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A psychological study of unconnected conditionals

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ABSTRACT

Unconnected conditionals, also called *irrelevant* conditionals, are sentences of form *if A, C*, whose antecedent and consequent bear no connection. According to the main theories of conditional reasoning, the truth or high probability of an antecedent and a consequent is sufficient to make true or highly probable the corresponding conditional. We tested this assumption and showed that it does not hold for unconnected conditionals. Furthermore, we investigated experimentally the factors which favour the endorsement of irrelevant conditional constructions and found that this rate increases when an analogy can be built between the antecedent and the consequent or when the conditional is asserted before its components.

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1. Introduction

Conditionals, like "if it's sunny, I will go to the beach", are sentences of form *if A, C* where A is called the antecedent and C the consequent. Their status is central in the study of reasoning because every deduction of a new belief C from a previous belief A can be reformulated through a conditional sentence. What is their exact meaning is a very old issue that is still not resolved. More than two thousand years ago, divergent positions were already expressed concerning the nature of conditionals in the first school that developed a logic of propositions: the Stoics.[1] Among them, two need to attract our attention. Famously, Philo defended that the antecedent and the consequent could be examined in isolation in order to determine the meaning of the conditional: "a true conditional is one which does not have a true antecedent and a false consequent; for example, when it is day and I am conversing, 'If it is a day, then I am conversing' [is true]." On the contrary, Chrysippus argues that the antecedent and the consequent must be relevant to each other. "Those who introduce connection or coherence say that a conditional holds whenever the denial of its consequent is incompatible with its antecedent; so, according to them, the above-mentioned conditional do[es] not hold."[2] This old debate has recently reappeared in the psychology of reasoning with the examination of the schema CS[3] : from *A & C*, infer *if A, C*. Some theories and most famously the *probability conditional* validates it, contrary to the *inferential* and the *connectional conditional*. We will examine in turn these three theories.

1.1. The probability conditional

The probabilistic approach (Baratgin et al., 2015; Evans & Over, 2004; Oaksford & Chater, 2007; Pfeifer & Kleiter, 2006) argues that binary logic, defended by the previous dominant paradigms which are the *mental logic* (Braine & O'Brien, 1998) and the *mental models* (Johnson-Laird & Byrne, 2002), is inadequate to account for performance in

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[1]The following citations are due to Sextus Empiricus and we use here their English translations found in Sanford (2003).

[2]The term of *connection* is usually the technical term used in the literature to describe the needed relation between the antecedent and the consequent of a true conditional. For instance, Stalnaker (1968) says that "[t]he material implication analysis fails, critics have said, because it leaves out the idea of connection which is implicit in an if–then statement". This usual terminology leads us to chose the term 'unconnected" over the one of "missing-link".

[3]The complete name of this schema is "conjunctive sufficiency" (noted CS), as given in Nute (1980). It is also called "centering" in Cruz, Over, Oaksford, and Baratgin (2016) and Douven (2015a) but this term refers in the literature to a specific condition in the possible worlds semantics of Lewis (1973b). Precisely, this condition states that *every world is more similar to itself than any other world*. We prefer the more general term "conjunctive sufficiency" and its abbreviation CS which both refer to an inferential schema independent of the underlying semantics.

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reasoning tasks because people use strategies to reason under uncertainty whose nature is probabilistic. This approach adopted the probabilistic Bayesian theory as a normative system of reference to study the uncertain deductive inferences which people carry out in daily life. This approach is also called the *new paradigm* (Elqayam & Over, 2013; Evans, 2012; Evans & Over, 2013; Over, 2009) because this shift of model of reference implies some important conceptual and methodological modifications in the study of human reasoning (Baratgin and Politzer, 2016).

There are different ways to model conditionals in this paradigm. Here, we will consider the simplest hypothesis, which is that the probability of a conditional is the conditional probability of the consequent on the antecedent. We obtain therefore that P(IfA, thenC) = P(C | A).[4] The schema CS is valid in this framework. Indeed, with the premises A and C, P (A), P(C) and P(A and C) are all close to 100%. Thus, P (A and C) and finally P(C | A) are also close to 100% and can be deduced. Notice that CS is also valid in bivalent classical logic and consequently in the two following traditional cognitive psychology theories: the *mental logic* of Braine and O'Brien (1998) and the *mental models* of Johnson-Laird and Byrne (2002).

1.2. The inferential conditional

Filter theories endorse classical logic but put limits on its deductive power when applied to natural language. Smiley (1959) and Tennant (1984) have developed the first versions of filter logics, in which constraints are imposed on the relation of semantic consequence.[5] The same strategy is reused by Krzyżanowska, Wenmackers, and Douven (2013, 2014) but applied this time to the conditional which is defined in the following way. *If A, C is true only if C is a deductive, inductive, abductive or mixed consequence of A and the background knowledge B*. The theory is supplemented by the following filtered constraints. *If C does not follow from A alone, the inference is invalid if i) C follows from B alone or ii) C is inconsistent with B*. The first condition ensures that the antecedent is relevant for the consequent. The second condition forbids the derivation of an inconsistent consequent from a combination of the antecedent and the background knowledge. This theory defines a conditional which is called *inferential* because it models the reasoning process leading from an antecedent to a consequent through a variety of inferential relations.

Actually, this theory is only detailed for the deductive conditional which relies on the material conditional of classical logic. The authors do not provide a formal account of the inductive and abductive conditionals and actually "do not commit to any specific proposals in this regard" (Krzyanowska et al., 2013, p. 318). In the following and in particular in our two experiments, we will focus on the deductive conditional because it is actually the only one which offers completely precise predictions. Restricted to this case, the conditional is purely and simply the connective of classical logic, minus the invalidation of some reasoning lacking relevance or inconsistent between their components through the application of the filter conditions. In particular, the schema CS is invalid in this theory (Douven, 2015b). This means that these authors consider classical logic as the general explanation of the conditional reasoning process in deductive cases but try to forbid inferences when there is a lack of relevance or a derivation of an inconsistency. However, inferentialism theory can also be considered from a larger perspective, where the conditional relations are not limited to the deductive one. At this point, this theory does not commit itself to any specific logic for non-deductive inferences and a formalization of the inductive and abductive inferential relations has to be developed. In this broader context, the conditional is not restricted to classical logic.[6]

1.3. The connectional conditional

The most famous possible worlds conditional logics are Stalnaker's **C2** system (Stalnaker, 1968) and Lewis's **VC** system (Lewis, 1973a). Stalnaker's approach and also Lewis's approach can be seen as a psychological process (Cariani & Rips, 2016; Rips & Marcus, 1977), inspired by the Ramsey test (Ramsey, 1990). First, add the antecedent to the stock of beliefs represented by a possible world,

[4]More complex theories defend the choice of the subjective Bayesian theory of de Finetti (1974a,b) in which the logic of reference is a trivalent logic where the uncertainty represent an additional truth value (Baratgin, Over, & Politzer, 2013, 2014; Baratgin & Politzer, 2016; Over & Baratgin, 2017) and probabilistic inferences can be analysed in the light of coherence intervals (Coletti & Scozzafava, 2002; Pfeifer & Kleiter, 2006; Politzer, 2016).

[5]For instance, in Smiley's system, to be valid, an inference must be classically valid and furthermore, the conjunction of the premises cannot be a (classical) contradiction and the consequent cannot be a (classical) tautology.

[6]We will come back to the distinction between the narrow and the broad perspective for inferentialism in the final discussion of this paper.

then adjust the possible inconsistencies and finally check whether the consequent is obtained. Both systems endorse the schema CS. Indeed, in these semantics, when the antecedent is true, the actual world is the only world selected for conducting the evaluation of the whole conditional. Hence, if the consequent is also true in the actual world, the conditional is automatically validated.[7] However, CS becomes invalid in alternative systems in which the actual world is just one among the possible worlds used to conduct the final evaluation. Technically, this solution is known at least since Lewis (1973a), von Kutschera (1974) and Chellas (1975), and is defended by Nute (1980) and Vidal (2012, 2016a,b). We will focus on this last proposal in this paper for the following reasons. First, Vidal's theory provides an intuitive justification of this weaker semantic condition by describing a process of evaluation for conditionals conducted in two phases. In the first phase, *the antecedent and related beliefs are inhibited: they are no more believed true or false*. In the second phase, *the antecedent is reconstructed before evaluating whether the consequent is obtained*. Hence, different ways of reconstructing the antecedent can lead to several alternatives which slightly differ from the actual world. With this intuitive background for the semantics, we obtain a set of worlds in which the actual world is only one of the possible alternatives for the final evaluation when the antecedent is initially true. Second, a general reason for focusing on Vidal's approach is that a formal distinction is made between the "even if" (Vidal, 2016a), "if then" (Vidal, 2016b) and "only if" conditionals (Vidal, 2017). Hence, this theory is actually the only one able to provide a compositional semantics in which the meanings of the words "even", "then", "only" and "if" are analysed and combined in order to obtain the meaning of these different conditional expressions.

In this approach, a conditional is believed to be true only if all the reconstructions of the antecedent, described by possible worlds, are also reconstructions where the consequent is true. Indeed, having inhibited the antecedent and possibly also the consequent, if the consequent is always found in the possible worlds where the antecedent is reconstructed, then the presence of the consequent must be related in some way to the presence of the antecedent. The two of them must have some sort of connection. Like the inferential approach, this theory invalidates the inferences for the cases where there is no relevance between the components of a conditional. It predicts therefore that the inference will not always supported by the subjects and will often be declared false. Concerning the probability of the conditional, it is predicted that the probability will be far below 100%. Contrary to the inferential theory, a connectional conditional belongs primarily to a non-classical logic grounded on a possible worlds semantics, in which the conditional connective (and not the consequence relation) does not stem from the material conditional. As a result, the process of evaluation is based not only on what occurs in the actual world but also on what we can imagine about other alternatives. Another important difference is that the meaning is considered as semi-dynamic in this theory. The assertion of a first conditional builds a context of discourse in which subsequent conditionals are evaluated. This feature explains why counterexamples to transitivity have the premises in this particular order *if q, r; if p, q. Thus if p, r* and not the other way around *if p, q; if q, r. Thus if p, r*. The order of utterance for the conditionals is therefore important for the reasoning, contrary to what classical logic stipulates.

1.4. The pragmatic answer

A standard answer to the problem of unconnected conditionals is to call on pragmatic principles. Following Grice (1967a), one could argue that a conversation must respect some pragmatic rules to be cooperative. In particular, the maxim of relevance specifies that a new item in the discourse must bear some relation with at least one previous item. Clearly, unconnected conditionals do not respect this principle as their consequent does not bear any relation with their antecedent. The presence of a connection would therefore be a pragmatic feature and not a core part of the semantics of conditionals. This lack of relevance applied to the relation between the antecedent and the consequent is defended by Grice himself in Grice (1967b).

This call to pragmatics to repel potential counterexamples is highly problematic. Indeed, there is actually no consensus about where to put the limit between the semantic and pragmatic components

[7]The same issue occurs for Kratzer's theory which is actually the most influential development of the possible world semantics and whose articles are gathered in Kratzer (2012). Because we do not want to adopt the validity of CS, we will also not adopt her framework.

of meaning. In particular, many researchers in the field (Korta & Perry, 2011; Recanati, 2004; Sperber & Wilson, 1996) argue now for a contextualist approach to semantics. Furthermore, most psychological experiments do not provide any additional context for the judgement of conditionals. Without any additional context, that subjects find a conditional odd when its antecedent and its consequent have no connection suggests that the existence of a link between the two is part of the standard interpretation of such sentences. This shows that the existence of a connection between an antecedent and a consequent belongs to the meaning and therefore to the semantics of conditionals. Finally, pragmatic theories do not explain much. To stipulate through a maxim of relevance or a conventional implicature that the antecedent must be relevant to the consequent does not clarify what is this underlying connection and does not account for this essential component of the meaning of conditionals (Douven, 2015b).

Another difficulty with the call to pragmatics is that it prevents us to find the real explanatory factors behind our judgements. Grice was well aware of this problem for his maxim of relevance and says about it that

> its formulation conceals a number of problems that exercise me a good deal: questions about what different kinds and focuses of relevance there may be, how these shift in the course of a talk exchange, how to allow for the fact that subjects of conversations are legitimately changed, and so on. (Grice, 1967a)

A call to pragmatic principles just in order to put away the recalcitrant cases is not a good scientific approach. On the contrary, we argue for an investigation of the explanatory factors concerning our judgements about unconnected conditionals. Indeed, a unified formal semantics that could both explain our understanding of connected and unconnected conditionals would be better than a divide of the explanation into two parts, particularly if one of this part is pragmatic, because a unique formal semantics would be mathematically more precise and more easily testable (Vidal, 2012).

1.5. Objectives of the experiments

The first question we will try to settle experimentally is whether unconnected conditionals have a distinct behaviour compared to other hypothetical sentences. To do this, we will employ both agreement and probability tasks. The inferential and connectional conditionals are both bivalent connectives but can be extended to degrees of belief by considering that in a probabilistic context, they measure degrees of belief that something is true. These two conditionals both indicate that the truth of the unconnected conditional will not follow simply from the truth or high probability of the premises. This behaviour was already found in previous experiments (Matalon, 1962; Skovgaard-Olsen, Singmann, & Klauer, 2016) and we hope to observe it again. On the contrary, the probability conditional predicts that the presence of a connection will not change the endorsement of the hypothetical relation by the subjects.

The second question that we will address is the determination of some influencing factors on our judgements concerning unconnected conditionals. In a first experiment, we will examine whether we can bridge the irrelevant gap between two unrelated sentences by letting them share some common elements. These elements will be for instance a common theme, a common subject or a common verb phrase. In a second experiment, we will examine whether the order of presentation of the antecedent, the consequent and the whole conditional has an influence. We will try to settle whether having first the antecedent and consequent in isolation will rise, diminish or have no impact on the acceptance. This will give us an indication on whether the pondering order of the constitutive elements of an unconnected conditional promotes the chances for the hearer to establish a link between them. The examination of these two factors will help us to break the tie between the inferential and connectional theories.

In these experiments, we will use the schema CS in order to test the endorsement rate of the conditional and its components. This reasoning allows inferring a conditional from any conjunction: $A \wedge C \vdash A \rightarrow C$.[8] The schema CS has recently been studied for connected conditionals, with participants being asked about inferring "if A then C" from 'A $\wedge$ C'. In these two studies, people appear to endorse this explicit inference, with a concrete material (Cruz, Baratgin, Oaksford, & Over, 2015) but also with an abstract material (Politzer & Baratgin, 2016). The question is whether the same

[8]We use here the symbols $\wedge$ for the conjunction, $\vdash$ for the consequence and $\rightarrow$ for the conditional.

endorsement will be found for unconnected conditionals. In this new context, the meaning of CS can be illustrated by the following thought experiment. Imagine that you have two beliefs A and C not related to each other. Can we construct from them a true conditional of form *If A, C*? For instance, let A be "Mickey Mouse has four fingers per hand" and C be "the Moon is a satellite of the Earth." Is the conditional "If Mickey Mouse has four fingers per hand, the Moon is a satellite of the Earth" acceptable? Intuitively, the answer is no because there is no connection between the antecedent and the consequent. We shall see whether this prediction is confirmed by the experiments.

2. Experiment 1

The first aim of this experiment is to test the endorsement of unconnected conditionals with both acceptability and probabilistic questions. Its second aim is to check whether the rating of endorsement of unconnected conditionals varies when the antecedent and its consequent have some common elements.

2.1. Method

2.1.1. Participants

The experiment was conducted in 2015 over the Internet with 200 people who received a small fee for completing the test. The participants were coming from the UK, USA and Australia. The exclusion of the participants from the final results was conducted along the following criteria: participants whose native language was not English, participants who did not complete the test, participants who completed the whole test in less than 100 seconds, participants whose responses were inconsistent concerning basic logical or probabilistic tasks (e.g. accepting a conjunction but not the conjuncts, giving a probability for conjunction greater than for the conjuncts)[9], and participants who signalled that they did not answer seriously. After excluding these cases, the data of 164 participants remained for analysis.

2.1.2. Design

The conditionals were divided into two main categories: the relevant ones and the irrelevant ones. Furthermore, they were evaluated by two different modes: acceptability and probability. Each subject answered questions about these four groups: Acceptability concerning Connected conditionals (AC), Acceptability concerning Unconnected conditionals (AU), Probability concerning Connected conditionals (PC) and Probability concerning Unconnected conditionals (PU).

2.1.3. Materials and procedure

All questions were in English. Ten connected conditionals and ten unconnected conditionals were prepared for the experiment. A block of four questions was associated with each conditional and each time, the choice of the block of four questions presented to the subject was randomised. Each participant answered a block concerning each of the four groups of categories (AC, AU, PC, PU), for a total of 4 blocks and 16 questions (4 blocks times 4 questions inside each block). The order of presentation of these blocks was also randomised. Inside each block, the subject evaluated the conditional "if A then C", its antecedent "A", its consequent "C" and the conjunction of the antecedent and the consequent "A $\wedge$ C". The values of the antecedent and of the conjunction were used to compute the conditional probability: $P(A \mid C) = P(A \wedge C)/P(A)$. The value of the consequent was used to control the coherence of the estimations given by the subject. According to the probabilistic, inferential and connectional conditional, the order of presentation of these different items has no impact on the inference and was therefore randomised in order to introduce no bias. One item was presented per page and an answer was mandatory to display the next question.

For the acceptability task, the following question was presented to the subject: *Do you agree with the following sentence?* Below was the item to judge, for instance "If Global Warming continues, there will be less snow in the future". Finally, the subject chose one answer among the three following choices: *Yes*, *No* or *Indeterminate*.

For the probability task, the subject received the following question: *In your opinion, how probable is it that:* The item to judge (for instance "Obama is President of the United States and the Pacific is an ocean") was presented on the next line. Finally, the subject selected a value between 0% and 100% using a slider to answer the question.

[9]The motivation for this exclusion was to avoid a probability higher than 100% for the conditional. In the present experiment, the number of persons excluded by this criteria alone was really low, 5 subjects (2.5%) and did not impact the other computations.

The unconnected conditionals were classified into five groups. The first one contained sentences where the antecedent and the consequent belong to different categories. For instance, "the name 'Mary' is made up of four letters" displays a linguistic judgement and "a car is a vehicle" is a taxonomic judgement about physical entities. The second group contained conditionals about physical entities but with different themes. For instance, "Obama is President of the United States" speaks about a political figure and "the Pacific is an ocean" is about a geographical entity. The third group contained judgements about physical entities sharing the same theme. For instance, "Eminem is a rapper" and "Beyoncé is a singer" are two assertions about music. The fourth group gathered sentences with the same subject as "Mickey Mouse has four fingers" and "Mickey Mouse has big ears." Finally, the last group contained sentences with the same verbal phrase like "Putin is a politician" and "Obama is a politician."

Finally, this test was preceded by some questions about the personal data of the subjects. These data concerned their age, gender, primary language, level of education and previous exposition to a course in logic or probability. The test was also followed by a question about the seriousness of the answers given.

2.2. Results and discussion

2.2.1. Difference between relevant and unconnected conditionals

Knowing the evaluation given by the subjects for the antecedent, the consequent and their conjunction, and with the auxiliary hypothesis that $P(\text{If A, then C}) = P(C \mid A)$, the Bayes formula predicts a value for the evaluation of the conditional. Here, we compare the correlation between this predicted value given by the Bayes formula and the real value given by the subjects for the conditional. Furthermore, we separate this result into two cases: the connected and the unconnected conditionals. To that end, we use Spearman's rank-order correlation because the variables studied did not follow a normal distribution, rendering inapplicable an ANOVA or Pearson's correlation.

For the agreement task, the correlation is higher for the connected conditional (0.35, p = 4.08e-6) than for the unconnected conditional (0.10, p = 0.19)[10] For the probabilistic task, the difference is even greater: (0.69, p = 5.63e-15) for the connected conditional and (0.22, p = 0.02) for the unconnected conditional.

In all cases, we see an important drop in correlation for the unconnected conditionals compared to the correlation observed for the connected conditionals, in both the agreement and probabilistic tasks. If we take Cohen (1988)'s interpretation of correlation by thresholds, we find that for connected conditionals, the correlation is moderate for the agreement task and large for the probabilistic task. But this correlation turns out to be small for the two types of task when we consider unconnected conditionals. The absence of a connection produces therefore a significant effect on the way people judge conditionals.[11]

2.2.2. Factors favouring irrelevance

Concerning the influence of common elements between the antecedent and the consequent on the endorsement of unconnected conditionals, we first expected that this rate would vary with the sharing of a common topic. Prior to the experiment, we thought that when the categories or themes of the antecedent and consequent were different, the endorsement would be lower than when they share a theme, a subject or a verbal phrase. This is not what we obtain. To perform this analysis, we focus on the schema CS ($A \wedge C \vdash A \rightarrow C$) by comparing the endorsement of the conjunction and the conditional. We cannot use a correlation or a covariance for exploring their relation because the conjunction or the conditional is in some cases unanimously hold true by the participants. We measure therefore the difference between the mean of the values obtained for the conjunction and the mean of the values obtained for the conditional. To raise the number of answers to around 30 per conditional, we group the data issued from

[10]The p-value obtained in this case is superior to 5% but this value is not worrying because the correlation is low (0.1). As this number is close to zero, the high score of the p-value only indicates that the correlation is close to fall out on the negative side.

[11]We do not observe an effect of the age, sex, level of education and previous exposition to a course in logic or probability of the participants on their answers. We give here the 95% confidence interval obtained for Spearman's correlation for these different parameters and respectively for unconnected conditionals (UC) and connected conditionals (CC). Notice that all these intervals contain the value zero so the influence is either null or minimal. The intervals are for age : UC = [−0.26; 0.04], CC = [−0.05; 0.26]; for gender : UC = [−0.16; 0.15], CC = [−0.8; 0.22]; for the level of education : UC = [−0.21; 0.1], CC = [−0.22; 0.09] and for having followed a course in logic or probability : UC = [−0.24; 0.06], CC = [−0.04; 0.27].

Table 1. Factors favouring irrelevance.

Conditional	Classification	Difference
If Einstein had a moustache then Einstein was a physicist	Common subject	57.5
If Mickey Mouse has four fingers then Mickey Mouse has big ears	Common subject	52.5
If LeBron James is a basketball player then Usain Bolt holds the 100 meters world record	Common theme	43.3
If the name "Mary" is made up of four letters then a car is a vehicle	Different category	40.4
If Obama is President of the United States then the Pacific is an ocean	Different theme	36.3
If green is a color then 1+1=2	Different category	33.4
If Eminem is a rapper then Beyoncé is a singer	Common theme	32.7
If Putin is a Russian then the end of World War II occurred in 1945	Different theme	26.2
If Mickey is a mouse then Speedy Gonzales is a mouse	Common VP	22.7
If Putin is a politician then Obama is a politician	Common VP	19.4

the agreement and the probability tasks in the following way. We convert each agreement score 1, 2 and 3 (respectively false, indeterminate and true) to the probabilities 0%, 50% and 100%.

Table 1 presents these results. The first column shows the conditional tested. The second column displays the initial classification. The third column shows the difference in endorsement between the conjunction and the conditional.

The first finding is that the difference score is always positive. Hence, the conjunction is unanimously more endorsed than the conditional, contrary to what is predicted by the probability conditional theory. These scores confirm our previous results, but this time at a more fine-grained level. The first consequence is that this difference in endorsement is always a drop. The second consequence is that this feature is not only a mean result but is valid for all unconnected conditionals that we tested.

The second finding is that this drop differs between types of conditionals. If we take our initial classification, the difference is stronger when the antecedent and the consequent have a common subject and the difference is weaker when they have a common verbal phrase. The other types are situated between these two extremes and no clear trend emerges for them.

Our new interpretation of this classification is that some of these conditionals allow more easily to build a link between their antecedent and their consequent. In each case, they are unconnected because the happening of the fact described by their antecedent is unrelated to the happening of the fact described by their consequent. However, some permit the following relation to hold: they say that if x can be considered as an A, then y can also be considered as an A. This is a classificatory judgement. If x exemplifies a sufficient number of properties to be taken as an A, then y is also an A because it has the same sufficient properties allowing to be classified in this way.

This explanation applies straightforwardly to unconnected conditionals with a common verbal phrase which expresses a membership (*is an A*). This is the case for our two examples which can be reformulated with the locution *can be considered as*. *If Mickey can be considered as a mouse then Speedy Gonzales can be considered as a mouse*. *If Putin can be considered as a politician then Obama can be considered as a politician*. This explanation also applies very well to the conditional with a common theme expressed by the *is an A* locution in the antecedent and in the consequent: *If Eminem can be considered a rapper then Beyoncé can be considered a singer*. We have here three of the four conditionals with the smaller difference scores.

This classificatory judgement cannot apply to our examples concerning conditionals sharing a common subject. The verbal phrases of their antecedent and consequent differ and can be seen as independent. Furthermore, three of them contain the particle "have", which forces a binary interpretation. For instance, either Mickey Mouse has four fingers per hand or he does not have four fingers. This leaves less place for a gradation in the interpretation. Hence, this explains why these conditionals display the highest difference scores.

3. Experiment 2

The main objective of this experiment is to test whether the order of presentation of the antecedent, the consequent and the whole conditional has some effect on the endorsement rate of the unconnected conditionals. We test therefore a variant of the schema CS where the premise is not the conjunction but the antecedent and the consequent considered in isolation: $A, C \vdash A \rightarrow C$. From a logical point of view, most systems and in particular those associated with the probabilistic, inferential and connectional conditionals treat the premise $A \wedge C$ and the premises A,C as being equivalent. But from a psychological point of view, there can

be a difference and we will test whether the drop of endorsement for unconnected conditionals can be replicated in this case.

3.1. Method

3.1.1. Participants

This experiment was conducted in 2015 with 58 students in psychology from first year to fifth year from Paris 8 University. All these students were French native-speakers.

3.1.2. Design

The same three conditionals, all of them already used in the first experiment, were presented to all subjects. The first one was a connected conditional: "If fertility treatment improves then the world population will rise" and is issued from Over, Hadjichristidis, Evans, Handley and Sloman (2007). The second and third sentences were unconnected conditionals: "if Obama is President of the United States then the Pacific is an ocean" and "if the name 'Mary' is made up of four letters then a car is a vehicle."[12] The first group of students completed a judgement task in terms of yes or no answers. The second group of students completed a judgement task in terms of probabilistic answers. Finally, the third group of students directly gave the probability of the sentences.

3.1.3. Materials and procedure

All materials were in French and were grouped in a booklet. Its first page contained two questions about the sex and the level of study of the student.[13] Each participant had to evaluate three items per conditional: the antecedent, the consequent and the whole conditional (Table 2). This made nine items (three items times three conditionals) per booklet:

The items stemming from a conditional constituted a group of questions. Inside this group, the order of presentation of the items was randomly distributed. Furthermore, the order of the groups inside the booklet was also randomised. The following description of the task was given at the beginning of each booklet. "You will find sentences that you will read carefully. For each of these sentences, we ask you whether you agree with their content."

The first group of students (N=20) performed a binary agreement task. The booklet contained for each item a section of the following form:

Do you agree with:
Item (for instance "Obama is President of the United States")
Circle your answer: Yes No

The second group of students (N=20) performed a probabilistic agreement task. The booklet contained for each item a section of the following form:

Do you agree with:
Item (for instance "Obama is President of the United States")
Give your answer in the form of % of agreement:

The third group of students (N=18) performed a probabilistic task. The booklet contained for each item a section of the following form:

What is in your opinion the probability that:
Item (for instance "Obama is President of the United States")
Give your answer in %:

For the first group, we considered only the cases were the antecedent was judged true. The probabilistic theory predicts therefore that the acceptance of the whole conditional is equivalent to the acceptance of the consequent. For the second and third groups, we used the ratio definition to compute the conditional probability: $P(C \mid A)$ equals $P(A \wedge C)$ divided by $P(A)$(if $P(A)$ is not equal to zero), otherwise $P(C \mid A)$ is not defined. Notice that we did not ask participants to directly evaluate the probability of the conjunction. The advantage of this procedure was that the answer to this question cannot influence the answer given for the conditional. However, we had to find a way to recover this value. We did this by using Fréchet's inequalities to approximate a discrete value for the conjunction starting from the conjuncts.[14]

[12]In French, the first name "Mary" is "Marie" and has five letters. Accordingly, the French antecedent was changed to use the number five.

[13]These data were used to ensure that we had male and female participants from all levels of study. But the panel size was too small to investigate correlations stemming from these factors.

[14]This work, first presented in Fréchet (1935), is a generalisation of Boole's algebra to probability logic and provides intervals. With the interval obtained from the conjuncts, we approximate a discrete value for the conjunction by taking its mean. One interesting property of Fréchet's inequalities is that as soon as at least one conjunct has a probability equal to 100%, the interval is reduced to a discrete value which is equal to the probability of the other conjunct. In this case, the result is completely deterministic and does not suffer from approximation. Concerning the values

Table 2. Items for the questions of Experiment 2.

Item
Fertility treatment improves
The world population will rise
If fertility treatment improves then the world population will rise
Obama is President of the United States
The Pacific is an ocean
If Obama is President of the United States then the Pacific is an ocean
The name "Mary" is made up of four letters
A car is a vehicle
If the name "Mary" is made up of four letters then a car is a vehicle

3.2. Results and discussion

3.2.1. Difference between relevant and unconnected conditionals

To interpret the data obtained from this experiment, we cannot use ANOVA or correlation analyses. Indeed, for the unconnected conditionals, their antecedent and consequent is fully endorsed by almost all participants. Hence, we obtain the same constant value for all the subjects and these usual statistical tools become inapplicable.

We rather choose to compute a percent of errors. For the binary agreement task, an error is detected when the truth-value predicted simply differs from the truth-value really given for the conditional. For the probabilistic agreement task and for the probability task, an error is detected when the theoretical value and the value really given by the subject for the conditional differ by more than 25%. We consider that such a gap clearly constitutes a wrong prediction for the theoretical estimation.

For the binary agreement task, the percentage of errors is much higher for unconnected than for connected conditionals: 60% versus 35%. We find the same result for the probabilistic agreement task: 45% versus 15% and also for the probabilistic task: 50% versus 34%.

In all cases, we see an increase in the rate of errors for the unconnected conditionals compared to the connected conditional. For the binary agreement task, this rate is even worse that what would be obtained by pure chance. For the other two tasks, the results are only slightly better and show a wrong prediction in almost one out of two cases. We see here a confirmation of the results obtained in the first experiment.

3.2.2. Factors favouring irrelevance

Let us now turn to the order of presentation of the items. Each time, the participant had to judge the antecedent, the consequent and the whole conditional. A legitimate question is whether the order of presentation of these items has an impact on the rate of errors for the unconnected conditionals. All in all, we have six possibilities of presentation. We reduce this number to three by only focusing on the last element displayed: the whole conditional, the consequent or the antecedent.

The following results are displayed in this order: conditional last, consequent last and antecedent last. We obtain for the binary agreement task: 88%, 42% and 42%; for the probabilistic agreement task: 71%, 33% and 29%; for the probabilistic task: 56%, 40% and 30%.

We see that when the whole conditional is the last item presented, the rate of errors systematically increases and for all the tasks. In this case, the participant had already judged the antecedent and the consequent. Theoretically, it would have been easier for the participants to compute the value of Bayes' formula with the value of the antecedent and the consequent at their disposal. But this is not the case. Hence, the first lesson to be drawn is that Bayes' formula can only approximate the way the final evaluation of a conditional is obtained. The psychological process performed by the subjects is certainly not equivalent to the algorithm used to compute this value.

Our explanation of the stronger rate of errors when the conditional arrives last is the following one. Part of the usual meaning of a conditional is the establishment of a connection. Hence, faced with a new conditional, people will try to build this connection. When both the antecedent and the consequent have already been presented in isolation, the subject has judged them by considering the most normal circumstances of their occurrence. But when they are presented as the components of an unconnected conditionals, the subject must consider abnormal links between the antecedent and the consequent to make sense of this assertion. This abnormality goes against the usual circumstances previously considered when they were judged in isolation. Hence, the subject is not able to construct a link between the two and conclude that the conditional is false or has low credentials, despite that he believes in the truth of its components. When only one of its components is

obtained for unconnected conditionals in this experiment, in 96% of the cases, the antecedent or the consequent received a probability of 100%. So no distortion of the results was obtained by using Fréchet's inequalities for these cases. In 75% of the cases for the connected conditional, the antecedent or the consequent received a probability superior to 80%. Hence, the interval obtained was small and the risk of deviation minim.

previously considered, it is easier for the subject to adapt the other one to build a missing link. It is even easier when it is the whole conditional which is presented first, before its antecedent and its consequent.

4. General discussion

In two experiments, we investigated whether the schema CS is considered a valid inference and whether its acceptance depends on the presence of a connection between the antecedent and the consequent of the conditional. In the two of them, we found that CS is acceptable for connected conditionals but unacceptable for unconnected conditionals. In the first experiment, the correlation between the theoretical predictions and the real values given by the participants was large to moderate for the connected conditionals, but small for the unconnected conditionals. In the second experiment, the rate of errors for the theoretical predictions largely increases when applied to unconnected conditionals and was no better than pure chance, an error being obtained in around one out of two cases. This work demonstrates experimentally and in accordance with previous studies (Matalon, 1962; Skovgaard-Olsen et al., 2016) that contrary to what is predicted by most of the main theories, a subject does not systematically endorse a conditional when he or she believes its antecedent and its consequent. This result shows a strong deficiency for the probabilistic approach in its actual form but also more generally for most theories of conditionals. Indeed, this shows that the connection between the antecedent and the consequent which is a necessary condition to consider true or highly probable a conditional cannot be established by the simple truth or high probability of its components taken in isolation. The characterisation and the theoretical description of conditionality needs therefore a stronger relation.

An objection to this need for a connection could be that people do not reject all unconnected conditionals when their antecedent and consequent are true. Indeed, few subjects respect the CS rule, even in the case of a missing relation. We think about two possible explanations for this behaviour. First, the connection being part of the meaning of a conditional, people will try to find one, even if the components are not related at first sight. In some cases, they are perhaps able to find such a link, even if it is an unexpected one. The second explanation could be based on Piaget's work on child development (Piaget, Gruber, & Vonèche, 1977). Piaget showed that when the child is young, he interprets the conditional as a conjunction, later as a biconditional and again later as a sufficient condition. Perhaps some of the subjects revert to the conjunctive interpretation when they cannot apply the usual one (Politzer, Over, & Baratgin, 2010). Or perhaps the way some people interpret conditionals did not evolve with age: they kept the conjunctive interpretation even in adulthood (Barrouillet & Gauffroy, 2015). Some more work and experiments are needed to test these hypotheses.

In order to make progress in the understanding of conditionals, we argued that unconnected conditionals could not be simply dismissed from the field of investigations, for instance by using pragmatic principles. Indeed, the strategy of repelling the contravening counterexamples is more a hindrance towards the understanding of this phenomenon. On the contrary, we preferred to explore the factors that diminish or reinforce the judgements of irrelevance. In the first experiment, we found that a common topic was by itself insufficient to raise the acceptance of an unconnected conditional. However, a subject could build a link between an antecedent and a consequent lacking an initial connection and declare the conditional true or highly probable when he was able to establish an analogy between the two judgements of categorisation supported by the components of the hypothetical sentence. In particular, this was facilitated by the sharing of a common verbal phrase or a common theme between the antecedent and the consequent. In the second experiment, we showed that the establishment of a connection was much more difficult once the antecedent and the consequent were considered before the whole conditional. Our explanation was that the components were first judged as happening in the most normal circumstances. It was therefore more difficult for the participants to imagine abnormal circumstances enabling the creation of a connection between the two when the whole conditional was judged shortly after. To our knowledge, they are the first investigations concerning the factors influencing the judgements of unconnected conditionals. There are surely more experiments to do and more factors to test but we hope to have raised interest in the way unconnected conditionals must be investigated.

Finally, we can use the results of these experiments to evaluate the different theories of conditionals. Clearly, the probability conditional theory in the form presented in our introduction cannot cope with the problem of unconnected conditionals and a more sophisticated version still has to be presented in order to solve this issue. Let us now turn to the two theories left which both invalidate the schema CS. The only formalisation actually given for the inferential conditional is given for deductive inferences with the help of a fully extensional theory based on classical logic and which filters some of its inferences. The connectional conditional is an intensional theory using a semi-dynamic possible worlds semantics. The first factor clearly favours the connectional conditional. Indeed, we showed that the establishment of a connection was facilitated when an analogy with other situations could be built for the antecedent and the consequent. It is therefore insufficient to consider what there is in the actual world (extensional approach) and necessary to evaluate what happens in slightly different situations which can be modelled by possible worlds (intensional approach). The second factor also encourages the connectional conditional. Indeed, we showed that the evaluation of conditionals depends on dynamic aspects. It is more difficult to imagine a connection when the antecedent and consequent are previously judged, leaving no room to envisage abnormal circumstances for the whole conditional. The actual implementation of the inferential conditional is wholly static and cannot cope with this problem. The connectional conditional is semi-static and is compatible with these observations. Even if this theory in its present state does not precisely predict this effect, it could be easily extended to treat this aspect.

All in all, our two experiments clearly show that the connectional conditional offers better predictions and explanations than its competitors concerning the treatment of unconnected conditionals. However, taken from a larger perspective, the inferential theory is not far away from the views defended by the connectional approach. Indeed, Krzyanowska et al. (2013) emphasise the need for inductive, abductive, and mixture inferential relations, in addition to deductive relations, even if they do not actually provide a formal account for their treatment. This leaves room for further developments of this approach that could solve the issues raised in this paper. Such developments could be done for instance by endorsing part of the connectional theory or by turning to other recent contributions such as Spohn (2013) or Skovgaard-Olsen (2016). Whichever developments follow next and for any of these different theories, the most important point made in this paper is that a constitutive part of the meaning of a conditional is the establishment of a connection between its antecedent and its consequent. No theory can dispense with an explanation of this relation.

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