conditionals requires us to engage in mental simulations (see Kahneman & Tversky, 1982; Mandel, this volume). Although the account claims that people's beliefs about the truth of conditionals depends in large part on the mental simulation of a world in which the antecedent holds, there is some evidence that people also consider possibilities in which the antecedent does not hold when judging the truth of causal conditionals (see Over et al., 2007). We will argue that this finding is of relevance to counterfactual, and other, accounts of causation (Lewis, 1973; Woodward, 2003) and we will informally describe two new experiments designed to further examine the role of simulations of false antecedent worlds in judgments concerning the truth of causal conditionals.

By way of introduction we will survey relevant ideas about causation before turning to an account of the suppositional theory, the methods that have been used to test the theory, and the results of experiments using those methods to examine different conditional forms. An additional aim of the experiments was to study concessive conditionals (*even if* conditionals) under the suppositional framework. Concessive conditionals are interesting in this context because intuitively they seem to deny rather than to assert causal claims (see Byrne, 2005). Once we have surveyed the literature on the suppositional theory we will consider this type of conditional form in detail and how it might inform our understanding of how people think about causal relations

2. Accounts of causation

What does it mean to make a causal claim? According to regularity or covariation views (e.g. Hume, 1739) causal claims are based on our observation that cause (*C*) and effect (*E*) co-occur. Thus, for *C* to be a cause of *E*, P(*E*/*C*) should be greater than P(*E*/¬*C*). The difference between these two probabilities is known as delta p (Δp), and for *C* to cause *E*, Δp must be positive. Of course the problem with this view is that it equates causation with correlation and there have been a number of attempts in philosophy and psychology (see Cheng, 1997) to surmount that problem.

One particular attempt in philosophy to remedy problems with the covariation view of causality has been influential in psychology (see Woodward, this volume; Mandel, this volume). According to this view of causation, in order to be able to make the claim that *C* caused *E*, we must also be able to make the claim that "if *C* had not occurred then *E* would not have occurred". This view is the counterfactual view of causation and is most often associated with Lewis (1973). Interestingly from our point of view, Lewis (1986) also specified a probabilistic variant of his counterfactual theory of causation. Thus in cases of uncertain causation *C* can be said to have caused *E* if and only if, if *C* had not occurred the chances of *E* occurring would have been less.

Although the counterfactual theory was meant to remedy problems with the covariation theory, viewed from a certain perspective the theories are very similar. Wolff (2007), for example, classes covariation and counterfactual theories as dependency accounts of causation, because in both the effect is in some way contingent upon the cause. Furthermore, when we consider Lewis's probabilistic variant of the counterfactual theory, then the theories appear very similar in that Lewis's specification appears to reduce to Δp. (One important difference is that Δp is expressed in terms of conditional probabilities whereas Lewis did not express the probabilistic variant of his account in those terms). For our purposes it is important to emphasise that central to both accounts is a consideration of the possibility where the antecedent has not occurred or does not occur.

As well as differences between theories of causation, there are also important differences between type causation and token causation (see Woodward, this volume). The former involves general claims about causation without reference to particular instantiations whereas the latter involves claims about particular effects and particular causes. As Woodward (this volume) shows, type causal judgements are often forward looking, in that one reasons from a cause to an effect, whereas token causal claims are made after a particular outcome has occurred. Much work in the psychological literature has concerned people's reasoning about token causal claims. In particular, work on the relationship between counterfactual and causal thinking has tended to focus on token claims (for reviews see Mandel, this volume). As we will shortly see, because our work has primarily (but not exclusively) been about causal conditionals concerning future events, it relates more to an understanding of the psychology of type causal judgements. For this reason also, the possibilities which participants might consider when evaluating such conditionals are more akin to future hypotheticals than to what are commonly thought of as counterfactuals in the psychological literature. Although there appear to be important developmental effects caused by the difference between counterfactual conditionals whose antecedents are false and future hypotheticals (see Perner, this volume), alongside Woodward we argue that future hypotheticals are closely tied to an understanding of type causal judgements.

3. The Suppositional Account of Conditionals

The framework we will use to consider conditionals in this chapter is known as the suppositional account (see Evans & Over, 2004; Evans, Over & Handley, 2005; Handley et al, 2006). This account draws upon Ramsey's idea (1931) that ordinary conditionals are evaluated by adding 'p' to one's stock of beliefs and evaluating 'q' in that context. According to the Ramsey test conditionals are believable to the extent that q is probable given p. This view forms the basis of the suppositional account, which claims that when people understand conditionals they engage in a process of mental simulation, which involves simulating the hypothetical world in which p holds and evaluating one's belief in q in the light of this simulation (see, for example, Handley, Evans & Thompson, 2006).

One of the key predictions that arises from this account is that people should evaluate the believability of a conditional statement as a function of the probability of the consequent in the light of the antecedent [P(q/p)]. The 'conditional probability' hypothesis has been tested in a number of recent studies. In these studies the typical approach involves asking participants to provide a probability judgment concerning the truth of a given conditional, for example:

1) If less violence is shown on television, then the amount of violent crime will reduce

Later participants are presented with a 'probabilistic truth table task' (PTT), where they are asked to assign percentage probabilities to each of the four truth table cases associated with the conditional statement. For example, participants would be asked to assign probabilities to each of the four conjunctions corresponding to the truth table cases for the conditional in 1), summing to 100%:

(TT)	Less violence is shown on television, the amount of violent crime reduces	___
(TF)	Less violence is shown on television, the amount of violent crime does not reduce	___
(FT)	No less violence is shown on television, the amount of violent crime reduces	___
(FF)	No less violence is shown on television, the amount of violent crime does not reduce	___
		100%

Based upon participant's responses, it is possible to calculate a range of conditional probabilities, drawing upon an individual's beliefs about the likelihood of various outcomes pertaining. For example, conditional probability, P(q/p) (the probability that violent crime will reduce given that less violence is shown on television) is a function of the probability assigned to the TT case weighted by the total probability assigned to TT and TF cases (TT/TT+TF). It is also possible to evaluate people's beliefs about the probability that the consequent will occur in the absence of the antecedent (P(q/not-p)) which is a function of the probability assigned to FT cases in proportion to FT and FF cases combined (FT/FT+FF). Thus, it is a simple matter to calculate Δp and we will return to this presently.

Research using this method has provided strong support for the conditional probability hypothesis and the suppositional account of conditionals. Conditional probability has been shown to be strongly correlated with judgments of the probability of abstract conditionals and ordinary conditionals (Evans et al., 2003; Over et al., 2007). For example, Over et al (2007) reported a study testing whether the conditional probability hypothesis also holds for counterfactual conditionals. In that experiment, participants were shown causal counterfactual conditional statements such as 2).

2) If New York had not been attacked by terrorists in 2001, then the US would not have attacked Iraq.

Participants were asked to judge the probability that the conditionals were true. The truth table task was modified for this experiment so that participants were asked to estimate the probability of each of the truth table cases from the perspective of a point in time before the events referred to had occurred. The results of this study, once again, contained strong support for the conditional probability hypothesis. That is, P(q/p) was the strongest predictor of the judged probability of a set of 32 counterfactual conditionals. This result is consistent with the claim that in judging the probability of counterfactual conditionals people imagine themselves at a point in time before the events described became counterfactual and simply apply a Ramsey test via a process of mental simulation. This finding suggests, contrary to other claims in the literature, that counterfactuals are understood in a similar way to conditionals that refer to future hypothetical events.

Typically, recent studies have used causal conditionals of the kind shown in 1) and 2) above, where there is a hypothesized causal relationship that holds between the antecedent and consequent events. Now, if conditionals of this kind are understood as expressing a causal relationship then other probabilities become important. For example, under a covariation view of causation, Δp (P(q/p) – P(q/not-p)), should be related to the strength of the causal relationship that holds between p and q. If we accept that when the causal link is uncertain the counterfactual view and the covariation view are indistinguishable, then the counterfactual view makes this prediction as well. Importantly both predict that P(q/not-p) should be negatively correlated with people's conditional probability judgements. This is important because whereas P(q/p) and Δp are not statistically independent (Δp includes P(q/p)), P(q/not-p) and P(q/p) are statistically independent (entirely different truth table cases go into their calculation). There is mixed support for the proposed negative relationship, with some evidence for a weak negative relationship between P(q/not-p) and probability of conditional judgments. For example, in Experiments 1 and 2 of Over et al. (2007), although Δp was strongly correlated with people's judgements of the probability that the causal conditionals were true, P(q/not-p) was not significantly correlated with those judgements. Furthermore, the latter correlation was positive rather than negative in both experiments. Experiment 3 of that paper concerned counterfactuals and produced a negative and significant correlation between P(q/not-p) and judgements about the probability of the conditional, and a significant and negative correlation (r = -.31) was reported by Evans et al. (2007a).

One possible reason for these mixed results is that in all of the studies described, the correlations were calculated over a relatively small sample of 32 conditionals. One of the aims of the experiments we will describe below was to increase the size of the sample of conditionals. Under such circumstances, if there are reliable effects of P(q/not-p) then we should have sufficient power to detect them. Most studies to date have examined participant's beliefs about the truth of causal conditional statements. In the first experiment presented here we asked for an evaluation of causal strength as a more direct measure of beliefs about causal relations.

Certain conditional expressions, rather than expressing a causal relationship, expressly deny that a casual relationship exists. Even-if or concessive causal conditionals are used when there is reason to question that an expected relationship holds. Consequently one would expect even-if assertions to show opposite patterns of relationship to P(q/not-p) than causal judgments. One of the primary aims of the experimental work that we will shortly present was to test this intuition. However, before describing the experimental work, it is necessary to introduce some of the relevant philosophical and linguistic analyses of even-if conditionals.

4. Concessive or "even if" conditionals

Even-if conditionals invite the listener to suppose that a relation that one might have expected to hold in the world, in fact does not. Consider, for example, the following assertion:

3) Even if the US had ratified the Kyoto protocol, carbon emissions would have increased

Such assertions are referred to as semi-factuals, because they describe a world in which the consequent event is assumed to have pertained (i.e., carbon emissions have increased), but the antecedent action was not carried out (The US did not ratify the Kyoto agreement). Such conditional assertions are interesting from the perspective of causal reasoning because they are often used to deny a causal link between an antecedent and consequent event (in this case the link between ratifying Kyoto and carbon emissions). Even-if assertions operate equally well when referring to future events, for example:

4) Even-if the Conservatives win the election there will be an increase in taxes

Where the outcome of the election is unknown (at the time of writing), but the implication is that taxes will increase irrespective of what outcome pertains, once again denying a causal link between election outcome and tax increases.

A number of authors have emphasized that in order to understand how people represent and reason from even-if, one must first consider the function of *even* in everyday natural language. Consider, for example, the assertion in 5):

5) Even Tony distrusts George

Several philosophers (Jackson 1987; Sanford 1989) have suggested that *even* serves to deny an available presupposition; for example, that we might expect Tony to trust George. It serves to pick out an extreme position and calls up a range of contextually determined alternatives that are less surprising; for example, that Gordon distrusts George, Barrack distrusts George, or Jacques distrusts George. In so doing the utterance invites the listener to infer that George is a man not to be trusted.

Whilst there exist exceptions, most authors have treated *even-if*, not as a distinct logical connective, but as a construction that consists of a combination of the focusing particle *even* and the *if* of a conditional. The analyses presented above can readily be extended to *even-if*. To illustrate consider the statement in 4) above. The assertion denies a general presupposition that the Conservatives are a tax reducing party; that is, it denies an association of the following kind:

6) If the Conservatives win the election then taxes will be reduced

As we have seen *even* picks out an extreme possibility on a scale of related statements that are more probable in a given context. This provides a series of effects related to unexpectedness or surprise. Declerck and Reed (2001) have argued that *even-if* similarly induces a sense of unexpectedness. This sense of unexpectedness relates to the conditional as a whole and leads to what they label an expectation understanding, i.e one might expect p to preclude q (a Conservative victory to preclude tax rises), and a non-preclusive understanding, p does not (in fact) preclude q (In fact a Conservative victory will not preclude tax rises). The focal conditional lies at the extreme point of a scale of unexpectedness, consequently calling to mind a range of conditionals that are more likely and less surprising, such as:

7) If the Liberal Democrats win the election then there will be tax rises

8) If the Labour party wins the election then there will be tax rises

Consequently licensing the inference that the conditional relationship holds for all other values of the same scale and hence for a series of antecedents (Konig, 1986). According to Jackson (1987, see also Declerck & Reed, 2001) the range often consists of the conditional with the antecedent negated:

9) If the Conservatives don't win the election then taxes will rise

The combination of 9) with the assertion in 4) leads to the inference that taxes will rise whether or not the conservatives win the next election. In formal terms this inference is what logicians would term *constructive dilemma* and it corresponds to the intuition that many *even-if* assertions appear to entail their consequent.

5. A Psychological Account of Even If

A key question in this paper, concerns the component probabilities, and the associated mental simulations, which predict judgments about the probability of even-if conditionals. Before outlining our predictions we will briefly present our psychological account of even-if, which draws heavily on the linguistic accounts described earlier combined with the suppositional account of conditionals, described above (for an alternative account see Byrne, 2005; Moreno-Rios, Garcia-Madruga & Byrne, 2008). Consider, to start with, the following causal conditional:

10) If the Conservatives win the election then taxes will be reduced

Of course one might not believe (given a bleak economic outlook) that any sort of relationship holds between the election outcome and tax reductions. These conditions create a perfect opportunity for asserting an even-if conditional of the kind shown in 4). As argued above even-if calls up a range of alternative conditionals on a probability scale that are less surprising or unexpected such as the conditionals in 7) and 8). In probabilistic terms, the probability of the consequent (a reduction in taxes) is greater given this range of alternative antecedents (such as a Labour or Liberal victory), compared to the probability of the consequent given the antecedent in 4). Thus, the conditions required to support an even-if assertion will be the opposite of those required to support the assertion of a causal conditional. Specifically an even-if assertion will be assertable under conditions where P(q/not-p) is high. These are the very conditions under which a causal relationship is called into question, thus supporting the general intuition that even-if, not only serves to deny an existing presupposition, but is also used to cast doubt on a causal relationship between an antecedent (election outcome) and a consequent event (tax outcome).

In the two experiments that follow we evaluate the extent to which judgments concerning causal strength, the probability of even-if statements and the probability of causal conditionals are influenced by various conditional probabilities. In Experiment 1 we compare causal strength judgments with judgments concerning the truth of even-if assertions. We predict that the conditional probability hypothesis will be supported in both cases, but that P(q/not-p) will be negatively associated with judged causal strength, but positively related to judgments about the probability of even-if conditionals.

6. Experiment 1

64 undergraduate student volunteers from the University of Plymouth took part in Experiment 1 in return for participant payment. There were 24 men and 40 women whose ages ranged from 19 to 45 years of age. We employed a within participants design in which all participants completed the probabilistic truth table task (PTT) and one of two judgement tasks. One of these tasks required participants to rate the probability that a series of "even-if" statements was true. This task was modelled on the conditional judgment task as used by Over et al, (2007). Participants who completed the other task were asked to estimate the strength of the causal link between the antecedent and the consequent of the base conditionals from which the even-if sentences were constructed. Each task was presented in a booklet, with each booklet containing items derived from the same base set of 48 conditional statements (see Table 1 for examples), and participants were randomly allocated to one of the two conditions.

The even-if conditionals were constructed from a set of base conditional statements by adding a negation to the consequent clause. An example base, and even-if, conditional, along with the corresponding causal statement, is shown below:

Base conditional: If car ownership increases, traffic congestion will get worse

Even If Conditional: Even if car ownership increases, traffic congestion will not get worse

Causal Statement: An increase in car ownership will cause traffic congestion to get worse

The 48 statements in the conditional probability and causal strength judgements tasks were presented in a random order for each participant. Participants were told that they would be presented with a list of statements relating to events that may occur in the next 10 years. In the conditional judgment task they were asked to provide an estimate of the probability that each sentence is TRUE, on a percentage scale. Participants who received the causal statements were asked to indicate how strongly they judged the causal link between the two events described. They indicated their judgment on a 5 point scale with the end points labelled 'weak causal link' and 'strong causal link' respectively.

In the probabilistic truth table task (PTT) participants are required to assign percentage probabilities to each of the four conjunctive truth table cases corresponding to each conditional. For example, the truth table cases presented to participants corresponding to the conditionals above were:

(TT) Car ownership increases and traffic congestion gets worse __

(TF) Car ownership increases and traffic congestion doesn't get worse __

(FT) Car ownership doesn't increase and traffic congestion gets worse __

(FF) Car ownership doesn't increase and traffic congestion doesn't get worse __

100%

Participants were asked to judge the probability that the specified events would occur in the next 10 years. They were instructed to assign a probability to each of the truth table cases with a requirement that the probabilities summed to 100%. 48 sets of truth table cases were presented corresponding to each of the 48 conditional statements. These were presented in a random order for each participant. Half of the participants received the conditional judgment task followed by the probabilistic truth table task, with the remaining participants receiving the tasks in the reverse order.

6.1 Findings

The even-if assertions were constructed from the base conditionals by adding a negation to the consequent clause as indicated above. For clarity we calculated the conditional probabilities relative to the Antecedent (A) and Consequent (C) clauses, regardless of negation. For example, given the even-if assertion, 'Even-if car ownership increases traffic congestion will not get worse', P(C/A) represents the probability that traffic congestion will not get worse given an increase in car ownership, whereas for the conditional, 'If car ownership increases then traffic congestion will get worse, P (C/A) represents the probability that traffic congestion will get worse given an increase in car ownership. This approach allows us to directly examine the extent to which conceptually equivalent probabilities predict probability and causal strength judgments in different ways for the different tasks.

The analyses of interest here concern probabilities calculated on the PTT task and their relationship to judged probabilities assigned to the conditional sentences, and ratings of the strength of the causal link between antecedent and consequent. The analysis we report collapses over participants, relating these probabilities as measured across problem materials, in line with previous research using this method (see Over et al., 2007). This was achieved by first computing the mean for all participants for each sentence and then calculating correlations and regressions on these mean scores. Table 2 shows the raw correlations between each of three relevant probabilities (P(C/A), delta-p, and P(C/not-A)) and both causal strength ratings and probability judgments for even-if sentences.

Looking first at the raw correlations corresponding to the conditional probability and delta p hypotheses outlined earlier, it is clear that both are significant. However, whilst judgements about the strength of the causal link between antecedent and consequent are approximately equally well predicted by conditional probability and delta-p, even-if is not predicted as well by either of these measures and is predicted less well by delta-p than by conditional probability. Recall that one proposed function of even-if is to deny a causal link between the antecedent and consequent clauses. On this basis one might expect delta-p to be negatively correlated with the probability of even-if, given that a weak causal relation provides stronger conditions for asserting a concessive conditional. The correlational data do not appear to support this analysis, although it is important to note that delta-p is highly correlated with the other predictors and this makes it difficult to draw conclusions based upon raw correlations. In order to provide a more robust test of our proposals we used the approach adopted in Over et al. (2007), performing multiple linear regression analyses with judged probability as the dependent variable with two statistically independent predictors: P(C/A) and P(C/not-A).

To the extent that judgements of the strength of the causal link between the antecedent and the consequent of a causal conditional draws on the same processes as judging the probability of a causal conditional, the conditional probability hypothesis predicts a strong effect of P(C/A) on judgements of causal strength. According to the delta-p rule, P(C/A) should be a positive predictor of causal judgements and P(C/not-A) should be a negative predictor. For "even-if" conditionals on the other hand, P(C/not-A) should be a positive predictor as a high value of P(q/not-p) provides the conditions for making an assertion of this kind. Table 3 shows the beta weights and regression models for each type of judgement for both predictors.

The regression models for causal and even-if judgments are both highly significant explaining 94% and 64% of the variance respectively. As predicted, conditional probability, P(C/A), was a significant positive predictor of causal strength judgments, whilst P(C/not-A) was a negative predictor. This finding is consistent with the delta-p hypothesis, although it is worth noting that the beta weight for P(C/A) is much larger than the beta weight for P(C/not-A) indicating that conditional probability is over weighted in an evaluation of causal strength relative to the normative model. Turning now to ratings of even-if, as with causal judgements, P(C/A) had a large and reliable beta weight. In line with the account outlined earlier, this was accompanied by a smaller, but highly reliable positive beta weight for P(C/not-A), demonstrating that the ratings of even-if increase as the probability of the consequent occurring in the absence of the antecedent increases. This quite clearly indicates that even-if cues people to think about alternative causes thus undermining the link between the antecedent event and the stated consequent.

The data thus far provide good evidence to suggest that causal and even-if judgements differ in the way in which they cue people to think about alternative causes. In contrast to causal judgements, even-if assertions are rated as more probable the greater the probability that the consequent will occur in the absence of the antecedent. Consistent with the delta-p hypothesis, and thus a probabilistic version of the counterfactual theory of causation, causal strength is negatively related to the judged probability that the consequent will occur in the absence of the antecedent.

We have found that P(C/A) is a positive predictor of judgements about even-if and we argue that this finding relates to the important function served by even-if in denying a presupposed relationship. Declerck and Reed (2001) have argued that even-if denies the presupposition that p would normally prevent q; that is p would normally lead to not-q. This presupposition clearly relates to an understanding of the relation that would normally hold between the antecedent and consequent. Therefore, one might expect the acceptability of an even-if assertion to be related to the ease by which the presupposition can be activated. It is of course well known that the ease of activation of a denied presupposition depends upon the extent to which the denial is a plausible one (see, for example, Wason, 1965). The data suggest that conditional probability is important in determining the acceptability of even-if assertions, but this may only be up to a certain point, because the higher the conditional probability, the less available a relevant presupposition will be; it will no longer be a case of a 'plausible denial'. To illustrate this, consider the assertion in 10). There is something odd about even-if assertions of this kind where the conditional probability is particularly high:

10) Even if Brazil score five goals they will win the game

because the presupposition, 'If Brazil score five goals then they will lose the game' is inconsistent with our beliefs about football matches in general and Brazilian football teams in particular. Thus, this presupposition is unlikely to be highly available to us when we process the even-if assertion. This example suggests that there may not be a simple linear relationship between conditional probability and the probability of even-if sentences. To test this hypothesis we carried out further analysis of the relationship between judgements for even if and P(C/A). Figure 1 presents a scatterplot showing the relationship between these two measures calculated across all 48 even-if sentences. Our analysis suggests that even-if sentences will be most acceptable where P(C/A) is neither at the extreme low-or high-end of the scale. This in turn suggest that the relationship between P(C/A) and sentence ratings will be curvilinear. Table 4 shows a comparison between a linear and quadratic curve fitting to the data. Although the linear model was a good fit, it was significantly outperformed by the quadratic model.

Experiment 1 employed the probabilistic truth table method to enable us to identify the underlying beliefs that relate to causal judgements and to the judged probability of even if conditionals. The findings are relatively clear; the acceptability of even-if is linked to our understanding of causality. As we have argued, the weaker the causal relationship between p and q, the more acceptable even-if should be. However, as a conditional, even-if's assertability conditions require that P(q/p) is also at an acceptable level. For a causal relation to be weak, P(q/not-p) must also be high. Our analysis confirms that both of these conditional probabilities are important in predicting the acceptability of an even-if assertion linking them squarely with an understanding of causality.

In Experiment 1 there was some evidence that P(q/not-p) is related to the strength of the causal relationship that is perceived to exist between p and q. This finding is consistent with both the covariation and the probabilistic variant of the counterfactual theory of causation. In Experiment 2 we asked participants to judge the probability that a series of future hypothetical conditionals are true. The aim of Experiment 2 was to compare judgments concerning the acceptability of even-if assertions and if assertions, evaluating the extent to which P(q/not-p) predicted differentially in each case. Experiment 2 also allowed us to attempt to replicate the striking curvilinear relationship we observed in Experiment 1 between P(C/A) and judgements about even-if.

7. Experiment 2

70 undergraduate student volunteers from the University of Durham participated in Experiment 2 in return for payment. There were 16 men and 54 women whose ages ranged from 18 to 49 years of age. We employed a within participants design in which all participants completed the probabilistic truth table task (PTT) and a conditional judgment task as used by Over et al, (2007). Each task was presented in a booklet, with each booklet containing items derived from the same base set of 48 conditional statements (see Table 1). Participants were randomly allocated to one of two conditions, providing ratings for conditionals containing the connectives 'if then' (IT), or 'even-if' (EI). As was the case in Experiment 1, the even-if versions were constructed from the base conditional statements by adding a negation to the consequent clause. The 48 statements in each of the conditional judgement tasks were presented in a random order for each participant. In the probabilistic truth table task participants are required to assign percentage probabilities to each of the four conjunctive truth table cases corresponding to each conditional. The 48 sets of truth table tasks were presented in a random order for each participant. Half of the participants received the conditional judgment task followed by the probabilistic truth table task, with the remaining participants receiving the tasks in the reverse order.

7.1 Findings

Table 2 shows the raw correlations corresponding to the conditional and causal (delta-p) hypotheses outlined earlier. Note that the pattern of correlations for even-if is very similar to those reported in Experiment 1 and the correlations between the predictors and judgements about causal conditionals are very similar to those reported for causal judgements in Experiment 1. Once again delta-p is a positive, rather than negative predictor for even-if, but a much stronger predictor for causal conditionals. Conditional probability is strongly positively correlated with both judgments. It is also worth noting that P(C/not-A) is a negative predictor for causal conditional judgments as expected, but as shown in Experiment 1, is uncorrelated with even-if judgments.

As in Experiment 1, the pattern of correlations provides mixed evidence to suggest that causal conditional and even-if judgments are related to the calculated conditional probabilities in different ways. Once again we adopted a regression solution by examining the extent to which our two independent predictors, P(C/A) and P(C/not-A), predicted judged probability of each sentence.

The conditional probability hypothesis predicts a strong effect of P(C/A), and if causal strength is a factor then P(C/A) should be a positive predictor and P(C/not-A) should be a negative predictor for 'if then' conditionals (which may, as a part of their meaning, assert a causal relation). On the other hand, P(C/not-A) should be a positive predictor for 'even-if'. Table 6 shows the beta weights and regression models for each type of sentence for both predictors.

In line with earlier findings this analysis revealed strong support for the conditional probability hypothesis for causal conditionals, with a highly significant regression model and P(C/A) having by far the highest beta weight. However, there was weak support for the causal hypothesis, with P(C/not-A) eliciting only a marginally significant beta weight. Turning now to the ratings of the even-if sentences, as Table 6 shows the regression model was highly significant. As with causal conditionals, P(C/A) had a large and reliable beta weight. In line with the findings of Experiment 1, this was accompanied by a smaller, but highly reliable positive beta weight for P(C/not-A).

Finally we examined the relationship between P(C/A) and ratings of even-if statements, in order to determine whether the curvilinear relationship reported in Experiment 1 was replicated in this data set. Table 7 shows a comparison of the linear and quadratic curve fitting and once again demonstrates a significant advantage of the curvilinear over the linear model (R2 change test: $F(1,45)=9.78$, $p<.001$), a pattern illustrated by the scatterplot in Figure 2.

8. Back to causality and counterfactuals

The two experiments we have described here contain a number of interesting findings. In Experiment 1 we examined people's beliefs about the strength of the causal relationship between the antecedent and consequent events together with beliefs about the truth of even-if assertions concerning the same relations. The findings show that whereas conditional probability is a positive predictor of both types of judgement, the probability of the consequent given the absence of the antecedent is a negative predictor of judgements of causal strength and a positive predictor of probability judgements for concessive conditionals. Two things should be noted here. First, P(C/A) was a much stronger predictor of causal judgements than was P(C/not-A). Second, P(C/A) best predicted probability judgements for concessives when it was neither so low as to make the concessive implausible nor so high as to make it infelicitous.

In Experiment 2 we compared probability judgements for concessive and causal conditionals. The results for even-if were consistent with Experiment 1. Thus, P(C/A) and P(C/not-A) were positive and significant predictors of participants' judgements about the probability that 'even if A then C' was true, and there was a curvilinear relationship between P(C/A) and P(even if A then C). For causal conditionals, on the other hand, the results strongly supported the conditional probability hypothesis, with P(C/A) being very strongly predictive of P(if A then C). However, there was only weak evidence to suggest that when considering the probability that a causal conditional statement is true people consider hypothetical possibilities in which the antecedent is false. Thus, whilst beliefs based upon 'undoing' the antecedent event are positively related to judgements about concessive conditionals, and negatively related to judgments of causal strength, they appear relatively weakly related to judgements about the truth of causal conditional claims. Previous research using this paradigm has produced inconsistent evidence to suggest that delta-p is related to beliefs in causal conditionals. Our findings, which are based upon a substantially greater set of conditional sentences, suggest that if the effect is present it is weak.

These results speak to the relationship between counterfactuals and causal claims in a number of ways. Most obviously they suggest that when evaluating the truth of type causal claims expressed as indicative conditionals, people rarely consider the false antecedent possibility identified as important by counterfactual and covariation theories of causation. That is, people don't appear to think about the likelihood of the effect in the absence of the cause. However, when participants are explicitly asked to consider the strength of the causal relationship between the antecedent and consequents of such causal claims people do think about whether the effect is likely to occur in the absence of the putative cause. Of course, as we pointed out earlier, considerations of false antecedent cases do not predict people's causal strength judgements as strongly as do considerations of true antecedent cases. This could be because people underweight the cause absent possibilities, which would be consistent with their tendency to underweight certain information when judging contingency (see Anderson, 1990; Shanks, 1995, Stanovich & West, 1998). Specifically, people tend to pay more attention to those cells in a 2x2 contingency table that correspond to the cause present cases here than they do to the cells corresponding to the cause absent cases here (see also Kao & Wasserman, 1993). It is also consistent with other work surveyed by Mandel (this volume) showing that the majority of participants interpret a causal claim such as "X causes Y" as meaning that when X happens, Y happens. In Mandel's (this volume) terms, such participants have a sufficiency interpretation of causality. It is possible that for the majority of participants in our experiments, judging the strength of the causal relation between an antecedent and a consequent is equivalent to answering a question about the sufficiency of the antecedent for the consequent. Certainly the very weak effect of P(C/not-A) for judgements about causal conditionals suggests that is what most participants are doing when judging the likelihood that a causal conditional statement is true.

Although P(C/not-A) was a weaker predictor of judgements about the causal strength in Experiment 1 than P(C/A), nonetheless, it was a significant predictor. It is possible that there are individual differences in the tendency to consider the probability of the effect in the absence of the cause when evaluating causal strength. It is already known that when judging causal conditionals, there are marked individual differences in the tendency to consider the probability of the effect in the presence of the cause (Evans et al., 2003) and that cognitive ability is positively associated with that tendency (Evans et al., 2007b). Cognitive ability is also associated with the tendency to underweight the C and D cells of the contingency table (see Stanovich, 1999). Mandel (this volume) in his survey of work on interpretations of causality also shows that there are individual differences. So, whereas the majority of participants in relevant studies (Mandel & Lehman, 1998; Goldvarg & Johnson-Laird, 2001; Mandel, 2003) interpret the statement “X causes Y” as meaning that when X happens, Y happens, a minority additionally interpret the statement as mean that when X doesn’t happen, Y doesn’t happen. An interesting question for future research is whether consideration of false antecedent cases when assessing the strength of a causal relation or even when explaining what causality is, might also be associated with cognitive ability.

Although in the task we have studied, consideration of cause absent possibilities is not strongly associated with judgments about causal conditionals, it is associated with judgements about concessive conditionals. Beliefs about false antecedent cases were significant positive predictors of judgements about the truth of even if statements. That is, if we believe the following statement, “even if car tax is increased, traffic congestion will get worse” then we are also likely to believe that that “traffic congestion will get worse if car tax is not increased”. Thus, although we have found limited evidence of an association between the assertion of causal conditional claims and consideration of cause absent cases, we have found an association between the denial of causal claims and the consideration of such cases.

We were not thinking of Mandel’s judgement dissociation theory when we designed our experiments, but we are struck by the consistency between the predictions of that theory and our results. The theory predicts that in counterfactually undoing outcomes people will focus on antecedents sufficient to prevent the outcome occurring. When evaluating concessive conditionals, people consider cause absent cases, which, according to JDT are the focus of counterfactuals to undo the outcome. That P(C/not-A) is a positive predictor of the probability of concessives suggests that one of the functions of an even if conditional is to deny the sufficiency of its antecedent in preventing the outcome.

Although our experiments required participants to make judgements about probabilities, it is worth remembering that the psychological account of the suppositional conditional (see Evans et al. 2005) is that people carry out simulations when assessing the probability of conditional claims. Thus, when we write that consideration of cause present or cause absent cases is associated with a particular probability judgement, we mean that participants are temporarily supposing the putative cause specified in the antecedent to be present or to be absent and assessing the ease with which they can imagine the effect specified in the consequent. As mentioned in other contributions to this volume (e.g. Mandel, Hitchcock), ideas in the psychological literature about mental simulation originate with Kahneman and Tversky (1982). Whereas other accounts with debts to the simulation heuristic (see Mandel, this volume) have sought to understand token causal claims concerning past events, the suppositional theory has, for the most part, been applied to the study of how people understand type causal claims about future events. Although there may be disagreements about what to call the mental simulations in each case (counterfactuals, future hypotheticals), psychologically speaking they are likely to involve very similar processes regardless of whether they concern specific events in the past or classes of events in the future (see, Over et al., 2007). The psychological processes underlying mental simulation are, as yet, quite poorly understood. However, it does seem likely that people use some characteristic of their processing as a surrogate for a probability judgement. One possibility is that ease of imagining a particular consequent given a temporarily supposed antecedent might be substituted for a probability judgement (for more on attribute substitution see Kahneman & Fredricks, 2002). However, the mental processes involved in the acts of imagining and supposing remain to be investigated.

Conclusions

In the experiments we described here we included only one condition asking for an evaluation of causal strength and we never asked people to evaluate a past tense counterfactual of the kind most often considered in the psychological literature. Nonetheless, we argue that our experiments have quite a bit to say about the relationship between causal and counterfactual thinking. Our results suggest that the mental simulation of hypothetical possibilities underlies people's evaluation of three different types of claim. Judgements about explicitly causal claims are associated with simulations in which the putative cause is temporarily supposed together with simulations where the cause is supposed to be absent. The evaluation of concessive conditionals, which are often understood to deny a causal relationship (see Byrne, 2005), is similarly associated with judgements based upon both types of simulation. In contrast to causal judgments , however, the likelihood of the effect in the absence of the putative cause is a positive rather than a negative predictor.

These results suggest that evaluating explicit causal claims, or conditional constructions used to deny such claims, cues a process of simulation that involves imagining that the antecedent event is 'undone'. This is akin to the 'undoing' associated with the generation of counterfactual possibilities and results in a belief that contributes to causal judgments in line with covariation accounts of causality. These findings suggest a mechanism through which people get a sense of the strength of causal relations in the world. The notion of a mental simulation is critical in this account as it is to other accounts described in this volume. However, a fuller understanding of the relationship between counterfactuals and causation will require a better theory of the specific processes involved in running such mental simulations.

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Table 1

Example sentences used in Experiments 1 and 2.

1. If oil prices continue to rise, then UK petrol prices will rise.
2. If car ownership increases, then traffic congestion will get worse.
3. If high-risk prisoners are released early, then the crime rate will increase.
4. If Adidas get more superstars to wear football their football boots, then sales will increase.
5. If children are paid to go to school, then attendance levels will increase.
6. If parenting is taught in schools, juvenile crime rates will increase.
7. If footballers' wages increase, then more goals will be scored during the football season.
8. If compulsory PE lessons are introduced until the age of 18, then child levels of obesity will rise.
9. If EU quarantine laws are strengthened, rabies will spread to the UK.
10. If the legal age of driving is lowered, then the number of accidents on the road will fall.

Table 2

Correlations between probability judgments and derived probabilities calculated over sentences in Experiment 1.

Predictors	Causal Strength	Even-if
P(C/A)	.96**	.76**
P(C/not-A)	-.39**	.08
Delta-p rule	.90**	.51**

Table 3

Regression models for even-if and causal strength judgments from Experiment 1based upon three independent predictors.

	Beta weights for predictors		F Value	$R^2_{adjusted}$
	P(C/A)	P(C/not-A)		
Causal	.92**	-.15**	F (3,44) = 381.8, p<.001	.94
Even-if	.84**	.29**	F (2,45) = 43.6, p<.001	.64

*p < .05, ** <.01

Table 4

Comparison of linear and quadratic curve fitting for even-if against P(C/A) in Experiment 1.

	Beta weights for predictors		F Value	$R^2_{adjusted}$
	P(C/A)	$P(C/A)^2$		
Linear	.76**	--	F (1,46) = 63.5, p<.001	.57
Quadratic	.82**	.28**	F (2,45) = 42.7, p<.001	.64
	R^2 change test: F(1,45)=9.78, p<.001			

*p < .05, ** <.01

Table 5

Correlations between probability judgments and derived probabilities in Experiment 2 calculated over sentences.

Predictors	If then	Even-if
P(C/A)	.96**	.83**
P(C/not-A)	-.45**	.06
Delta-p rule	.89**	.62**

Table 6

Regression models for even-if and if-then in Experiment 2 based upon three independent predictors.

	Beta weights for predictors		F Value	$R^2_{adjusted}$
	P(C/A)	P(C/not-A)		
If-then	.92**	-.09†	F (2,45) = 249.9, p<.001	.91
Even-if	.96**	.32**	F (2,45) = 81.56, p<.001	.77

†p < .1, *p < .05, ** <.01

Table 7

Comparison of linear and quadratic curve fitting for even-if against P(C/A) in Experiment 2.

	Beta weights for predictors		F Value	R^2 adjusted
	P(C/A)	$P(C/A)^2$		
Linear	.83**	--	F (1,46) = 105, p<.001	.69
Quadratic	.94**	.33**	F (2,45) = 86.8, p<.001	.78
	R^2 change test: F(1,45)=21.41, p<.001			

*p < .05, ** <.01

Figure 1

The relationship between P (C/A) and sentence ratings for even-if in Experiment 1.

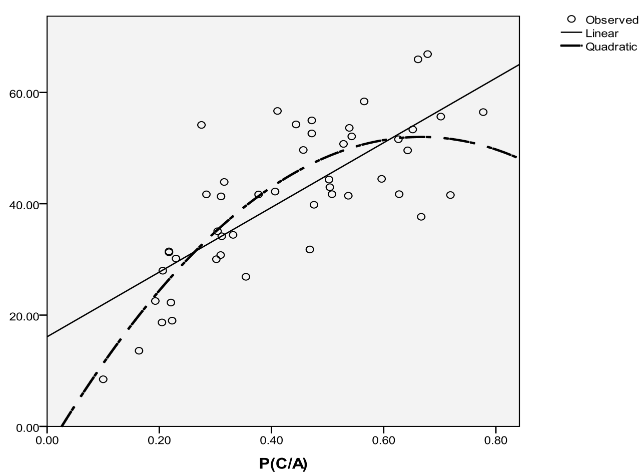

Figure 2

The relationship between P(C/A) and sentence ratings for even-if in Experiment 2.