

IMPLICIT FACILITATION EFFECT ON COUNTERFACTUAL AND SEMIFACTUAL THINKING

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Abstract

The aim of this contribution is to provide novel evidence concerned with the mental representation of counterfactual and semifactual thinking. Previous studies found a facilitation effect for inferences derived from the representation of counterfactuals and semifactuals, but such facilitation was studied only for explicit propositions. The present contribution extends the evidence to implicit propositions. Two experiments were conducted, one focused on counterfactuals, the other on semifactuals. The first experiment suggests that counterfactuals promote the acceleration of the antecedent and the consequent, implicitly uttered. The second experiment found the same pattern for semifactuals, but only for the antecedent, also implicitly uttered. Taken together, this evidence supports the account proposed by the mental models' theory of human thinking for counterfactuals and semifactuals. The results are discussed in the context of the psychology of reasoning.

Keywords

Reasoning-counterfactuals-semifactuals-implicit-facilitation-representation

Introduction

Researchers in the fields of Philosophy and History have warned against the use of counterfactuals [1]. That is, to think about the consequences of the opposite to what really happened might lead to misleading conclusions. What would have happened if Germany and Japan had won World War II? From a scientific perspective, this kind of questions might promote imagination, but do not really provide advances for historic knowledge. Contrarily, in our daily life we often use counterfactuals, even with sound and healthy results [2]. In the context of the psychology of reasoning, a factual utterance can be understood as a conditional proposition [3]. 'If p , then q ' is the general form for a factual proposition, where p represents a fact or a factual condition and q represents a consequence of such condition [4]. A counterfactual has the form 'If there had been $-p$, then there would have been $-q$ ', where negation is represented by the symbol '-' [5,6]. Furthermore, a variant of the counterfactual known as semifactual has the form 'Even if there had been p , then there would have been q ' [4,7]. The following sentences show concrete examples of these reasoning varieties. A factual: 'If there is a pen, then there is a notebook'. A counterfactual: 'If there had been no pen, then there had been no notebook'. A semifactual: 'Even if there had been a pen, then there had been a notebook'.

The mental models' theory of human thinking account for these varieties of conditionals [3,4,8]. According to this theory, the human mind operates by means of mental models, which can be understood as cognitive representations of possibilities [9]. That is, we imagine possible worlds while processing available information [10]. The mental models' theory has found evidence that supports such view [9]. More specifically, the experimental evidence suggests that counterfactuals promote the mental representation of p and q , but also $-p$ and $-q$ [3]. Semifactuals promote the representation of p and q , but also $-p$ [4]. This duality has found experimental support for *explicit*

negation (3,4). For example, when the utterance 'no pen' is used to negate 'pen'. However, if the model theory is correct, then the *implicit* negation should generate the same result [7]. For example, 'pencil' negates 'pen' implicitly. That is, no explicit negation of 'pen' is uttered in 'pencil', though it is negated because it is absent.

The mental availability of $-p$ and $-q$ after a counterfactual accelerates the further processing of $-p$ and $-q$ as explicit negation [4,5]. A similar facilitation effect -understood as response time acceleration- should occur for r and s , where r implicitly negates p , and s implicitly negates q . For example, a pen implicitly negates a pencil and a paper sheet implicitly negates a notebook. The representational dynamics might promote faster response times for the mentioned implicit propositions [7].

To test these predictions derived from the mental models' theory of counterfactuals and semifactuals we tested four experimental hypotheses. This contribution continues as follows. First, we describe the experimental paradigm used to test such predictions. Then, we describe two experiments conducted to evaluate our hypotheses. Then, we discuss the results. Finally, we propose evidence-based conclusions that contribute to the understanding of counterfactual and semifactual reasoning.

A paradigm to test counterfactuals and semifactuals

A standard experimental paradigm has been proposed to test hypotheses concerned with this kind of conditionals [4]. It includes a task, materials and procedures. The task requires to read a series of sentences on a computer screen and to answer simple questions about such sentences. Typically, a brief description of a daily situation is presented. For example, 'At the botanic garden there are often apples and oranges'. Then, a factual, counterfactual, or semifactual sentence is presented. For example, a factual sentence might be 'If there are apples, then there are oranges'. Then, a question is introduced, 'Indicate please which of the following sentences are consistent with the described situation'. Then, one by one, four sentences are presented on the screen, 'there are apples', 'there are no apples', 'there are oranges', 'there are no oranges'. Participants give consistency responses, that is, they answer yes or no after reading each sentence. The response time measured in milliseconds is registered. We modified this original paradigm by adding two sentences concerned with implicit negation [5]. For the given example, these are 'there are pears', 'there are grapefruits'. That is, pears implicitly negate apples, and grapefruits implicitly negate oranges. The general form of the added response sentences was defined as r instead of $-p$, and s instead of $-q$.

The materials of our modified experimental paradigm include a description and associated components of six different scenarios. A botanic garden, a library, a supermarket, a cinema, a grocery, and a bakery.

A semantic test was introduced after the scenario description to test reading comprehension. That is, half of the participants received the question 'Is this about finding fruits at the botanic garden?'. The other half received the question 'Is this about finding fruits at the library?'. If the first question was answered with the selection of 'yes' and the second with 'no', then the responses to the implicit components were computed. If this condition was not satisfied, the responses of this participant were not considered for the statistical analysis. All the participants gave responses after reading the six scenarios, but twice. In one occasion, the scenario was followed by a counterfactual sentence. In the other occasion, the scenario was followed by a semifactual sentence. In both occasions, the response time to each implicit component proposition was registered using E-Prime [11]. The sequence of scenarios (six descriptions), conditional form (counterfactual or semifactual), and component response (p , q , r , s for counterfactuals and p_2 , q_2 , r_2 , s_2 for semifactuals, as explained below), were randomized for each participant on each trial.

Experiment 1: Implicit facilitation on counterfactual reasoning

Sample: A random sample of 38 students at a public university of Argentina was recruited. The representation by gender was balanced. 52,6% were female (20 participants) and 47,4% were male

(18 participants). The mean age was 21,07 years old (SD = 1,85). No reward was given for participation.

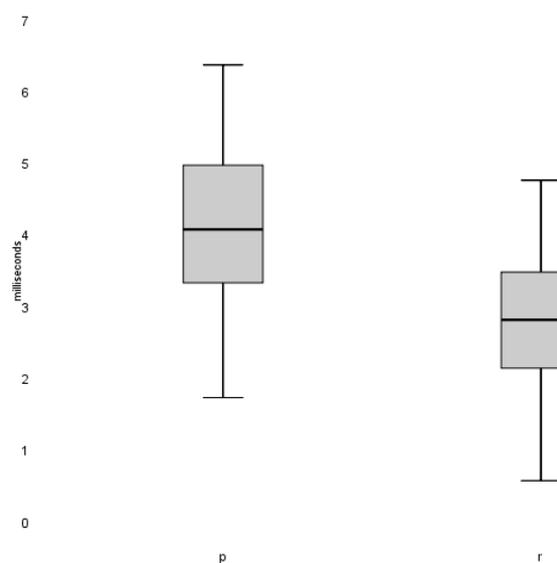
Design, materials, procedure: A fully randomized experimental design was applied. The independent variable was the scenario assignation to a factual or a counterfactual condition. The dependent variable was the response time to the component propositions p , q , r , s , where p is the antecedent, q the consequent, r is the implicitly negated antecedent, and s is the implicitly negated consequent. Participants gave their answers on a computer at a laboratory. All the international ethical standards for psychological research were applied to protect the participants' rights including their anonymity.

Hypotheses: Since the mental models' theory predicts processing facilitation for implicit component sentences like r and s following a counterfactual of the form 'If there had been $\neg p$, then there had been $\neg q$ ', where r implicitly negates p and s implicitly negates q , two hypotheses were formulated. Hypothesis H1 predicts faster response times for r than p . H2 predicts faster response times for s than q . For example, after reading 'At the botanic garden there are often apples and oranges', and then a counterfactual 'If there had been no apples, then there had been no oranges', participants are expected to give faster responses to 'there are pears' when compared to 'there are apples' according to H1. According to H2, faster response times are expected for 'there are grapefruits' when compared to 'there are oranges'. Hypothesis H1 is concerned with the antecedent and H2 with the consequent in counterfactuals.

Results and discussion: H1 and H2 were consistent with the evidence. Concerning H1, mean response time for p was 4080 milliseconds (SD = 1,03) and for r was 2940 milliseconds (SD = 1,17). That is, r responses were faster than p responses ($z = 2,76$; $p < 0,05$; *Cliff's* $\delta = 0,62$, large effect size). Concerning H2, mean response time for s was 3010 milliseconds (SD = 0,95) and for q was 4390 milliseconds (SD = 0,65). Faster responses were found for s than for q ($z = 2,72$; $p < 0,05$; *Cliff's* $\delta = 0,73$, large effect size). These chronometrical vectors were not consistent with normality assumptions according to Kolmogorov-Smirnov test. Hence, non-parametric statistical tests and robust effect sizes were applied test H1 and H2.

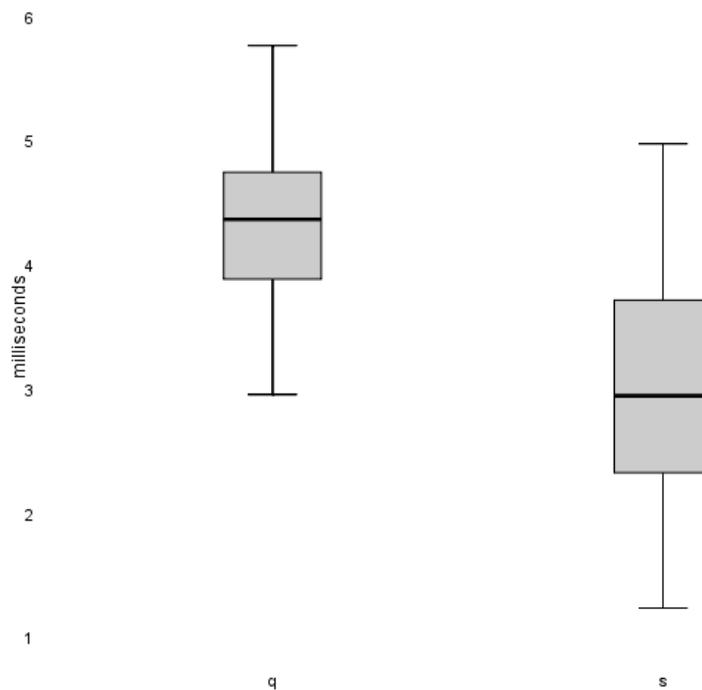
Figures 1 and 2 provide visual evidence for the implicit facilitation effect of counterfactuals. Figure 1 is concerned with the antecedent and Figure 2 with the consequent. In both cases, the implicit negation was processed faster than the corresponding factual component.

Figure 1: Implicit facilitation of the counterfactual antecedent



Note: the vertical axis scale shows integers that give milliseconds when multiplied by 1000. The p boxplot represents the factual antecedent and the r boxplot represents the implicitly negated antecedent.

Figure 2: Implicit facilitation of the counterfactual consequent



Note: the vertical axis scale shows integers that give milliseconds when multiplied by 1000. The *q* boxplot represents the factual consequent and the *s* boxplot represents the implicitly negated consequent.

Experiment 2: Implicit facilitation on semifactual reasoning

Sample: A random sample of 31 students was recruited from a population of university students at a public university in Argentina. All the participants of Experiment 1 were excluded from Experiment 2. The representation by gender was balanced. 51,6% were female (16 participants) and 48,4% were male (15 participants). The mean age was 21,33 years old ($SD = 1,77$). No reward was given for participation.

Design, materials, procedure: The same design as in Experiment 1 was applied in Experiment 2. The independent variable was the scenario assignment to a factual or a semifactual condition. The dependent variable was the response time to the component propositions $p2$, $q2$, $r2$, $s2$, with an analogical meaning to Experiment 1. That is, $p2$ is the factual antecedent, $q2$ is the factual consequent, $r2$ is the implicitly negated antecedent, and $s2$ is the implicitly negated consequent.

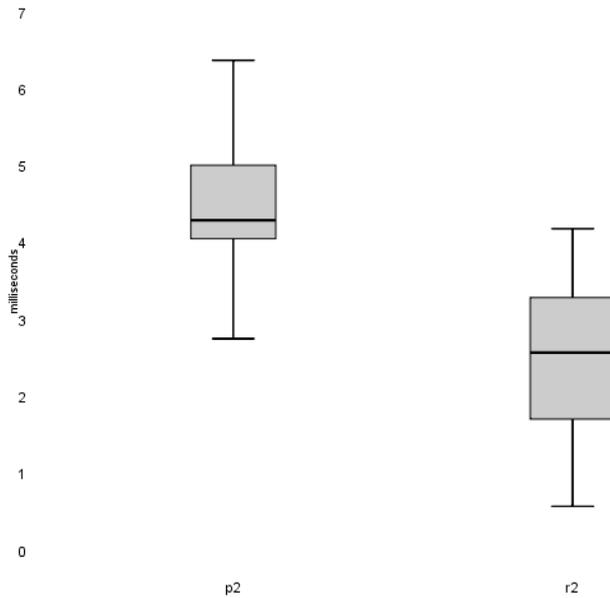
Hypotheses: Hypothesis H3 predicts faster response times for $r2$ than $p2$. H4 predicts no difference in response time between $s2$ than $q2$. For example, after reading 'At the botanic garden there are often apples and oranges', and then a semifactual 'Even if there had been apples, then there would have been oranges', participants are expected to give faster responses to 'there are pears' when compared to 'there are apples' according to H3. According to H4, participants are expected to produce no significant differences in response time between 'there are grapefruits' and 'there are oranges'. Hypothesis H3 is concerned with the antecedent and H4 with the consequent in semifactuals.

Results and discussion: H3 and H4 were consistent with the evidence. Concerning H3, mean response time for $p2$ was 4420 milliseconds ($SD = 0,87$) and for $r2$ was 2440 milliseconds ($SD = 0,97$). That is, $r2$ responses were faster than $p2$ responses ($z = 2,51$; $p < 0,05$; *Cliff's* $\delta = 0,87$, large effect size). Concerning H4, mean response time for $s2$ was 4520 milliseconds ($SD = 0,84$) and for $q2$ was 4370 milliseconds ($SD = 0,71$). No significant difference was found between these measures ($z \rightarrow 0$; $p \rightarrow 1$; *Cliff's* $\delta \rightarrow 0$, close to null effect size). These vectors resulted not consistent with the normality assumption according to the Kolmogorov-Smirnov test. Hence H3

and H4 were tested using non-parametric statistics, that is, the Sign test. Accordingly, non-parametric effect sizes were used, that is, the Cliff's delta estimator was applied.

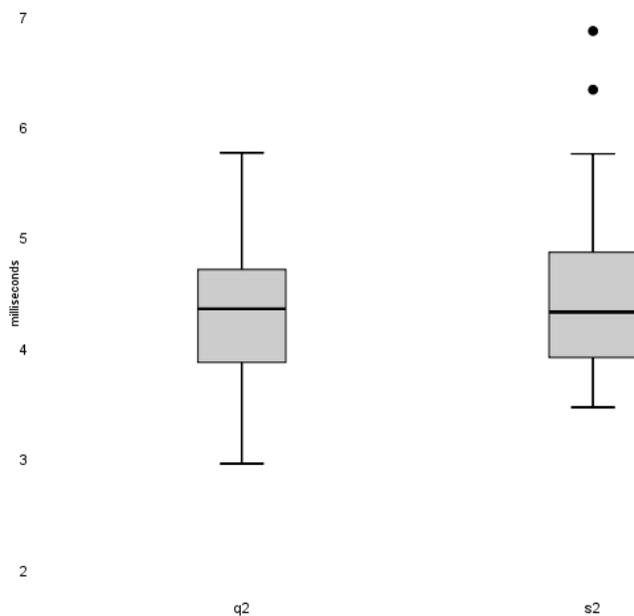
Figure 3 provides visual evidence for the implicit facilitation effect of semifactuals. Figure 3 is concerned with antecedent and Figure 4 with the consequent. For the antecedent, the implicit negation was processed faster than the corresponding factual component as shown in Figure 3. No facilitation effect was found for the consequent as shown in Figure 4.

Figure 3: Implicit facilitation of the semifactual antecedent



Note: the vertical axis scale shows integers that give milliseconds when multiplied by 1000. The p2 boxplot represents the factual antecedent and the r2 boxplot represents the implicitly negated antecedent.

Figure 4: Implicit lack of facilitation of the semifactual consequent



Note: the vertical axis scale shows integers that give milliseconds when multiplied by 1000. The q2 boxplot represents the factual consequent and the s2 boxplot represents the implicitly negated consequent.

General discussion

The mental models' theory of human thinking predicts a dual cognitive processing [9,15] of counterfactuals and semifactuals [2,4]. That is, the mental representation includes the factual proposition and the corresponding counterfactual or semifactual [3]. Since the negated antecedent and the negated consequent in counterfactual and the negated antecedent in semifactual are included in the dual representation, some further specific inferences are expected to occur faster [7]. Such facilitation effect has been found in previous studies for explicit negation [4]. The present contribution extends the evidence to include implicit negation. That is, the negation of a proposition such as 'apples' can take the form of 'no apples', which is explicit, or the form of 'oranges', which implicitly negates the original proposition [5,16,17]. The cognitive processing of these inferences showed facilitation in two experiments. Experiment 1 found a facilitation effect for implicit inferences in counterfactuals. Experiment 2 found facilitation for implicit semifactual inferences.

These results have been specifically predicted by the mental models' theory of human thinking [8,9,10]. The facilitation seems to occur because counterfactuals and semifactuals promote dual representations [2]. Such mental representation includes the negated antecedent and the negated consequent for counterfactuals [3] and the negated antecedent for semifactuals [4,7].

No other current theory of human thinking can predict such phenomena [3,4,7]. In particular, from the most prominent theory of thinking based on the logic form [12], that is the theory of proof [13,14], the opposite prediction can be derived. The theory of proof predicts that negative propositions, explicit or implicit, should require more processing time than affirmations. Since negation operates upon a proposition, the processing of such proposition has to occur before. Therefore, the processing of a proposition plus its negation should require more time than the processing of the same proposition without negation. An implicit negation might require even more time because it might activate semantic processing. Hence, this formal theory [13,14] cannot predict the pattern of results obtained in Experiments 1 and 2.

One limitation of the present study is concerned with the exclusive use of implicit negations to produce comparisons with the corresponding factual propositions. That is, in Experiment 1 we compared the processing of factual propositions p , q , with the processing of implicit counterfactual propositions r , s , where r replaces $\neg p$ and s replaces $\neg q$. We also used p_2 , q_2 , r_2 , s_2 with analogical meaning in Experiment 2. It is recommended for future experiments on this subject to conduct straightforward comparisons between implicit and explicit negation, that is, the latencies of $\neg p$ in comparison with r , and the latencies of $\neg q$ in comparison with s for counterfactuals. For semifactuals, it is recommended to extend the corresponding comparisons using $\neg p_2$ versus r_2 , and $\neg q_2$ versus s_2 . These comparisons might provide further relevant evidence to the understanding of conditional reasoning.

Conclusions

Two conclusions can be drawn from the novel experimental evidence generated in the present study. Both are concerned with mental representation and inference of counterfactuals and semifactuals [2,3,4]. They can be considered as extensions of the account provided by the mental models' theory of human thinking [8,9,10]. Since previous experiments found a facilitation effect for explicit negation [4], the present contribution focused on implicit negation suggests that the facilitation effects of counterfactuals and semifactuals are robust phenomena. In sum, the evidence-based conclusions of this study are: 1) Counterfactual reasoning promotes the processing acceleration of the implicitly negated antecedent and the implicitly negated consequent. 2) Semifactual reasoning promotes the processing acceleration of the implicitly negated antecedent, but not of the implicitly negated consequent.

This evidence suggests that counterfactual and semifactual reasoning operates by means of dual representations [2]. The facts or supposed facts are represented by one side. Their negation is represented by the other side. The latter generates a cognitive facilitation effect that was previously observed for explicit negation. The same chronometrical pattern was found in the present study for implicit negation.

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