Counterfactuals, indicative conditionals, and negation under uncertainty: Are there cross-cultural differences?

Niki Pfeifer (niki.pfeifer@lmu.de)
Munich Center for Mathematical Philosophy, LMU Munich, Germany

Hiroshi Yama (yama@lit.osaka-cu.ac.jp)
Graduate School of Literature and Human Behavioral Sciences, Osaka City University, Japan

Abstract

In this paper we study selected argument forms involving counterfactuals and indicative conditionals under uncertainty. We selected argument forms to explore whether people with an Eastern cultural background reason differently about conditionals compared to Westerners, because of the differences in the location of negations. In a 2×2 between-participants design, 63 Japanese university students were allocated to four groups, crossing indicative conditionals and counterfactuals, and each presented in two random task orders. The data show close agreement between the responses of Easterners and Westerners. The modal responses provide strong support for the hypothesis that conditional probability is the best predictor for counterfactuals and indicative conditionals. Finally, the grand majority of the responses are probabilistically coherent, which endorses the psychological plausibility of choosing *coherence-based probability logic* as a rationality framework for psychological reasoning research.

Keywords: argument forms; cross-cultural comparison; counterfactuals; indicative conditionals; negation; probability logic; reasoning under uncertainty

Introduction

In this paper we study selected argument forms involving counterfactuals and indicative conditionals under uncertainty. The aim is to explore potential cross-cultural differences in human reasoning about conditionals and negation under uncertainty between Easterners and Westerners. There are two possible hypotheses: A universal hypothesis and a cultural differences hypothesis. Like universal grammar (Chomsky, 1957), the human mind is conceived as universal across cultures according to mainstream 20^{th} century psychology. Researchers who agree with this hypothesis usually assume that cultural differences are very small since human reasoning has evolved universally (e.g., Mercier & Sperber, 2011). So far, cross-cultural differences in reasoning involving negations have been described in the classical-logic based (old) paradigm psychology of reasoning literature (see, e.g., Nisbett, Peng, Choi, & Norenzayan, 2001; Norenzayan, Smith, Kim, & Nisbett, 2002; Peng & Nisbett, 1999; Yama, in press). These previous studies demonstrate that Westerners are inclined to engage in rule-based reasoning whereas Easterners are apt to engage in intuitive or dialectical reasoning. In other words, Easterners are more likely to consider contradictory premises dialectically than Westerners. However, Zhang, Galbraith, Yama, Wang, and Manktelow (2015) report that Easterners are not actually more dialectical when they meet contradictory opinions, but they believe due to cultural reasons that dialectical thinking is wiser than Westerners. Because contradictory premises are not used in this experiment, we do not make predictions concerning whether Easterners reason more dialectical or not (see, e.g., Peng & Nisbett, 1999). Rather, we explore whether the location of negation in the context of conditionals impacts on reasoning and whether our Japanese sample differs from corresponding data of Western samples. If Japanese people see a stronger cultural value in dialectical thinking, it is plausible to assume that they may hesitate to show stronger confidence in the correctness of their judgments. Moreover, the Japanese language differs from European languages in the location of verb and negation. Usually, the verb is placed at the end of a sentence in Japanese. Furthermore, the term "not" is placed after the negated verb. Thus, the word order of a negated sentence is: *complement—verb—not*. In spite of these differences, cross-cultural studies on logical reasoning which focus on these differences systematically are rare. Our study presents one of the first attempts (see also Yama, in press) to identify cross-cultural differences within the framework of the new probability-based paradigm psychology of reasoning.

Among the various ways of expressing and using counterfactuals (see, e.g. Declerck & Reed, 2001), we restrict our investigation of counterfactuals to conditionals in subjunctive mood, where the grammatical structure implies that the counterfactual's *antecedent* (A) is factually false. For instance, consider the utterance of the following counterfactual in the context of a randomly drawn poker card:

$$\text{If the drawn card were to show an ace } (A), \text{ then it would show spades } (C). \tag{1}$$

The grammatical structure of (1) pragmatically entails that the drawn card is not an ace ($\neg A$), i.e., the antecedent A of (1) is false. By "indicative conditional" we mean an "if–then" statement of the form *If A, then C*, e.g.,

$$\text{If the drawn card shows an ace, then it shows spades}. \tag{2}$$

Contrary to the counterfactual (1), the indicative conditional (2) does not imply whether the card actually shows an ace or not. While the core meaning of indicative conditionals was equated with the semantics of the *material conditional* in the classical logic-based paradigm (or "old") psychology of reasoning (see, e.g., Braine & O'Brien, 1998; Johnson-Laird, 1983; Rips, 1994; Wason & Johnson-Laird, 1972), our work is located in the new paradigm psychology of reasoning, where conditionals are interpreted as *conditional probability* assertions (see, e.g., Elqayam, Bonnefon, & Over, 2016;

Oaksford & Chater, 2007; Over, 2009; Pfeifer, 2013). Instead of using (fragments of) classical logic, the new paradigm psychology of reasoning uses probability theory as a rationality framework. Probability as a rationality framework is psychologically and philosophically appealing for many reasons (see, e.g., Pfeifer & Douven, 2014). Let us mention three of them.

First, probability theory allows for managing *degrees of belief* instead of restricting belief to the two values *true* and *false* as in the case of bivalent classical logic. Thus, probability theory provides a much richer framework to study conditionals. It allows for analysing different psychological predictions concerning conditionals: not only in terms of the material conditional ($A \supset C$) and the conjunction ($A \wedge C$) as defined in classical logic, but also in terms of the conditional event ($C|A$), as defined in coherence-based probability logic (see, e.g., Coletti & Scozzafava, 2002; Gilio, Pfeifer, & Sanfilippo, 2016; Pfeifer & Kleiter, 2009). Table 1 presents the truth conditions of these three interpretations. Note that the conditional event cannot be expressed in classical bivalent logic. We hypothesise that the degree of belief in a conditional *If A, then C* is interpreted by a suitable conditional probability assertion ($p(C|A)$) and neither as the probability of the material conditional ($p(A \supset C)$) nor as the probability of the conjunction ($p(A \wedge C)$). We will test these three interpretations in the following experiment.

Table 1: Truth tables for the material conditional $A \supset C$ interpretation, the conjunction $\wedge$ interpretation and the conditional event interpretation $C|A$ of a (counterfactual) conditional *If A (were the case), then C (would be the case).*

A	C	$A \supset C$	$\wedge$	$C|A$
true	true	true	true	true
true	false	false	false	false
false	true	true	false	undetermined
false	false	true	false	undetermined

Second, probability logic blocks so-called paradoxes of the material conditional (see, e.g., Pfeifer, 2014). For example, $\neg A$ ("not-A") logically entails $A \supset C$. The paradox arises, when the material conditional is used to formalize a natural language conditional. Then, for example, the conditional "if it rains today, then I'll be a billionaire tomorrow", follows from the premise "it does not rain today": this inference violates common sense but it is logically valid. In probability logic, the inference from $p(\neg A) = x$ to $p(C|A)$ is probabilistically non-informative, i.e., if $p(\neg A) = x$, then $0 \leq p(C|A) \leq 1$ is coherent; hence, the paradox is blocked (Pfeifer, 2014). Whether an inference is probabilistically informative or not is a binary question: if the best possible coherent probability bounds on the conclusion coincide with the unit interval $[0,1]$, then the argument form is probabilistically non-informative; otherwise, it is probabilistically formative (i.e., the premise set constrains the probability of the conclusion). The theoretical prediction that the paradox is probabilistically non-informative also matches experimental data based on samples involving Westerners (Pfeifer & Kleiter, 2011; Pfeifer & Tulkki, 2017b). Note that the paradox is not blocked if the conditional probability (conclusion) is replaced by $p(A \supset C)$ or by $p(A \wedge C)$. A subgoal of this paper is to explore how Japanese participants reason about this paradox.

Third, probability allows for retracting conclusions in the light of new evidence while classical logic is monotonic (i.e., adding a premise to a logically valid argument can only increase the set of conclusions). The suppression effect (see, e.g., Byrne, 1989; Stenning & van Lambalgen, 2005) illustrates peoples' capacity to retract conclusions if new premises are learned. Moreover, experimental data suggests that most people satisfy basic nonmonotonic reasoning postulates of System P (see, e.g. Benferhat, Bonnefon, & Da Silva Neves, 2005; Pfeifer & Kleiter, 2005, 2010). The rules of System P describe formally basic principles any system of nonmonotonic reasoning should satisfy (Kraus, Lehmann, & Magidor, 1990) and different semantics were developed, including probabilistic ones. Probabilistic semantics postulate that conditionals should be represented by conditional probability assertions (see, e.g., Adams, 1975; Gilio, 2002). Interestingly, inference rules which are (in)valid in System P are also (in)valid in standard systems of counterfactual conditionals (like Lewis, 1973). This convergence shows a close relation between conditional probabilities and counterfactuals. Compared to the big number of psychological investigations on indicative conditionals (for overviews see, e.g., Evans & Over, 2004; Nickerson, 2015), studies on adult reasoning about counterfactuals are surprisingly rare (Over, Hadjichristidis, Evans, Handley, & Sloman, 2007; Pfeifer & Stöckle-Schobel, 2015; Pfeifer & Tulkki, 2017b). Our study sheds new light by adding a cross-cultural perspective on indicative conditionals and counterfactuals.

Table 2: Task names, their abbreviations and formal structures used in the experiment, where $\neg$ denotes negation, $\rightarrow$ is a placeholder for denoting the indicative conditional or the counterfactual, $\supset$ denotes the material conditional, $\therefore$ denotes "Therefore".

Task name (abbreviation)	Argument form
Aristotle's thesis #1 (AT1)	it's not the case that:$(\neg A \rightarrow A)$
Aristotle's thesis #2 (AT2)	it's not the case that:$(A \rightarrow \neg A)$
Negated Reflexivity (NR)	it's not the case that:$(A \rightarrow A)$
From "Every" to "If" (EIn)	Every S is $P \therefore S \rightarrow \neg P$
From "Every" to "If" (EI)	Every S is $P \therefore S \rightarrow P$
Modus Ponens (MP)	$A, A \rightarrow C \therefore C$
Negated MP (NMP)	$A, A \rightarrow C \therefore \neg C$
Paradox (Prdx)	$\neg A \therefore A \rightarrow C$

Table 2 lists the task names, their abbreviations, and their underlying logical form used in our experiment. All argument forms were investigated previously in the literature on Western samples. Each argument form is suitable for indicative and subjunctive formulations. They are carefully selected to distinguish between the material conditional, conjunction and conditional event interpretation of conditionals. Tasks AT1, AT2, and NR (adapted from Pfeifer, 2012) are about negating conditionals. AT1 and AT2 are contingent (i.e., they are neither tautologies nor contradictions) under the material conditional interpretation of conditionals: specifically, $\neg(\neg A \supset A) \equiv \neg(\neg\neg A \vee A) \equiv \neg A$ and $\neg(A \supset \neg A) \equiv \neg(\neg A \vee \neg A) \equiv \neg\neg A \equiv A$. Since we don't know anything about $(\neg)A$, probability logic predicts for AT1: $0 \leq p(\neg(\neg A \supset A)) \leq 1$; likewise, for AT2: $0 \leq p(\neg(A \supset \neg A)) \leq 1$. For the conditional event interpretation, however, both AT1 and AT2 obtain probability one, since in general coherence requires that $p(A|\neg A) = p(\neg|A) = 0$ for any contingent A and since by the narrow scope reading of conditionals, AT1 is represented by $p(\neg A|\neg A)$ and AT2 is represented by $p(A|A)$ and 1 is the only coherent assessment for the respective conditional probabilities. Note that there are two ways to negate material conditionals, namely the wide scope negation of material conditionals (i.e., $A \supset C$ can be negated by $\neg(A \supset C)$) and the narrow scope negation of material conditionals (i.e., $A \supset C$ is negated by negating its consequent C: $A \supset \neg C$). Note that if people interpret $\rightarrow$ by $\supset$ but negate the conditional by the narrow scope interpretation of negation of conditionals, the predictions for AT1 and AT2 coincide with the predictions of the conditional probability interpretation of conditionals (since AT1: $p(\neg A \supset \neg A) = p(\neg\neg A \vee \neg A) = p(A \vee \neg A) = 1$ and since AT2: $p(A \supset \neg\neg A) = p(\neg A \vee \neg\neg A) = p(\neg A \vee A) = 1$). To disentangle the conditional probability interpretation and the narrow scope negation of the material conditional interpretation, we added the NR task. The NR task, the narrow scope negation of the material conditional interpretation predicts that the whole unit interval is coherent, since the instruction does not reveal any probabilistic information about $\neg A$ and since $(A \supset \neg A) \equiv (\neg A \vee \neg A) \equiv \neg A$, hence $0 \geq p(A \supset \neg A) \leq 1$, while coherence requires that $p(\neg A|A) = 0$.

Table 3 lists the normative predictions of the different argument forms. Averaging the percentages of responses in three studies reveals that 73% of the participants in task AT1, 75% in task AT2, and 80% of the participants in task NR responded probabilistically coherently according to the conditional probability interpretation (Pfeifer, 2012; Pfeifer & Stöckle-Schobel, 2015; Pfeifer & Tulkki, 2017b).

Task EI (resp., task EIn) connects the basic syllogistic sentence type "*Every S is P*" with associated conditionals (resp., conditionals involving negations) in the indicative and in the counterfactual form. The motivation for these tasks is to shed light on the hypothesised close relations between quantified statements and conditional probability assertions in the literature (see, e.g. Cohen, 2012; Pfeifer & Sanfilippo, 2017, submitted). Recent data of Westerners suggest, that in task ASP 73% of the participants respond that the conclusion holds, whereas 88% of the participants respond that the conclusion in task ASnP does not hold (Pfeifer & Tulkki, 2017b), which corresponds to the normative predictions.

We also investigate the well-known MP and its not logically valid but probabilistically informative counterpart NMP. In a sample of Western participants (Pfeifer & Tulkki, 2017b), 68% responded correctly, that the conclusion in task MP holds, and 63% responded correctly that the conclusion in task NMP does not hold (see also Pfeifer & Kleiter, 2007).

Although tasks EIn, EI, MP, and NMP do not differentiate among the three considered interpretations of the conditionals, these tasks were selected (i) to test whether the responses of the Japanese sample differs from responses of corresponding Western samples and (ii) to investigate whether there are differences in the responses between the two experimental conditions (i.e., indicative versus counterfactual conditionals).

Finally, as mentioned above, we investigate one of the paradoxes of the material conditional. Western data on Task Prdx indicates that most people (87% on the average) understand that this argument form is probabilistically non-informative (Pfeifer & Kleiter, 2011; Pfeifer & Tulkki, 2017b).

Method

Materials and Design

We used a 2×2 between-participants design where we crossed task formulations in terms of indicative conditionals versus formulations in terms of counterfactuals. To control for position effects, we used two random orders (generated by `random.org`). This resulted in four different task booklets.

Each booklet consisted of a brief introduction, of eight tasks, and of questions about the booklets (task difficulty, whether participants took logic or probability classes and whether they like maths). Furthermore, we included usual demographic questions at the end. The logical forms of the eight tasks are explained in Table 2. We instantiated these logical forms into a cover story which was already used in studies on Western samples (see, e.g., Pfeifer & Kleiter, 2011; Pfeifer & Tulkki, 2017b). We adapted and translated this cover story for the Japanese sample.

For each task, the participants were asked to imagine the following situation:

> *Hanako works in a factory that produces toy blocks. She is responsible for controlling the production. Every toy block has a shape (*cylinder, cube *or* pyramid*) and a colour (*red, blue *or* green*). For example:*
>
> - *Red cylinder, red cube, red pyramid*
> - *Blue cylinder, blue cube, ...*
> - *Green cylinder, ...*

Then, for example in task AT1 (indicative conditional), the participants were asked to consider the following sentence:

> ***It is not the case**, that: **If** the toy block is **not** a* cube*, **then** the toy block is a* cube.

(もしおもちゃのブロックが立方体ではないならば、そのおもちゃのブロックは立方体である、というわけではない。)

The instructions continued by the following questions, which prompt answers in a forced choice format:

Can Hanako infer at all how sure she can be that the sentence in the box holds? (please tick the appropriate box)

- ☐ *NO, Hanako can* **not** *infer how sure she can be that the sentence in the box holds.*
- ☐ *YES, Hanako can infer how sure she can be that the sentence in the box holds.*

The previous question serves to give the opportunity to respond in a non-informative way and thereby avoid conversational implicatures which could bias the participant to respond in an informative manner. Specifically, we aim to investigate to what extent the participants are able to distinguish probabilistically informative and non-informative argument forms. The next question prompts a qualitative evaluation of the conclusion of argument forms which are perceived to be probabilistically informative:

*If you chose "*YES*", please tick one of the following answers:*

- ☐ Hanako can be sure that the sentence in the box holds.
- ☐ Hanako can be sure that the sentence in the box does **not** hold.

After each target task, the participants were instructed to rate on a scale their subjective confidence in their response. The corresponding AT1 task involving counterfactuals was formulated in exactly the same way with the difference, that the indicative conditional was replaced by a corresponding counterfactual, as follows:

It is not the case*, that:* ***If*** *the toy block were* ***not*** *a* cube*,* ***then*** *the toy block would be a* cube.

(もしおもちゃのブロックが立方体ではなかったとすれば、そのおもちゃのブロックは立方体であるだろう、というわけではない。)

Note that AT1 can be conceived as an inference from an empty premise set. For those tasks involving explicit premises (i.e., in tasks EIn, EI, MP, NMP, and Prdx), we formulated uncertainties in terms of verbal descriptions ("極めて確実である"; "*quite sure*"). For instance, consider task MP:

(A) …quite sure *that the toy block is a* cube.
(B) …quite sure *that* ***if*** *the toy block is a* cube*,* ***then*** *it is* red.

Our reason for qualitative premise and conclusion probabilities in terms of verbal descriptions of probabilities (instead of quantitative probabilities) was to reduce the psychological complexity of the probabilistic inference. In this study, we were interested in the interpretation of negations and conditionals but not in the numerical propagation of the probabilities from the premises to the conclusion.

Participants and procedure

63 Osaka City University undergraduate students participated in this study (mean age 20.02 ($SD = 1.05$) years, 34 females, 21 males, 8 did not disclose their gender). Their major subjects included various humanistic fields (3 commerce, 5 culture, 1 geography, 5 history, 4 Japanese, 8 law, 5 linguistics, 1 pedagogy, 2 philosophy, 17 psychology, 2 sociology, and 10 other). Nobody had ever taken logic classes but two participants had previously taken some probability classes. At the end of the experiment, participants evaluated the set of tasks as rather difficult (mean 2.76 ($SD = 2.11$) on a scale ranging from 0 ("very difficult") to 10 ("very easy")). 82.54% reported that they do not like maths.

All participants were tested at the same time during a lesson in a course on cultural psychology. For reducing the probability for copy-pasting responses, the booklets were distributed such that the two task orders and the two formulations of the conditionals (indicative vs. counterfactual) alternated systematically. Moreover, the experimenter announced that the task booklets differ before the participants started with filling in their responses. The booklets were formulated in Japanese, the participants' mother tongue.

Results and discussion

We performed Fisher's exact tests to compare the response frequencies among the four booklets (task order 1 × task order 2 × indicative conditionals × counterfactuals) and did not observe any significant differences after performing Holm-Bonferroni corrections for multiple significance tests. Likewise, analyses of variance on the participant's confidence ratings in the correctness of their responses did not show statistically significant differences among the four booklets. This replicates previous findings in studies which used Western samples. Specifically, studies on probabilistic truth table tasks (Over et al., 2007; Pfeifer & Stöckle-Schobel, 2015) and on uncertain argument forms (Pfeifer & Tulkki, 2017b) did not detect significant difference between indicative conditionals and counterfactuals. Thus, our data speak against cross-cultural differences between Easterners and Westerners. This calls for further experiments to clarify whether this interesting negative result is due to a too high dissimilarity of our tasks compared to those in other studies on cross-cultural differences. Or, alternatively, whether cross-cultural differences are not that strong as they are claimed to be (see, e.g., Zhang et al., 2015).

Since there were no significant differences in the responses among the four booklets, we pooled the data for the following data analysis ($N = 63$). Concerning the interpretation of conditionals, we observed high endorsement rates of the conditional probability hypothesis (see Table 3). This is strong support for the hypothesis that both indicative conditionals and counterfactuals are best modeled by conditional probability.

Table 4 presents the mean confidence ratings, which shows how sure the participants are that their responses are correct.

Table 3: Percentages ($n = 63$) of "holds" (hld), "does not hold" ($\neg$hld), and probabilistic non-informativeness responses (n-inf; see also Table 2). Predictions based on the conditional probability hypothesis of conditionals are in **bold**. Alternative hypotheses are indicated in parentheses: $\neg_\supset$ (resp., $\supset_\neg$) denotes wide (resp., narrow) scope negation of the material conditional $\supset$; $\wedge$ denotes conjunction. If not specified otherwise, predictions coincide.

	AT1	AT2	NR	EIn
hld:	**65.08**$\left(^{\supset_\neg}_{\wedge}\right)$	**76.19**$\left(^{\supset_\neg}_{\wedge}\right)$	6.35	6.45
$\neg$hld:	15.87	11.11	**63.49**$(^{\neg\supset})$	**69.35**
n-i:	19.05$(^{\neg\supset})$	12.70$(^{\neg\supset})$	30.16$\left(^{\supset_\neg}_{\wedge}\right)$	24.20
	EI	MP	NMP	Prdx
hld:	**88.89**	**53.97**	9.52	0.00$(^{\supset})$
$\neg$hld:	6.35	3.17	**52.38**	17.46$(_{\wedge})$
n-inf:	4.76	42.86	38.10	**82.54**

The confidences are relatively high, with an average value of 7.2 on a rating scale from 0 to 10.

Table 4: Mean (*M*) and standard deviations (*SD*) of the participants' confidence ratings ($n = 63$) on a scale from 0 ("very sure that my response is not correct") to 10 ("very sure that my response is correct"; see also Table 2).

	AT1	AT2	NR	EIn	EI	MP	NMP	Prdx
M	6.77	6.86	7.20	7.71	8.02	7.18	7.02	6.82
SD	1.99	2.06	2.37	1.99	1.97	2.10	2.08	1.93

Concluding remarks

Our data suggest that people form their degree of belief in the counterfactual *If A were the case, C would be the case* by equating it with the corresponding conditional probability of $C|A$. This is consistent with the observation in previous experimental work (with Western participants) that people treat the factual statement as irrelevant when they form their degree of belief in a counterfactual (Pfeifer & Stöckle-Schobel, 2015; Pfeifer & Tulkki, 2017b, 2017a). This can be justified and explained by the coherence-based theory of nested conditionals (Gilio & Sanfilippo, 2013, 2014; Gilio, Over, Pfeifer, & Sanfilippo, 2017, submitted). Given three events A, B, C with incompatible A and B (i.e., $A \wedge B$ is a logical contradiction) the prevision of the conditional random quantity $((C|B)|A)$ is equal to $p(C|B)$ (Gilio & Sanfilippo, 2013, Example 1, p. 225). Thus, the counterfactual *If A were the case, C would be the case* can be modeled by the degree of belief in the conditional random quantity $(C|A)|\neg A$ which equals to $p(C|A)$ (i.e., $Prevision((C|A)|\neg A) = p(C|A)$). This is an explanation for why people—as experimentally demonstrated in Western samples and also in our Japanese sample—respond by corresponding conditional probabilities when asked to give a degree of belief in a counterfactual.

Our data suggest a negative answer to the question whether there are cross-cultural differences between Easterners and Westerners w. r. t. reasoning about indicative conditionals, counterfactuals, and their negations. Further experimental work, e.g., involving causal task material (see, e.g. Over et al., 2007; Pfeifer & Tulkki, 2017a), is needed to substantiate the hypothesis that conditional probability is the *universal* key ingredient for psychological theories of indicative conditionals and counterfactuals.

The material conditional interpretation of conditionals was the gold standard to evaluate human reasoning about conditionals in the old paradigm psychology of reasoning. Our data do not support the material conditional interpretation. Rather, our results strongly support the conditional probability interpretation of conditionals, which became prominent in the new paradigm psychology of reasoning and which received strong experimental support in recent years (see, e.g., Elqayam et al., 2016; Fugard, Pfeifer, Mayerhofer, & Kleiter, 2011; Over, 2009). Even though most of the data was collected on Western samples, but given the theoretical plausibility of the the conditional probability interpretation, we think that this is further suggests that universality in human reasoning.

Finally, we note that adaptation of reasoning styles can be one of the universal adaptive strategies across cultures. The question of which aspects of human reasoning are universal, and in how far they are universal, is important and calls for collaborations of psychologists of reasoning and cultural psychologists.

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