# Evidence for the Jeffrey Table Credibility Ratings for Conditionals Given False Antecedent Cases

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# Evidence for the Jeffrey Table: Credibility Ratings for Conditionals Given False Antecedent Cases

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Abstract

Conditionals statements are a common component in natural languages. The research reported in this paper is on a fundamental question about singular conditionals. Is there an adequate account of people's truth, falsity, and credibility (probability) judgments about these conditionals when their antecedents are false? Two experiments examined people's quantitative credibility ratings and qualitative truth and falsity judgments for singular conditionals, *if p then q*, given false antecedent, *not-p*, cases. The results demonstrate that, when relevant knowledge about the conditional probability of *q* given *p*, $P(q|p)$, is available to participants in *not-p* cases, they tend to make credibility ratings based on $P(q|p)$, and to make "true" (or "false") judgments at a high (or low) level of these credibility ratings. These findings favor the Jeffrey table account of these conditionals over the other existing accounts, including that of the de Finetti table.

Keywords: singular conditionals; truth judgment; credibility rating; conditional probability; the Jeffrey table

Conditionals, *if p then q*, are extensively used in natural languages, like Chinese and English, and in scientific research, and there is a fundamental research question about them (Evans & Over, 2004). When do people regard them as “true”, or “false”, or judge them high, or low, credible? For example, what cases render a conditional, e.g., *If the next card drawn from the pack is a red card, then it is a square card*, true or false? The classical truth table task (Evans & Over, 2004; Over & Baratgin, 2016) asks people to judge whether such a conditional *if p then q* is true or false, given the four possible truth table cases (where ¬ = not): *p & q*, *p & ¬q*, *¬p &q* or *¬p & ¬q*. A *singular*, or specific, conditional refers to one particular item, e.g., the next card drawn from a pack. A *general* conditional would be about every card in the pack, e.g., *if a card in the pack is face card, then it is a red card* (see Cruz & Oberauer, 2014 on general conditionals). The research in paper only concerns singular conditionals.

Four answers to the above question will be considered: the classical material conditional (or material implication) account (Wason & Johnson-Laird, 1972), the latest version of mental models theory (Johnson-Laird, Khemlani, & Goodwin, 2015), the de Finetti table and its extension, and the Jeffrey table (Cruz & Oberauer, 2014; Over & Cruz, 2018). The material conditional, the de Finetti table, and the Jeffrey table were first proposed in formal logic and philosophy, but could still yield descriptive accounts of people's actual judgments. Mental models theory was proposed as descriptive account from the start. These accounts make different predictions for singular conditionals. Table 1 shows the respective predictions of the material conditional account, the de Finetti table, and the Jeffrey table.

The material conditional (or material implication) account proposes the classical truth table in which the truth of the conditional, *if p, then q*, is a function of truth values of *p* and *q* (Wason & Johnson-Laird, 1972). Each combination of truth or falsity for *p* and *q* determines a corresponding truth value of the conditional. There are four possible truth table cases in Table 1: *p & q*, *p & ¬q*, *¬p & q* and *¬p & ¬q*. The material conditional account is that the conditional, *if p then q*, is true in each of these cases, *p & q*, *¬p & q* , and *¬p & ¬q*, and false in the remaining one, *p & ¬q*.

Table 1

Truth tables for singular conditionals

| Possible cases | *if p then q* | | |
|---|---|---|---|
| | Classical truth table | de Finetti table | Jeffrey table |
| *p & q* | True | True | True |
| *p & ¬q* | False | False | False |
| *¬p & q* | True | Uncertain | *P*(*q*\|*p*) |
| *¬p & ¬q* | True | Uncertain | *P*(*q*\|*p*) |

Note: ¬ = not, and *P(q|p)* = the conditional subjective probability of *q* given *p*.

The latest version of mental models theory holds that a basic conditional is true if *p & q*, *¬p & q* and *¬p & ¬q* are all possible and *p & ¬q* is impossible (Johnson-Laird et al., 2015; Hinterecker, Knauff, & Johnson-Laird, 2016). There are serious objections to this claim (Baratgin, Douven, Evans, Oaksford, Over, & Politzer, 2015; Oaksford, Over, & Cruz, in press; Over & Cruz, 2018), but importantly for our purposes here, mental models theory does not predict that the value of *if p then q* should be *P*(*q*|*p*) when *¬p* holds, and it is inconsistent with the hypothesis that people will sometimes judge that *if p then q* is "true" when the credibility of *if p then q* is high but less than 100%.

The de Finetti table is a "defective" truth table in which the conditional is true only for *p & q* cases, and false only for *p & ¬q* cases, being "void" or uncertain for *¬p & q* and *¬p & ¬q* cases. The false antecedent cases are irrelevant to the truth of the conditional in the de Finetti table, and so do not make the conditional is true or false (Baratgin, Over & Politzer, 2013, 2014; Evans & Over, 2004; Over & Baratgin, 2016). Moreover, the de Finetti table implies that when *p*, or *q*, is uncertain, the conditional is also uncertain.

The Jeffrey table extends the de Finetti table by replacing “uncertain” with the conditional subjective probability of *q* given *p*, P(*q*|*p*), which can indicate any degree of belief in *if p then q*. The Jeffrey table is based on the Ramsey test, according to which people evaluate *if p then q* in ¬*p* cases by hypothetically supposing *p*, making any changes necessary to preserve consistency, and then judging the extent to which *q* follows, with a judgment about *P*(*q*|*p*) as a result (Adams, 1998; Edgington, 2010; Jeffrey, 1991; Over & Baratgin, 2016; Pfeifer & Kleiter, 2010; Stalnaker & Jeffrey, 1994). The Ramsey test implies *the conditional probability hypothesis*: that people will judge the credibility, or probability, of the conditional, *P(if p then q)*, to be *P*(*q*|*p*), and so their judgments of the credibility of the conditional should increase with *P*(*q*|*p*). The conditional probability hypothesis has been highly confirmed in general (Baratgin, Over, & Politzer, 2013; Cruz & Oberauer, 2014; Evans et al., 2007; Evans, Handley, & Over, 2003; Fugard, et al., 2011; Kleiter, Fugard, & Pfeifer, 2018; Oberauer & Wilhelm, 2003; Over & Baratgin, 2016; Over, et al., 2007; Pfeifer, 2013; Politzer, Over, & Baratgin, 2010; Singmann, Klauer, & Over, 2014; but see also Douven, Elqayam, Singmann, and Wijnbergen-Huitink, 2018, and Skovgaard-Olsen, Singmann, & Klauer , 2016, for a possible limitation of the hypothesis). The Jeffrey table and the conditional probability hypothesis are proposals within the probabilistic approach to the psychology of conditionals (Elqayam & Over, 2013; Kleiter, Fugard, & Pfeifer, 2018; Oaksford & Chater, 2007; Over & Cruz, 2018; Wang & Yao, 2018a, 2018b). One view within this approach that people's understanding of the conditional *if p then q* is given by the de Finetti table, or its extension, the Jeffrey table, and by the Ramsey test, and that people will tend to assert *if p then q* without qualification, or as “true”, when $P(q|p)$ is high in context, including some contexts where $P(q|p)$ = 100% (Over & Cruz, 2018).

As a normative theorist, Jeffrey (1991) originally proposed the Jeffrey table as a development of de Finetti's subjective probability theory, and as an extension of the de Finetti table, but it could still correspond with ordinary people's actual judgments. Suppose as a psychological hypothesis that it does. Then in the false antecedent cases of $\neg p \& q$ or $\neg p \& \neg q$, people's judgments about the credibility of *if p then q* will correspond to their judgments about $P(q|p)$ in light of the information (frequency or other) available to them. According to a probabilistic approach to the psychology of conditionals, based on the Ramsey test and the Jeffrey table, we can make the following prediction. High credibility $P(q|p)$ ratings are likely to elicit “true” judgments about *if p then q*, whereas low credibility $P(q|p)$ ratings are likely to elicit “false” judgments for *if p then q*. Moreover, moderate $P(q|p)$ credibility ratings are likely to elicit “neither true nor false” judgments for *if p then q*. For example, consider the singular conditionals: *If the observed animal is a cat then it can climb trees* and *If the observed animal is a pig then it can climb trees*. Then by the Ramsey test and Jeffrey table, the former conditional has very high credibility, since the conditional probability is very high, and the latter very low credibility, since the conditional probability is very low. These judgments follow even if the observed animal is a duck and it can only swim, and so is a $\neg p \& \neg q$ case. People will regard the former conditional as highly credible and “true”, and the latter conditional as of low credibility and “false”. Thus for this approach, an extended prediction is that false antecedents cases can elicit both “true” and “false” judgments, depending on the conditional probability. In complete contrast, in a material conditional account, all conditionals with false antecedents are “true” and highly probable, since the material conditional is true in these cases. Probabilistic theorists argue that, whatever the virtues of the material conditional in formal theories, a natural language conditional like *If the observed animal is a pig then it can climb trees* cannot be a material conditional.

To test the above predictions, we asked participants to judge the extent to which *if p then q* is true or credible when they were given ¬*p & q* or ¬*p &* ¬*q* cases. Important previous studies have asked their participants for probability judgments about *if p then q* when they were not given specific truth table cases (Kleiter, Fugard, & Pfeifer, 2018; Over et al., 2007; Singmann, Klauer, & Over, 2014), but to our knowledge, no previous studies have investigated probability judgments for *if p then q* when participants were given false antecedent, ¬*p & q* and ¬*p &* ¬*q* cases.

Table 1 shows the difference between the de Finetti table and the Jeffrey table. The de Finetti table implies that people should judge that a conditional is uncertain for ¬*p & q* and ¬*p &* ¬*q* cases. The Jeffrey table implies, more specifically, that for ¬*p & q* and ¬*p &* ¬*q* cases people can rate the probability of *if p then q* based on $P(q|p)$, and make "true" and "false" judgments for it, when information on $P(q|p)$ is available to them. No previous studies have tested this difference. In the classical truth evaluation task, experimenters asked people to make qualitative truth-value judgments, "true", "false", or "uncertain", for *if p then q*, but no information on $P(q|p)$ was available to them. These classical experiments could not tell whether the participants conformed to the Jeffrey table. In contrast, our studies were designed to answer this question, by investigating people's probability judgments for *if p then q* given ¬*p & q* and ¬*p &* ¬*q* cases when $P(q|p)$ information was available.

Some classical truth evaluation tasks found that people judge that *if p then q* is "true" for *p & q* cases, "false" for *p &* ¬*q* cases, and neither true nor false, or "uncertain" for ¬*p & q* and ¬*p &* ¬*q* cases (Baratgin, Over & Politzer, 2013; Over & Baratgin, 2016; Politzer, Over, & Baratgin, 2010; Wason & Johnson-Laird, 1972). The meta-analysis of Schroyens (2010) showed that people sometimes judge ¬*p & q* cases as "false". This could happen because people interpreted *if p then q* as *p if and only if q* (Evans & Over, 2004). Hence the results of the classical truth evaluation studies do not appear to be uniform. The results from recent studies (Baratgin, Over & Politzer, 2013; Baratgin, Politzer, Over & Takahashi, 2018; Over & Baratgin, 2016; Politzer, Over, & Baratgin, 2010) are consistent with the de Finetti table, but do not tell us about its extension, the Jeffrey table. In these recent tasks, each truth table case was presented in an isolated manner, without additional or background information. For a given ¬*p & q* or ¬*p &* ¬*q* case, no information was available to the participants for judging the probability of *if p then q* by the Ramsey test, and so the test could not be run. Consequently, people tended to judge that *if p then q* was "uncertain" for ¬*p & q* and ¬*p &* ¬*q* cases. When additional or background information about $P(q|p)$ is available, the Ramsey test and Jeffrey table imply that people will not generally give undifferentiated "uncertain" responses. In our experiments, we made such additional or background evidence available to our participants.

Moreover, both the material conditional account and mental models theory represent conditionals as "deterministic", without exceptions (Johnson-Laird et al., 2015). They are disconfirmed if people sometimes judge that *if p then q* is "true" when $P(q|p)$ is high but less than 100%. These two accounts do not imply that the content of conditionals can be represented with the de Finetti table or Jeffrey table, in which there is a probabilistic element.

Our research was designed to test the distinctive prediction for *if p then q*, based on the Jeffrey table, in ¬*p & q* or ¬*p &* ¬*q* cases. Two experiments investigated whether credibility ratings for *if p then q* would increase with $P(q|p)$, and whether truth judgments for *if p then q* would depend on credibility ratings, given ¬*p & q* or ¬*p &* ¬*q* cases. Experiment 1 examined credibility ratings for abstract conditionals when additional frequency information was available. Experiment 2 examined credibility ratings and truth judgments for concrete conditionals. Concrete conditionals, e.g., *If the* *animal is a bird, then it has wings*) can make contact with background knowledge, and hence no frequency information was given to participants in Experiment 2.

## Experiment 1

Experiment 1 investigated whether credibility ratings for abstract conditionals *if p then q* would increase with $P(q|p)$, when the participants were explicitly given $\neg p$ & $q$ or $\neg p$ & $\neg q$ cases.

### Method

Participants: A total of 80 college students (30 men, 50 women) from Shaanxi Normal University in China participated in Experiment 1.

Design and materials

Experiment 1 was a paper-and-pencil experiment using the probabilistic truth table task. The experiment was a 2×2 mixed factorial design with type of given case, $\neg p$ & $q$ vs. $\neg p$ & $\neg q$, as the between-subjects factor, and conditional probability $P(q|p)$ based on frequency information, 60% vs. 90%, as the within-subjects factor. There were two groups: the $\neg p$ & $q$ and $\neg p$ & $\neg q$ group. The questionnaire for each group contained two problems. Each problem had frequency information for the participants on the truth table cases that was relevant to a conditional probability $P(q|p)$ judgment. The task was to rate how credible *if p, then q* was for a given a $\neg p$ & $q$, or a $\neg p$ & $\neg q$, case. $P(q|p)$ determined by frequency information, was low for one problem, 60/100, but was high for the other, 90/100. The problem design followed the conventional probabilistic truth table task in asking about singular conditionals. The participants were told that a *specific* card had been drawn from a pack of cards, and they were asked to rate the probability of a singular conditional referring to this specific card, and not the whole pack. In asking about a specific item, our task followed previous tasks (Evans, et al., 2003; Evans, et al., 2007; Fugard, et al., 2011; Kleiter, et al., 2018). However, previous tasks did not tell the participants anything about the specific card (or other item), only that it was randomly selected. Uniquely in our task, participants were told that the specifically selected card was a $\neg p$ *&* $q$ or a $\neg p$ *&* $\neg q$ card.

With the $\neg p$ *&* $q$ group as an example, one version of the questionnaire was as follows, with the English translated from the original Chinese. The task for the $\neg p$ *&* $\neg q$ group was similar, but the two problems were counterbalanced.

Instruction

Please read the following information and then answer the credibility questions by giving your estimates on a scale from 0% to 100%. The greater percentage indicates the greater credibility. Please answer the questions carefully in the given order.

1. There is a pack of 200 cards. It has the following composition:

| |
|---|
| 90 round red cards |
| 10 round blue cards |
| 50 square red cards |
| 50 square blue cards |

Now, a square red card is drawn from the pack. For the card, how credible is it that if the card is round then it is red? (          )

2. There is a pack of 200 cards. It has the following composition:

| |
|---|
| 60 round red cards |
| 40 round blue cards |
| 50 square red cards |
| 50 square blue cards |

Now, a square red card is draw from the pack. For the card, how credible is it that if the card is round then it is red? (          )

The questionnaire for the $\neg p$ *&* $\neg q$ group was identical to the above, except that the given case was a square blue card, a $\neg p$ *&* $\neg q$ case.

For each group, the Jeffrey table implied that credibility ratings would increase with *P*(*q*|*p*). In the material conditional account, *if p then q* is equivalent to ¬*p or q*. Since a ¬*p* implies ¬*p or q*, *P*(¬*p or q*) should be 100% given a ¬*p & q* or ¬*p &* ¬*q* card. Thus the material conditional account implies that, when given a ¬*p & q* or a ¬*p &* ¬*q* card, *P*(*if p then q*) would be 100%, regardless of *P*(*q*|*p*). Mental models theory and the de Finetti table do not predict probability judgments of *P(q*|*p)* for *if p then q* given a ¬*p & q* or a ¬*p &* ¬*q* card.

Procedure: Participants were assigned to one of the two groups. The experiment was conducted in a quiet classroom. Participants took about 5 minutes to complete the questionnaires. Each participant received a pen for participation.

Results

The results of credibility ratings are shown in Table 2.

Table 2

Credibility ratings *M* (*SD*) in Experiment 1

| Groups | *P*(*q*\|*p*) | |
|---|---|---|
| | 90/100 | 60/100 |
| The ¬*p & q* group | 62.88% (28.78%) | 42.70% (19.99%) |
| The ¬*p &* ¬*q* group | 44.38% (31.69%) | 28.58% (21.91%) |

The raw data showed that no participants gave the estimate of 100% for any problem. This implies that no participants interpreted *if p then q* as a material conditional, and so these data immediately refuted the material conditional account. Moreover, only three participants (7.5%) in the ¬*p & q* group and six participants (15%) in the ¬*p &* ¬*q* group gave the estimate of 0% for each problem, showing the deterministic reading of conditionals predicted by mental models theory. Most participants showed the probabilistic reading of conditionals, as deviates from the prediction of mental models theory.

The data were analyzed with a 2 (the within-subjects factor, conditional probability: high vs. low) x 2 (the between-subjects factor, type of given cases: ¬*p* & *q* vs. ¬*p* & ¬*q*) analysis of variance. The analysis revealed an effect of conditional probability. Credibility ratings increased with $P(q|p)$, $F(1, 79) = 19.18$, $p < .001$, $\eta_p^2 = .11$. There was also an effect of type of given cases. Credibility ratings in the ¬*p* & *q* group were significantly greater than those in the ¬*p* & ¬*q* group, $F(1, 79) = 15.77$, $p < .001$, $\eta_p^2 = .09$. There was no interaction between the two factors. Overall, given a ¬*p* & *q* or a ¬*p* & ¬*q* case, credibility ratings increased with $P(q|p)$. This result is therefore consistent with the implications of the Jeffrey table, and not with other accounts.

However, Table 2 shows that the average credibility rating for each problem was obviously lower than the corresponding $P(q|p)$. This was because a minority of participants gave extremely low ratings, such as 0%, 10% or 20%, which lowered the average credibility rating. These participants tended to be intolerant of possible *p* & ¬*q* counterexamples for *if p the q* in the given frequency distribution.

In summary, the overall response pattern of Experiment 1 favors the Jeffrey table over the other accounts.

## Experiment 2

Experiment 2 investigated whether credibility ratings would increase with $P(q|p)$, and whether truth judgments would depend on credibility ratings, given ¬*p* & *q* or ¬*p* & ¬*q* cases for concrete conditionals.

### Method

Participants: A total of 92 college students (40 men, 52 women) from Shaanxi Normal University in China participated in the experiment.

Design and materials

A paper-and-pencil experiment was conducted. There were two groups. One group completed the two problems with "definition" conditionals, e.g., *if the animal is a sparrow, then it can fly,* and the other group completed the two problems with "causal" conditionals, e.g., *if it rains then the game will be called off*. For each group, the two problems formed a 2 × 2 within-subjects design. The two within-subjects factors were type of given cases, $\neg p \,\&\, q$ vs. $\neg p \,\&\, \neg q$, and conditional probability $P(q|p)$, high vs. low levels. Each problem contained a $\neg p \,\&\, q$, or $\neg p \,\&\, \neg q$, case and two conditionals with different conditional probabilities, $P(q|p)$, which depended on background knowledge, and two questions. One question is to rate how credible each conditional was, and the other is to judge whether each conditional was "true" or "false".

In a probabilistic account of conditionals based on the Jeffrey table (Over & Cruz, 2018), high credibility ratings for *if p then q* can affect truth and falsity judgments in false antecedent $\neg p$ cases. High credibility ratings for *if p then q* can lead to "true" judgments about *if p then q*, moderate credibility ratings can lead to "neither true nor false" judgments, and low credibility ratings can lead to "false" judgments. In contrast, the de Finetti table implies that a $\neg p$ case would elicit "neither true nor false" judgments regardless of credibility ratings. The material conditional account implies that, for a given $\neg p$ case, *if p then q* will always be judged "true". In the latest version of mental models (Johnson-Laird et al., 2015), *if p then q* does not follow in a $\neg p$ case, because $\neg p$ conflicts with the $p \,\&\, q$ possibility in the mental model *if p then q*, but the theory is inconsistent with a finding that *if p then q* is sometimes judged "true" (in a given $\neg p$ case) when the credibility of *if p then q* is high but less than 100%.

The complete questionnaire of the definition conditionals is as follows. Here is the English version translated from the original Chinese version.

Instruction

Please complete the following problems. For the estimation questions, please give your estimates on a scale from 0% to 100%. The greater percentage indicates the greater credibility. For the choice questions, please tick your answers.

There is an animal that is a bat. It can fly. For the animal, there are the following statements:

A. If the animal is a sparrow, then it can fly. How credible is this statement? Is this statement true or false? (true false neither true nor false)

B. If the animal is a rat, then it can fly. How credible is this statement? Is this statement true or false? (true false neither true nor false)

There is an animal that is a duck. It can swim. For the animal, there are the following statements:

A. If the animal is a pig, then it can climb trees. How credible is this statement? Is this statement true or false? (true false neither true nor false)

B. If the animal is a cat, then it can climb trees. How credible is this statement? Is this statement true or false? (true false neither true nor false)

In the following questionnaire of the causal conditionals, we present here, to save words, only given cases and the conditionals, omitting the credibility rating and truth judgment questions.

A school holds a game on a certain day. It is a sunny day and the game is successfully held. For this game, there are the following statements:

A. If there is heavy rain on the day, the game is canceled.

B. If there is drizzle in the day, the game is canceled.

There is a dog. The dog suffers from a rash, and it itches.

A. If the dog has sand on it, it itches.

B. If the dog has fleas on it, it itches.

For each group, the two problems were counterbalanced. One was the above order. The other was the reverse version of the above. Within each problem, the two conditionals were also counterbalanced.

Procedure: The procedure was identical to that in Experiment 1.

Results

The results of credibility ratings and truth judgments are shown in Table 3.

Table 3

Credibility ratings *M* (*SD*) and frequencies (percentages) of truth judgments

| Given cases | Bat and fly | | Duck and swim | |
|---|---|---|---|---|
| Definition conditionals | If rat, then fly | If sparrow, then fly | If pig, then climb | If cat, then climb |
| Credibility ratings | 4.37% (11.42%) | 80.35% (21.83%) | 6.85% (13.92%) | 69.85% (30.33%) |
| True | 1 (2.2) | 30 (60.9) | 0 (0) | 29 (63.4) |
| False | 42 (91.3) | 2 (4.6) | 40 (87) | 6 (13.0) |
| Neither | 3 (6.5) | 14 (30.4) | 6 (13) | 11 (23.9) |
| Given cases | Sunshine and the game held | | Rash and itches | |
| Causal conditionals | If drizzle, then the game is canceled | If heavy rain, then the game is canceled | If sand, then itch | If fleas, then itch |
| Credibility ratings | 35.30% (22.87%) | 87.48% (15.27%) | 30.33% (20.96%) | 81.48% (15.83%) |
| True | 4 (8.7) | 32 (69.6) | 5 (10.9) | 31 (67.4) |
| False | 27 (58.7) | 2 (4.3) | 27 (58.7) | 3 (6.5) |
| Neither | 15 (32.6) | 12 (26.1) | 14 (30.4) | 12 (26.1) |

The credibility ratings data were analyzed using a mixed three-way ANOVA. It involved group (definition vs. causal conditional, between-subjects), conditional probability (high vs. low, within-subjects), and type of given case (¬*p* & *q* vs. ¬*p* & ¬*q*, within-subjects). The analysis revealed an effect of conditional probability. Credibility ratings increased with $P(q|p)$, $F(1, 90) = 783.65$, $p < .001$, $\eta_p^2 = .897$. The main effect of type of given cases was not significant: $F(1, 90) = 0.15$, $p > .05$, $\eta_p^2 = .002$. The main effect of group was significant: $F(1, 90) = 60.06$, $p < .001$, $\eta_p^2 = .4$. There was no significant interaction between conditional probability and type of given cases. There was a significant interaction between group and conditional probability: $F(1, 90) = 16.96$, $p < .001$, $\eta_p^2 = .159$. There was a significant interaction between group and type of given cases: $F(1, 90) = 6.15$, $p < .05$, $\eta_p^2 = .064$. There was no significant interaction among the three factors. In summary, for both definition and causal conditionals, given a false antecedent ¬*p* case, credibility ratings increased with $P(q|p)$. This response pattern is consistent with the implications of the Jeffrey table, and not those of the other three accounts.

For each conditional in each problem, truth judgments showed a non-uniform distribution. For the six conditionals in Table 3, from the left to the right and from the top to the bottom, the results of the Chi-square tests of uniform distributions were as follows: $\chi^2$ (2) = 69.70, 25.74, 25.13, 19.09, 17.26, 30.44, 15.96, 26.65, $p < .001$. For each conditional, the majority of participants made certain judgments, “true” or “false”, whereas the minority of participants made “uncertain” judgments. For each problem, high credibility ratings yielded more “true” judgments for the conditional, whereas low credibility ratings yielded more “false” judgments for the conditional. The majority of participants made “true” judgments for a conditional with high credibility ratings, and “false” judgments for a conditional with low credibility ratings. Moreover, participants showing moderate credibility ratings (40-60%) for a conditional generally made uncertain truth judgments for the conditional. Thus, moderate credibility ratings generally yielded uncertain truth judgments. In summary, given a false antecedent case for a conditional, truth judgments depended on credibility ratings. The majority of participants made certain judgments, and the minority of participants made uncertain judgments.

In summary, the overall response pattern of Experiment 2 supports a probabilistic account the conditional based on the Jeffrey table.

## Discussion

Experiments 1 and 2 found that for both abstract and concrete singular conditionals *if p then q*, and given a false antecedent ¬*p* case, participants made quantitative credibility ratings based on $P(q|p)$, supporting the conditional probability hypothesis and the Jeffrey table. Experiment 2 found that participants made "true" judgments, or "false" judgments, for *if p then q* based on whether the credibility of *if p then q* was high, or low. These findings confirm the distinctive prediction of a probabilistic account of conditionals based on the Jeffrey table. They show that, given false antecedent ¬*p* cases, people can make quantitative credibility ratings, and qualitative "true", and "false", judgments for *if p then q* in line with this account.

The material conditional account, the de Finetti table account, and the latest version of mental models theory all are unable to explain our results. The material conditional account implies, against our results, that *if p then q* will be judged "true" and have a probability of 100% in all ¬*p* cases. The de Finetti table implies, against our results, that *if p then q* will be judged uncertain in all ¬*p* cases. In the most recent version of mental models theory (Johnson-Laird et al., 2015), *if p then q* does not follow from ¬*p*, but there is no explanation of our finding that the judged probability of *if p then q* is based on $P(q|p)$ in ¬*p* cases, and the theory is inconsistent with our finding that people will tend to judge that *if p then q* is "true" in ¬*p* cases when the credibility of *if p then q* is high but less than 100%.

Our support for the conditional probability hypothesis is consistent with previous findings that, for a singular conditionals without given ¬*p* case, the probability of *if p then q* and *P*(*q*|*p*) are closely related in people's judgments (Kleiter, Fugard, & Pfeifer, 2018; Over et al., 2007; Singmann, Klauer, & Over, 2014). Given false antecedent ¬*p* cases, credibility ratings for *if p then q* are also consistent with the hypothesized use of the Ramsey test, and our results demonstrate that the conditional probability hypothesis extends to judgments about the probability of *if p then q* given false antecedent ¬*p* cases.

Our findings are different from the previous findings that ¬*p & q* or ¬*p &* ¬*q* cases generally elicit "uncertain" or "irrelevant" judgments for *if p then q* (Baratgin, Over & Politzer, 2013; Over & Baratgin, 2016; Politzer, Over, & Baratgin, 2010; Wason & Johnson-Laird, 1972). We explain this difference as follows. Our experiments used the quantitative credibility judgment task in which evidence about *P*(*q*|*p*), such the frequency information in Experiment 1, was available to participants in ¬*p* cases. Such tasks activate the Ramsey test, resulting in conditional probability and truth judgments as predicted by the probabilistic approach. In contrast, the earlier experiments used the qualitative truth evaluation task in which no evidence about *P*(*q*|*p*) was available for participants in ¬*p* cases. Participants in these earlier tasks could not engage the Ramsey test, resulting in "uncertain" judgments for conditionals in ¬*p* cases, as is predicted by the de Finetti table. Whether or not the Ramsey test can be run in ¬*p* cases depends on whether evidence about *P*(*q*|*p*) is available. For example, a probability judgment about *if the card is round then it is red* cannot be made, given a square card drawn from a pack of cards, when no frequency information of the cards in the pack is available.

Our results also show that truth judgments for *if p then q* given ¬*p* cases depend on whether knowledge about *P*(*q*|*p*) is available. When information about *P*(*q*|*p*) is available in ¬*p* cases, as it is from background knowledge in Experiment 2, and $P(q|p)$ is high in light of this information, people will tend to say that *if p then q* is "true". In this way, credibility ratings determine truth judgments. High (or low) credibility ratings will lead to "true" (or "false") judgments for conditionals. When no information about $P(q|p)$ is available in $\neg p$ cases, the Ramsey test cannot be run, and "true" or "false" judgments cannot be made. The result is that people will judge *if p then q* to be "uncertain" in these $\neg p$ cases, and so will conform to the de Finetti table. But they will comply with the Jeffrey table when information about $P(q|p)$ is available.

The above general pattern of our results on probability and truth judgments for *if p then q*, given $\neg p$ cases and evidence relevant to $P(q|p)$, is also consistent with the hypothetical inferential theory of Douven, et al. (2018), which anyway falls under the broad probabilistic approach. This theory states that the credibility of *if p then q* depends on whether or not there is a good inferential connection between *p* and *q* (see also Skovgaard-Olsen et al., 2016). If the connection is good, then individuals tend to judge the conditional true. If it is bad, they tend to judge the conditional false. If there is no apparent connection between both, then they tend to judge that the conditional has an indeterminate truth value. The inferential connection between *p* and *q* is also evidence knowledge about $P(q|p)$. Their research demonstrates that truth judgments for a conditional without given false antecedent cases depend on evidence knowledge about $P(q|p)$. Our research demonstrates that truth judgments for a conditional given a false antecedent case also depend on evidence knowledge about $P(q|p)$. Thus, truth judgments for a conditional depend on evidence knowledge about $P(q|p)$, independent of whether or not false antecedent cases are given. This implies that the Ramsey test is a general account for the interpretation of conditionals.

In summary, our research demonstrates that, when knowledge about $P(q|p)$ is available in false antecedent $\neg p$ cases, people make judgments about the probability of a singular conditional *if p* *then q* based on $P(q|p)$, and tend to judge that *if p then q* “true” when $P(q|p)$ is high, and “false” when $P(q|p)$ is low. These findings support the Jeffrey table account of *if p then q*, the conditional probability hypothesis, and the Ramsey test as a general way of determining the credibility or probability of *if p then q*.

The file of raw data is available at the URL, http://dx.doi.org/10.17605/OSF.IO/U649J

References

Adams, E. (1998). *A primer of probability logic.* Standford: CLSI publications.

Baratgin, J., Douven, I., Evans, J. S. B., Oaksford, M., Over, D., & Politzer, G. (2015). The new paradigm and mental models. *Trends in cognitive sciences*, *19*(10), 547-548. doi:10.1016/j.tics.2015.06.013

Baratgin, J., Over, D. E., & Politzer, G. (2013). Uncertainty and de Finetti tables. *Thinking & Reasoning*, 19, 308-328. doi:10.1080/13546783.2013.809018

Baratgin, J., Over, & Politzer, (2014). New psychological paradigm for conditionals and general de Finetti tables. *Mind and Language*, *29*, 73-84. doi:10.1111/mila.12042

Baratgin, J., Politzer, G., Over, D. E., & Takahashi, T. (2018). The psychology of uncertainty and three-valued truth tables. *Frontiers in Psychology*, *9*, 1479. doi:10.3389/fpsyg.2018.01479

Cruz, N., & Oberauer, K. (2014). Comparing the meanings of “if ” and “all.” *Memory &. Cognition*, 42, 1345–1356. doi:10.3758/s13421-014-0442-x

Douven, I., Elqayam, S., Singmann, H., & van Wijnbergen-Huitink, J. (2018). Conditionals and inferential connections: A hypothetical inferential theory. *Cognitive psychology*, *101*, 50-81. doi:10.1016/j.cogpsych.2017.09.002

Edgington, D. (2010). What if? Questions about conditionals. *Mind and Language*, *18*, 380- 401. doi:10.1111/1468-0017.00233

Elqayam, S. , & Over, D. E. . (2013). New paradigm psychology of reasoning: an introduction to the special issue edited by elqayam, bonnefon, and over. *Thinking & Reasoning*, *19*(3-4), 249-265. doi: 10.1080/13546783.2013.841591

Evans, J. St. B. T., Handley, S., Neilens, H., & Over, D. E. (2007). Thinking about conditionals: A study of individual differences. *Memory & Cognition*, *35*, 1772-1784. doi:10.3758/BF03193509

Evans, J. St. B. T., Handley, S. J., & Over, D. E. (2003). Conditional and conditional probability. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 321–335. doi:10.1037/0278-7393.29.2.321

Evans, J. St. B. T., & Over, D. E. (2004). *If*. Oxford: Oxford University Press.

Fugard, J. B., Pfeifer, N., Mayerhofer, B., & Kleiter, G. D. (2011). How people interpret conditionals: Shifts toward conditional event. *Journal of Experimental Psychology- Learning Memory and Cognition, 37,* 635-648. doi:10.1037/a0022329

Hinterecker, T., Knauff, M., and Johnson-Laird, P. N. (2016). Modality, probability, and mental models. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *42*(10), 1606-1620. doi:10.1037/xlm0000255

Jeffrey, R. C. (1991). Matter of fact conditionals. *Aristotelian Society Supplementary Volume*, 65, 161-183. doi:10.1093/aristoteliansupp/65.1.161

Johnson-Laird, P. N., Khemlani, S. S., & Goodwin, G. P. (2015). Logic, probability, and human reasoning. *Trends in cognitive sciences*, *19*(4), 201-214. doi:10.1016/j.tics.2015.02.006

Kleiter, G., Fugard, A, & Pfeifer, N. (2018). A process model of the understanding of conditionals. *Thinking & Reasoning*, *24*, 386-422. doi:10.1080/13546783.2017.1422542

Oaksford, M. & Chater, N. (2007). *Bayesian rationality: The probabilistic approach to human reasoning*. Oxford: Oxford University Press.

Oaksford, M., Over, D., & Cruz, N. (2019). Paradigms, possibilities, and probabilities: Comment on hinterecker, knauff, and johnson-laird (2016). Journal of Experimental Psychology: Learning, Memory, and Cognition, 45(2), 288-297. doi:10.1037/xlm0000586

Oberauer, K. & Wilhelm, O. (2003). The meaning(s) of conditionals: Conditional probabilities, mental models and personal utilities. *Journal of Experimental Psychology: Learning Memory* *and Cognition*, *29*, 680-693. doi:10.1037/0278-7393.29.4.680

Over, D. E., & Baratgin, J. (2016). The “defective” truth table: its past, present, and future. In Lucas, E., Galbraith, N., & Over, D (Eds.), *The Thinking Mind* (pp. 29-42). Psychology Press.

Over, D. E., & Cruz, N. (2018). Probabilistic accounts of conditional reasoning. In Linden J. Ball & Valerie A. Thompson (Eds.), *International handbook of thinking and reasoning*. Hove, Sussex: Psychology Press.

Over, D. E., Hadjichristidis, C., Evans, J. St. B. T., Handley, S. J., & Sloman, S. A. (2007). The probability of causal conditionals. *Cognitive Psychology, 54,* 62-97. doi:10.1016/j.cogpsych.2006.05.002

Pfeifer, N. (2013). The new psychology of reasoning: A mental probability logical perspective. *Thinking & Reasoning*, *19*(3-4), 329-345. doi:10.1080/13546783.2013.838189

Pfeifer, N., & Kleiter, G. D. (2010). The conditional in mental probability logic. In M. Oaksford & N. Chater (eds.), *Cognition and conditionals: Probability and logic in human thinking* (153-173). Oxford: Oxford University Press.

Politzer, G., Over, D. E., & Baratgin, J. (2010). Betting on conditionals. *Thinking & Reasoning*, *16,* 172-197. doi:10.1080/13546783.2010.504581

Schroyens, W. (2010). A meta-analytic review of thinking about what is true, possible, and irrelevant in reasoning from or reasoning about conditional propositions. *European Journal of Cognitive Psychology, 22*, 897–921. doi:10.1080/09541440902928915

Singmann, H. & Klauer, K. C., & Over, D. E. (2014). New Normative Standards of Conditional Reasoning and the Dual-Source Model. *Frontiers in Psycholog*y, 5. doi:10.3389/fpsyg.2014.00316

Skovgaard-Olsen, N., Singmann, H., & Klauer, K. C. (2016). The relevance effect and conditionals.

*Cognition*, *150*, 26-36. doi:10.1016/j.cognition.2015.12.017

Stalnaker, R., & Jeffrey, R. (1994). Conditionals as random variables, in E. Eells & B. Skyrms (eds.), *Probability and conditionals* (31-46). Cambridge: Cambridge University Press.

Wang, M., & Yao, X. (2018a). The dual reading of general conditionals: The influence of abstract versus concrete contexts. *Quarterly Journal of Experimental Psychology*, *71*, 859–869. doi:10.1080/17470218.2017.1281321

Wang, M., & Yao, X. (2018b). The contrast effect in reading general conditionals. *Quarterly Journal of Experimental Psychology, 71*, 2497–2505. doi:10.1177/1747021817746154

Wason, P., & Johnson-Laird, P. N. (1972). *Psychology of reasoning: Structure and content*. London: Batsford.