Short Research Article

The Online Processing of Hypothetical Events

A Visual World Eye-Tracking Study on Conditionals and Causal Statements

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Abstract: A conditional statement *If P then Q* is formed by combining the two propositions *P* and *Q* together with the conditional connective *If … then …*. When embedded under the conditional connective, the two propositions *P* and *Q* describe hypothetical events that are not actualized. It remains unclear when such hypothetical thinking is activated in the real-time comprehension of conditional statements. To tackle this problem, we conducted an eye-tracking experiment using the visual world paradigm. Participants' eye movements on the concurrent image were recorded when they were listening to the auditorily presented conditional statements. Depending on when and what critical information is added into the auditory input, there are four possible temporal slots to observe in the online processing of the conditional statement: the sentential connective *If*, the antecedent *P*, the consequent *Q*, and the processing of the sentence following the conditional. We mainly focused on the first three slots. First, the occurrence of the conditional connective should trigger participants to search in the visual world for the event that could not assign a truth-value to the embedded proposition. Second, if the embedded proposition *P* can be determined as true by an event, the hypothetical property implied by the connective would prevent the participants from excluding the consideration of other events. The consideration of other events would yield more fixations on the events where the proposition is false.

Keywords: conditionals, causal statements, hypothetical property, eye-tracking, visual world paradigm

A conditional is a complex statement, such as *If P then Q*, with two propositions *P* and *Q* being composited together by the conditional connective *If … then …*. The meaning of the conditional statement lies in the difference between the two propositions *P* and *Q* when they are asserted in insolation than when they are embedded under the conditional connective *If … then …*. The exact meaning of conditionals is complex and is still under hot debate (cf. Knauff & Gazzo Castañeda, 2021; Skovgaard-Olsen et al., 2021). Here, we focus on a specific aspect being generally accepted or implied by different theories, i.e., events described by the propositions *P* and *Q* are different when they are asserted alone than when they are embedded under the conditional connective *If … then …*. Events described by propositions such as *P* and *Q* are factual by default, i.e., they describe events happening here and now. When *P* and *Q* are embedded under a conditional connective, however, the two relevant events are no longer factual, which, according to Russell (1903/2010), the two propositions embedded under a conditional connective are merely *considered*, but not *asserted*, means that no truth-values are assigned to the two propositions. That is to say, a conditional in human language can refer to events beyond here and now (Hockett, 1960). If two people are arguing *If P then Q* and are both in doubt about *P*, then they are adding *P* hypothetically to their stock of knowledge and are arguing on that basis about *Q* (Ramsey, 1929). Recent development of conditional theories has incorporated these ideas. The suppositional theory (Evans & Over, 2004), for example, described the word *If* as a linguistic device to trigger a process of hypothetical thinking. Similarly, according to the mental model theory (Johnson-Laird et al., 2015; Lopez-Astorga et al., 2021), a conditional *If P then Q* refers to the possibility of *P* and presupposes the possibility of ¬*P* (¬ = Not). When *P* and *Q* are known to be true, the conditional connective should be replaced by its minimal pair, the causal connective *Because … then …* (Russell, 1903/2010). *Because* is merely a variant of *If* when *P* is known to be true (Ramsey, 1929; Sebben & Ullrich, 2021).

In the literature, the offline studies used to explore the meaning of conditionals mainly relied on participants' judgment of the truth-value of conditionals or evaluation of

the possibilities of different situations in light of the truth-value of conditionals. For instance, in the truth-table task (Barrouillet et al., 2008), participants were either asked to evaluate the truth-value of *If P, then Q* given that one or more of the four situations are true *PQ*, *P*¬*Q*, ¬*PQ*, and ¬*P*¬*Q* (i.e., judgment of truth-values), or to evaluate whether the four situations are likely to occur given that the conditional is true (i.e., reasoning about possibilities). Similarly, in the conditional reasoning task (Nickerson, 2015), participants judged the truth-value of *Q*, *P*, ¬*Q*, or ¬*P*, supposing that the major premise *If P, then Q* and one of the categorical premises *P*, *Q*, ¬*P*, or ¬*Q* are true. However, we wish to point out that these prior tasks might not be appropriate for investigating the comprehension of conditionals due to the nature of the tasks. In both the truth-value and conditional reasoning tasks, to judge the truth of a conditional, participants needed to know the truth-values of the two merged propositions. However, whenever the truth-values of the two merged propositions are already known, the conditional becomes infelicitous to utter in such context. In other words, once the events indicated by the two merged propositions are actualized, the conditional connective becomes no longer appropriate for combining the two propositions.

To empirically inspect its meaning when a conditional *If P then Q* is unfolded online, four temporal slots could possibly be used: The sentential connective *If*, the antecedent *P*, the consequent *Q*, and the processing of the sentence following the conditional. Results reported in the literature mainly focused on the latter three temporal slots. In the second temporal slot, subjunctive mood itself in the antecedent *P* elicited more negativity than the indicative mood (Kulakova et al., 2014). Hearing *If P* triggered more fixations on objects related to ¬*P* when the mood is subjunctive than when it is indicative (Orenes et al., 2019). When *P* is actually true, *If P*... elicited a larger N400 amplitude when the mood is subjunctive than when it is indicative (Kulakova & Nieuwland, 2016). In the third temporal slot, hearing *If P then Q*, object related to ¬*Q* was more fixated when the mood is subjunctive than when the sentential connective is *Because* (Orenes, 2021; Orenes et al., 2021). Furthermore, *Q* in the counterfactual *If* ¬*P then Q* and ¬*Q* in the causal statement *Because P then* ¬*Q* are similarly processed (Nieuwland, 2012, 2013; Nieuwland & Martin, 2012). When *P* and *Q* are actually true, *If* ¬*P then* ¬*Q* elicited more activation in right occipital cortex (cuneus) and right basal ganglia (caudate nucleus) when the mood is subjunctive than when it is indicative (Kulakova et al., 2013). In the fourth temporal slot, when the conditional was used as a context, the critical information consistent with *P* was more easily processed when the context is indicative or is a causal statement (Ferguson, 2012; Urrutia et al., 2012) than when it is subjunctive, as being reflected in the reading paradigm (Ferguson, 2012; Ferguson & Sanford, 2008), visual world paradigm (Ferguson et al., 2010), and ERP recordings (Ferguson & Cane, 2015; Ferguson et al., 2008). A further series of studies have used Electroencephalogram (EEG) (Xu et al., 2015), eye movements and reading (Xu et al., 2018), and fMRI technique (Xu et al., 2022) to compare the processing of casual statements *Because* and concessive statements *Although* and found that the causal relation was more easily processed than that of the concessive relation.

Based on the literature reviewed, we can see that the hypothetical property implied by the conditional has not been directly tested in empirical explorations, although they have been extensively discussed in theory and are presupposed by default. This property can only be explored by directly comparing the processing of casual statements and indicative conditional statements, rather than by comparing subjunctive and indicative conditionals, or by comparing subjunctive conditionals and casual statements. We can also see that the processing of the conditionals in the first temporal slot has not been tested yet: whether the connective *If* ··· only is sufficient to trigger the hypothetical property implied by the conditional.

To overcome the two shortcomings of the previous studies discussed earlier, we designed our current study. We briefly discuss the rationale of our study before presenting our design. We predict that if the hypothetical property encoded in conditional connectives can be utilized by participants during online processing of conditionals, hearing the connective should lead them to predict the most plausible proposition that could be merged by the connective, thereby launching more fixations on the event by the plausible proposition. So, we incorporated features in our experiment that could explore whether this hypothetical property of conditionals is activated by participants during their processing of conditionals. Participants' real-time eye movements and behavioral responses on *If P then Q* trials were compared to their responses to the corresponding control trials *Because P therefore Q* that require the actualization of the propositions (Tanenhaus et al., 1995). Suppose there are three events in the visual world, event *E1* affirmed the antecedent *P*, event *E2* negated it, and event *E3* did not assign a truth-value. If the hypothetical property is utilized by the participants, we should observe the following three eye movement patterns and behavioral responses (Table 1): (a) The fixation proportion on event *E3* should be higher when hearing the conditional connective *If* ··· than when hearing

Table 1. Experimental predictions

Events	Eye movements		Behavioral responses
	If/Because	*If/Because P*	*If P, Q*
E1 (affirm P)			
E2 (negate P)		If > because	
E3 (unknown)	If > because		E3 > E2

the connective *Because* ⋯. (b) The proposition *P* embedded in the conditional statement *If P then Q* is merely considered but not asserted, i.e., the truth-value of *P* could either be true or false. When the heard sentential fragment turns out to be *If P* ⋯, the fixation proportions on event *E2* should also be higher than when the heard sentential fragment is *Because P* ⋯. (c). If *E1* and *E3* are both available in the context, *E3* should be preferred for the conditionals due to its default reading.

Methods

Experimental Design

To test the predictions, we used a visual world paradigm where participants' eye movements on the images were recorded while they were listening to auditorily presented sentences. In addition, a sentence–picture verification component was incorporated where participants were asked to choose the correct icon in the image that corresponded to the sentence. A test image had one closed box and three open boxes pseudorandomly situated in the four quadrants. Each box contains an object in it and a trademark outside. We made it clear that the closed box contained an unknown object. In addition, if the object and the trademark were the same, then the unknown object in the box had good quality and the owner of the box would be happy. Otherwise, the owner would be sad. For illustration purposes, the open/closed box was labeled in the format of "Object/Closed-Trademark." Boxes A–D in Figure 1a were then labeled as "Fan-Zither," "Fan-Fan," "Closed-Fan," and "Zither-Zither."

Test sentences such as *If P then Q* or *Because P therefore Q* were constructed from two propositions. The first proposition *The box contains a fan* was a description of the object in a specific box. The second proposition *John is very happy* described the mental state of the owner *John*. Consider Figure 1, the object of the first proposition was either *fan* or *zither*, and the object of the second proposition was either *happy* or *sad*. The full-balanced design led to 2 (sentential connective: *If* vs. *Because*) × 2 (object of the antecedent: *Fan* vs. *Zither*) × 2 (mood or object of the consequent: *Happy* vs. *Sad*) = 8 experimental conditions. Specific experimental condition(s) and test sentence(s) were referred to as *Connective-Object-Mood* or *Object-Mood*, such as *If-Zither-Sad*. In Figure 1, there exists only one box that contains a zither (Box D), and the trademark on that box is also a zither, so it is impossible for John to be sad if the obtained box is the one containing a zither. In this situation, the sentence *Because-Zither-Sad* (i.e., *Because the box contains a Zither*, *therefore John is very sad*) was infelicitous or was inappropriate to be uttered given that the test image was Figure 1. Thus, the sentence was not used in the experiment, and only seven test sentences were constructed corresponding to each test image (Figure 1b). The test sentences were constructed in Mandarin.

Given the experimental setting, the truth-values of the first and second propositions were determined by the object in a box and by the relation between the object and the trademark of the box, respectively. The trademark of a box was always known, so once the object in a box was fixed, the truth-values of the two propositions were also fixed. For an open box, the object in the box was fixed and the truth-values of the two propositions were also fixed. For a closed box, the unknown object had two possibilities, thereby leading to two possible truth-values of each proposition. The truth-value relations between the four boxes in Figure 1a and the four Object-Mood combinations utilized in Figure 1b are summarized in Figure 1c.

The theoretical predictions described in the Introduction can now be rephrased as follows:

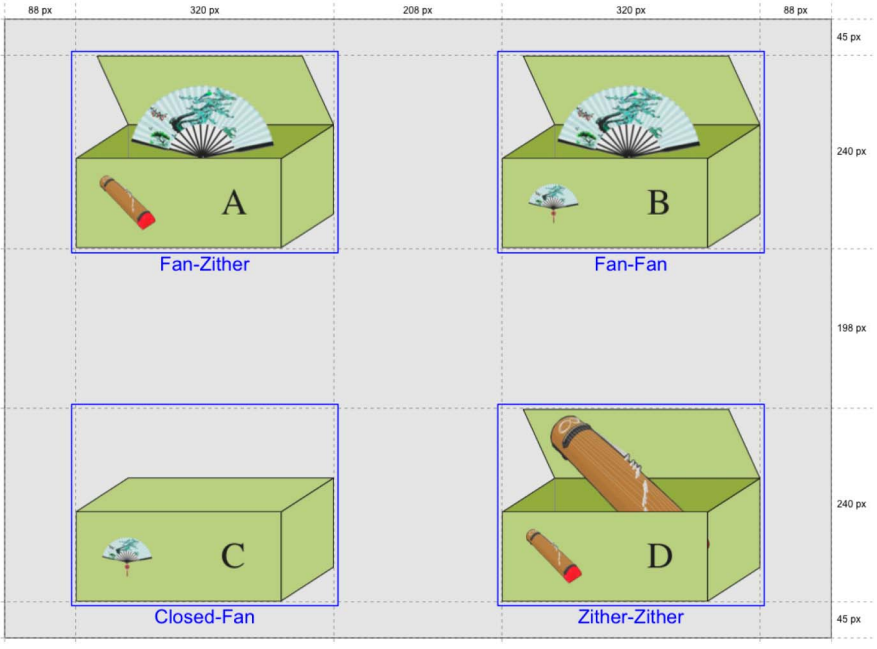
(a) Participants should launch more fixations on the closed box, when hearing the sentential fragment *If the box contains a* ⋯ than when hearing *Because the box contains a* ⋯;
(b) They should look more at the open box containing a zither, when hearing the sentential fragment *If the box contains a fan, then John will be very* ⋯ than when hearing *Because the box contains a fan, therefore John would be very* ⋯;
(c) More fixations and more behavioral responses should be observed on the closed box than on the open box "Fan-Fan," when the test sentence was *If* sentences than when it was the corresponding *Because* sentences.

Stimuli

Eighty-four test images like Figure 1a were created where the positions of the four boxes were counterbalanced. Seven test sentences as shown in Figure 1b were constructed corresponding to each test image, resulting in 588 test sentences in total. The spoken sentences were recorded by a female Mandarin native speaker. The 588 test trials were then split into seven groups, with 84 test sentences per group, each containing all seven experimental conditions, with 12 sentences per condition. We wish to point out that no filler items were included in the current experiment, given that hearing the 84 test trials was already a fairly long process and that the different test items could serve as baselines for the other.

In addition, to ensure the naturalness of the test audios, we did a survey where 20 native Mandarin speakers were recruited from the Beijing Language and Culture University (BLCU) to rate the naturalness of the test audios. They were

A



Because

因为	箱子里	是	扇子/古筝	所以	小明	很	高兴/* 伤心
yinwei	xiangzi li	shi	shanzi/guzheng	suoyi	Xiaoming	hen	gaoxing/*shangxin
because	box in	is	fan/zither	therefore	Xiaoming	very	happy/*sad

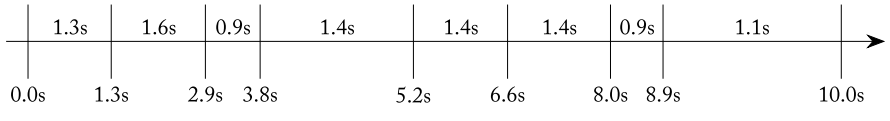
*Because the box contains a fan/zither, therefore John is very happy/*sad.*

If

如果	箱子里	是	扇子/古筝	那么	小明	就	高兴/伤心
Ruguo	xiangzi li	shi	shanzi/guzheng	name	Xiaoming	jiu	gaoxing/shangxin
If	box in	is	fan/zither	then	John	will	happy/sad

If the box contains a fan/zither, then John will be very happy/sad.

B



C

Test Sentence	Box (Object-Trademark) in Test Image				
Object-Mood (Antecedent-Consequent)	A Fan-Zither	B Fan-Fan	C (Closed-Fan) Fan-Fan	Zither-Fan	D Zither-Zither
Fan-Happy	True-False	True-True	True-True	False-False	False-True
Fan-Sad	True-True	True-False	True-False	False-True	False-False
Zither-Happy	False-False	False-True	False-True	True-False	True-True
Zither-Sad *	False-True	False-False	False-False	True-True	True-False

Figure 1. Experimental design: (a) Test image. This image is only for illustration purposes. In the actual test image, the blue rectangles, the text under each one, and the dashed lines were not visible to the participants. (b) Test sentences. The test sentence *Because-Zither-Sad*, i.e., *Because the box contains a Zither, then John is very sad*, was infelicitous for the given test image, so it was denoted with an asterisk and was not constructed in the experiment. The test sentence *If-Zither-Sad*, i.e., *If the box contains a Zither, then John will be very sad*, was constructed and was used to record data but was not used in the final analyses. (c) Experimental logics. Condition "*Because-Zither-Sad*" is infelicitous for the given test image and was not constructed in the test stimuli, so the *Object-Mood* relation "*Zither-Sad*" was denoted with an asterisk here. Note that the color is visible in the online version only.

undergraduate or postgraduate students of the university. In the survey, the participants were asked to judge the naturalness of the test audios they heard using a 7-point Likert scale, with 7 representing the most natural and 1 representing the least natural. The mean naturalness score for the *If* statement was 4.01 (*SD* = 1.54), and the mean naturalness score for *Because* statements was 4.81 (*SD* = 1.41). No significant difference was observed in the naturalness ratings of

the *If* and *Because* statements ($t = -1.72$, $p = .09$), indicating that these statements sounded natural and intelligible. All the stimuli, raw data, and scripts are provided in the OSF project: https://osf.io/uhcy7.

Participants

Seventy-two native Mandarin speakers (9 males, 63 females) from BLCU who did not take part in the survey were recruited to participate in the formal experiment. They were undergraduate or postgraduate students of different majors (age range: 18–25). The experiment followed a typical counterbalanced within-subject design: Each participant saw all the 84 test images but heard only one group (i.e., 84 sentences) of the seven groups of test sentences (i.e., 588 sentences in total). The 84 sentences contained all the seven condition types, with 12 sentences in each condition. Informed consent was obtained from each participant, and they were debriefed about the aims of the study after completing the experiment.

Experimental Procedure

Participants were seated approximately 64 cm from a 21 inch 4:3 color monitor with 1,024 × 768 pixel resolution. Their eye movements were recorded using EyeLink 1,000 Plus running under the free-to-move head mode with a monocular sampling rate of 500 Hz and a spatial resolution of 0.05° of visual angle and an average error of less than 0.5° of visual angle. The spoken sentences were presented via external speakers situated to the two sides of the monitor. At the beginning of the experiment, participants saw an introduction of the experiment in Mandarin on the screen. The instruction briefly explained the experimental task and procedure.

The standard EyeLink calibration and validation routines were performed. A black dot was then presented at the center of the screen. The participant was instructed to press the Space key while fixating on the dot. The press brought up the test image. The test image occurred 500 ms after the onset of the test image, 4,000 ms after the offset of the test audio, or pressing a key brought out a new trial. Participants' task was to determine which box the test sentence was talking about and pressed the corresponding key as soon as possible. Their eye movements were recorded from the onset of the test image to the offset of the trial.

Statistical Analyses

Participants' eye movements ranging from the onset to the offset of the test audio were analyzed. To process the eye movement data, we first deleted the samples where participants' eye movements were not caught. This process roughly affected 10% of the recorded data. Second, given that we were interested in comparing the differences between *If* and *Because* and that the condition *Because-Zither-Sad* was infelicitous in our experimental setting, we also excluded the conditions *If-Zither-Sad* from final analyses so as to balance the number of trials for comparison, thereby resulting in 6 = 2 (sentential connective: *If* vs. *Because*) × 3 (object-mood: *Fan-Happy* vs. *Fan-Sad* vs. *Zither-Happy*) conditions in the final analyses. Third, we defined four equal-sized areas of interest, containing the four boxes, respectively (the blue rectangles in Figure 1), namely, *Closed-Fan*, *Fan-Fan*, *Fan-Zither*, and *Zither-Zither*. Fourth, we coded the recorded data (dependent variable) as follows: for a specific area of interest, the samples where participants' fixations locating in that area were coded as 1 and the samples where participants' fixations locating out of that area were coded as 0. Fifth, we fitted a Bernoulli generalized linear mixed model to the data set at each sample point and each area of interest: *data* ~ 1 + *sentential_connective* + (1 + *sentential_connective* | *participant*) + (1 + *sentential_connective* | *item*). The model contained only one fixed term, i.e., sentential connectives, because the differences between conditional statements and the causal statements were the main focus of the current study. The fixed effect was dummy-coded, with the connective *Because* being used as the baseline, so a positive coefficient would mean that the proportion of fixation was larger when the connective was conditional connective than when it was causal and a negative coefficient would mean an opposite pattern. The model had two random terms, participants and items, and the random effects contained both intercept and slope with respect to each random term. The model fitting process was conducted via *MixedModels.jl* package (Bates et al., 2020) for *Julia* programming language (Bezanson et al., 2017). The length of the test audio was 10 s, and the sampling rate of the eye tracker was 500 Hz, leading to 5,000 = 10 × 500 sampling point in each trial. Four areas of interest (Box: *Closed-Fan* vs. *Fan-Fan* vs. *Fan-Zither* vs. *Zither-Zither*) and three object-mood combinations (*Fan-Happy* vs. *Fan-Sad* vs. *Zither-Happy*) were manipulated, yielding 60,000 = 5,000 × 4 × 3 fits of the same generalized linear mixed model (GLMM). Sixth, to overcome the possible family-wise error resulting from these multiple comparisons, we corrected the p values using Bonferroni methods, i.e., multiplying the obtained p value with 60,000.

Participants' behavioral responses were compared with the chance level using the Wilcoxon signed-rank test. There were four boxes in each test image. If there exists no preference among the four boxes, each box could then have 25% chance of being chosen. There were 12 trials in each experimental condition, so the chance level was set to 3. A Wilcoxon signed-rank test was used in each sentential connectives, object-mood, and areas of interest combinations to test

whether participants' choice was different from chance. In total, 24 = 2 (sentential connective: *If* vs. *Because*) × 3 (object-mood: *Fan-Happy* vs. *Fan-Sad* vs. *Zither-Happy*) × 4 (areas of interest: *Closed-fan*, *Fan-Fan*, *Fan-Zither*, *Zither-Zither*) Wilcoxon signed-rank tests were conducted.

Results

Participants' eye movements and behavioral responses were summarized in Figures 2 and 3, respectively. First, prior to the onset of the object of the first proposition, hearing the conditional fragment *If the box contains a* ⋯ triggered more fixations on the closed box than hearing *Because* fragment *Because the box contains a* ⋯ (Figure 2, row 1), confirming the first prediction.

Second, hearing ⋯ *fan, then John will be very* ⋯ triggered more fixations on the box containing a zither, i.e., box D "Zither–Zither" (Figure 2, row 2, columns 1–2) and fewer fixations on boxes containing a fan, i.e., boxes A and B "Fan-Zither/Fan" (Figure 2, rows 3–4, columns 1–2), compared to hearing ⋯ *fan, therefore John would be very* ⋯. By contrast, when the object of the first proposition was *zither*, more fixations were launched on box A "Fan-Zither" (Figure 2, row 3, column 3) and fewer fixations on box D "Zither-Zither" (Figure 2, row 2, column 3). No difference was observed on box A "Fan-Fan" (Figure 2, row 4, column 3). One possibility was that when the object of the antecedent was *Zither*, box A "Fan-Fan" had the same truth-value as the closed box C. However, a closed box with undetermined truth conditions was more salient and was the default denotation of a non-factual proposition. This possibility was manifested by the finding that during this period, the conditionals always triggered more fixations on the closed box, regardless of whether the object of the antecedent was *Fan* or *Zither* (Figure 2, row 1). To summarize, hearing the conditional sentential fragment *If P*, ⋯ triggered more fixations on boxes where *P* was false and fewer fixations on boxes where *P* was true, compared to the control condition, the *Because P* ⋯ fragment.

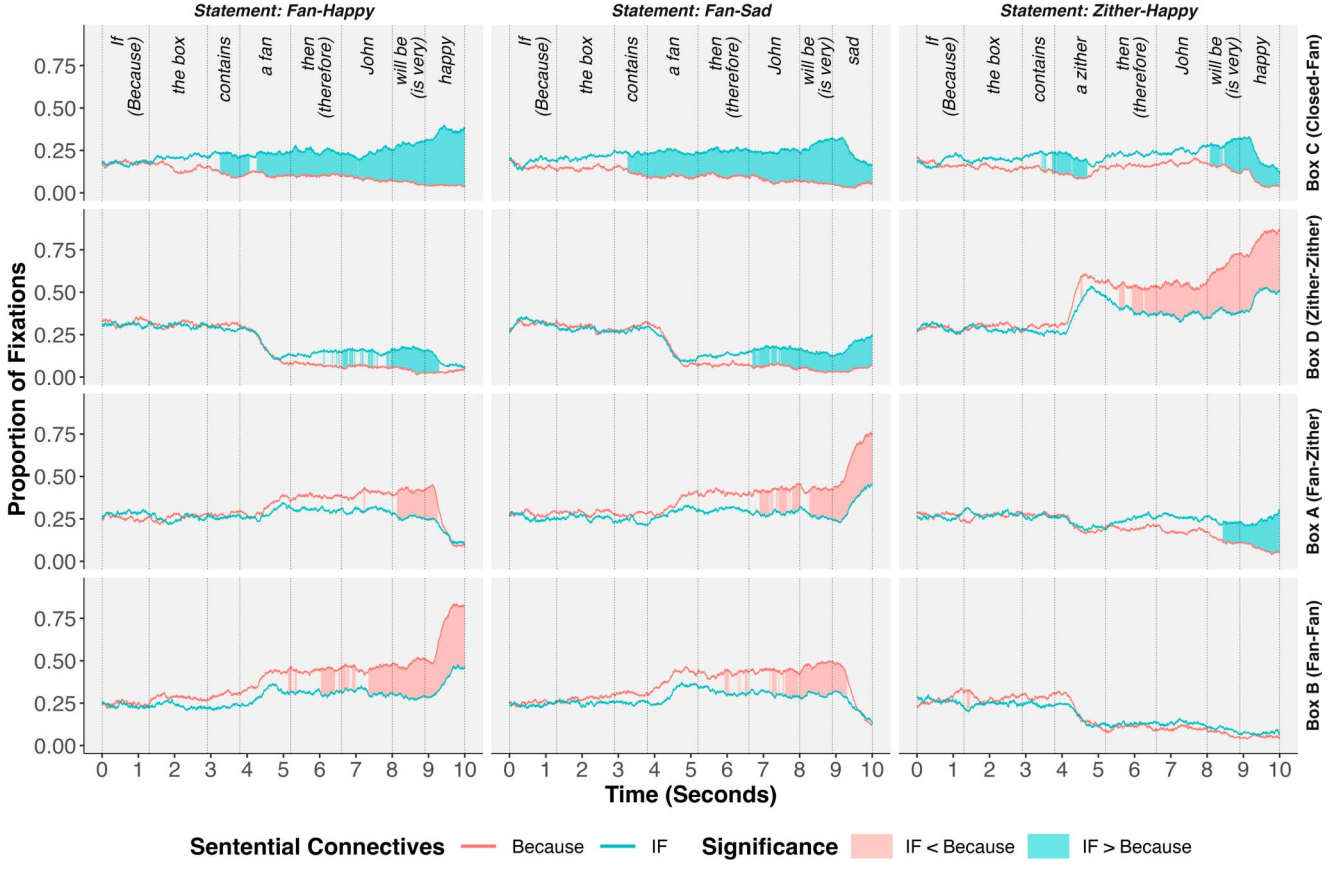


Figure 2. Eye movements results. Thousands of Bonferroni corrected *p* values were obtained, so we did not list them verbally in the text but illustrated each significant *p* value in the figure with a colored vertical line connecting the two connectives at the specific sampling point, specific area of interest, and specific *object-mood* combination. Red indicates that when the sentential connective was *If* the proportion of fixations (*y*-axis) in that area of interest at that sample point (*x*-axis) was significantly smaller than when the sentential connective was *Because*, Bonferroni corrected ($p < .05$). Blue means that that *If* was significantly larger than that of *Because* Bonferroni corrected ($p < .05$). Note that the color is visible in the online version only.

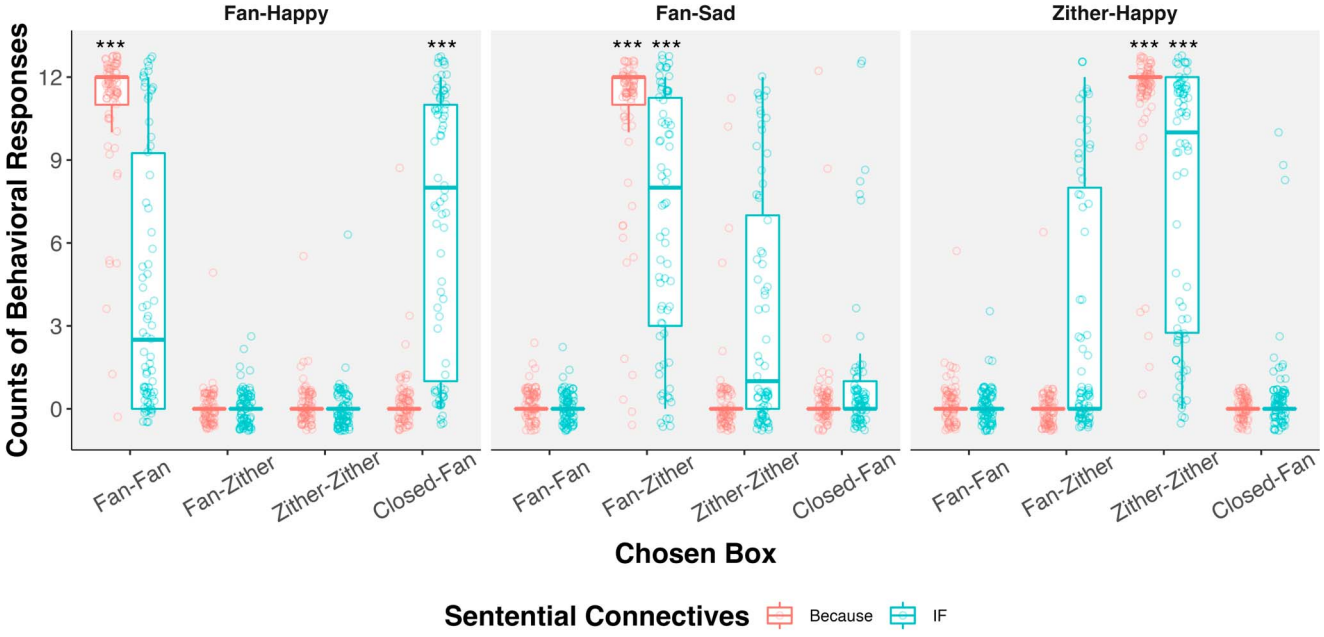


Figure 3. Behavioral responses. *** means participants' behavioral responses were significantly larger than n = 3, the chance level, $p < .001$, according to the Wilcoxon signed-rank test. Note that the color is visible in the online version only.

Third, when the test sentence was fully unfolded, participants' eye movements and behavioral responses could inform us about the following points:

(1) The box with the truth-value "True-False" had the lowest probability to be chosen, regardless of whether it was open or closed, as well as whether the sentential connective was *If* or *Because*. When the test sentence was *Zither-Happy*, for example, the closed box possibly had the truth-value "True-False" and had the lowest probability to be chosen (Figure 3, right panel).

(2) The box with the truth-value "True-True" had the highest chance to be chosen, regardless of whether the sentential connective was *If* or *Because*. When the test sentence was *Fan-Sad*, for example, the box "Fan-Zither" had the truth-value "True-True" and had the highest probability to be chosen (Figure 3, middle panel).

(3) When both the open and closed boxes possibly had a truth-value "True-True," the closed box had a higher probability of being chosen as the denotation of the *If* statement. When the test sentence was *If-Fan-Happy*, for example, both the open box "Fan-Fan" and the box "Closed-Fan" had the truth-value "True-True" (Figure 3, left panel). Participants' choices on the closed box were significantly above chance level, but their choices of the open box were close to chance.

Summary and Discussions

To summarize, the findings contribute to our understanding of the online processing of conditionals, and whether the hypothetical thinking involved in conditionals is activated in real time. Our findings show that conditionals are the appropriate statements to use when the two merged propositions lack truth-values or are regraded to lack truth-values. First, the most natural way to use *If P then Q* is when no corresponding event in the current situation could be used to judge the truth of the embedded proposition *P* and *Q*. In this situation, when a sentential fragment is preceded by the conditional connective, such as *If the box contains a* ⋯, it is easy to predict that the proposition *P* lacking truth-values in the current situation would be the most probable event to be described. This process happens in the first and third stages of our results. Second, when the proposition can be actually confirmed by an event in the current situation, the truth of the proposition has to be refrained, i.e., although the proposition can be determined as true by the event, the conditional connective does not allow it to be assigned a truth-value. Henceforth, it does not exclude the possibility that the proposition can be used to describe other events. This process was observed in the second stage of our results. Taken together, whether the described event lies here and now depends on two factors: whether the statement is by default used to describe a hypothetical event and whether there exists a corresponding event in the current situation.

Our results may shed some light on the selection of theories of conditionals and theories of human rationality. Determining the meaning of conditionals lies in the pivot of developing an appropriate theoretical framework for verbal reasoning and human rationality. Logic is originally proposed as the basis of rationality, and material implication defined in Boolean logic is regarded as the meaning of conditionals in human language. In Boolean logic, the material implication P^{Q} is true unless P is true and Q is false, i.e., it is true as long as PQ, $\neg PQ$, or $\neg P\,\neg Q$, where $\neg$ is read as *negation of* ⋯ or ⋯ *is false* (Russell, 1903/2010). Applying this definition to the interpretation of conditionals in human language has encountered several difficulties. One such difficulty is named paradoxes of material implication: If the conditional *If P then Q* has the truth-values as the material implication, then it is true whenever P is false or Q is true. Cognitively, however, the implications from $\neg P$ or Q to the truth of the conditional are unacceptable to naive human participants. To deal with the discrepancy between Boolean logic and human language, different approaches have been proposed in the literature (cf. Knauff & Gazzo Castañeda, 2021; Skovgaard-Olsen et al., 2021, for recent reviews).

If we stick to the classical logic explanation, the paradoxes of material implication can then be explained as follows: When the conditional *If P then Q* is true, the merged propositions P and Q should be both true and false. However, a proposition cannot be both true and false at the same time, so a conditional statement actually describes a superposition where the truth conditions of the merged propositions are not actualized. This is in accordance with the quantum theory of cognition (Pothos & Busemeyer, 2021). Whenever the truth-values of the two merged propositions are determined, the situations constructed from the conditional disappear and the conditional connective is no longer appropriate to combine them. Whenever the two merged propositions are known to be true, then the minimal variant of the conditional connective, *Because* ⋯ *therefore* ⋯, has to be used. Any new theory deviating from the classical logic must also include the hypothetical property. This is probably one reason why the mental model theory has been adapted from the original version (Johnson-Laird & Byrne, 2002) to the revised version (Johnson-Laird et al., 2015). The original version treated the meaning of the conditional as the disjunction of the three mental models corresponding to PQ, $\neg PQ$, or $\neg P\neg Q$ in classical logic, whereas the revised version regarded the meaning as the conjunction of the three mental models: *possible* (PQ), *possible* ($\neg PQ$), and *possible* ($\neg P\neg Q$), where a word *possible* was explicitly added to signify that the model is not actualized.

Conditional connectives are not the only element in human language that has the hypothetical property. Generally speaking, statements in human language can be divided into two categories – one has the hypothetical property and one does not. According to our understanding, in addition to conditional connectives, disjunctive connective *or*, negative connective *not*, and modal words *might/must* all fall into the first category, whereas conjunctive connective *and* belongs to the second category. To verify our hypothesis, future investigations are required, first, to empirically prove that the supposed hypothetical property indeed exists in the other proposed elements that fall in the first category; second, to demonstrate that the existing property of these elements is similar to the effect observed in the current study, and ideally, to further show that only humans but not other animals can represent the hypothetical property, as we believe that the first category is crucial for humans to surpass other animals.

We also wish to acknowledge that the experimental materials used in the study cannot be directly used in languages with a complex inflectional system. Unlike in Mandarin Chinese, in morphologically rich languages, the tense and mood morphemes might be different between the conditional and causal statements. Thus, this cross-linguistic variation should be considered when designing similar studies in these languages.

To conclude, the present study observed that the two events described by P and Q are only regarded as hypothetical or nonfactual when they are embedded under the conditional connective, *if* ⋯ *then*⋯. The conditional connective, among other similar linguistic operators, provides humans with a capacity to represent the information beyond here and now.

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