

## Processing effects of an indeterminate future: Evidence from self-paced reading

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Consider statements such as (1a-b):

- (1) a. Sally ate an apple before lunch.
- b. Sally will eat an apple before lunch.

The starting point of the present paper is the observation that (1a) and (1b) are likely to affect the beliefs of a listener or reader in qualitatively different ways. In the absence of conflicting evidence, (1a) is likely to generate the belief that Sally did, in fact, eat an apple before lunch. On the other hand, (1b) is likely to generate the belief that Sally will *probably* eat an apple before lunch, or that for all the speaker knows, Sally will eat an apple before lunch. In other words, (1a) may be regarded as true, while (1b) may be regarded as merely likely.

The different effects of (1a) and (1b) on a comprehender's set of beliefs may be understood in at least two ways. It may be understood in terms of naïve metaphysics: according to what is (arguably) a standard set of metaphysical assumptions, sentence (1a) has a determinate truth value at its time of utterance, while sentence (1b) does not. At the time (1b) is uttered, it is neither true nor false that Sally will eat an apple before lunch, as we generally assume some form of indeterminism about the future, which dictates that it cannot be completely settled, prior to Sally's eating the apple, whether she will do so or not. Perhaps (1b) acquires a truth-value later on, i.e., after lunch has begun (see, e.g., Belnap, Perloff, and Xu 2001, McFarlane 2003, for extended philosophical discussion). Alternately, it may be argued that both sentences do have a determinate truth-value at the time of utterance, but that as listeners, we recognize that statements about the past tend to have a stronger evidentiary base than statements about the future. An assertion about the past may be based on direct observation, testimony from someone who has made a direct observation, etc.; but an assertion about the future is, at best, based on inductive inference from secure premises (e.g., Sally said that she will eat an apple before lunch; Sally has eaten an apple before lunch every day this month; there are in fact apples in the house).

In this paper we present an experiment designed to investigate on-line processing effects of the purported difference between the comprehender's attitude toward propositions expressed in the past tense and her attitude toward propositions expressed in the future tense. The experiment investigates whether a reader or listener becomes rapidly committed to the truth of a past-tense assertion like (1a), but not to the truth of a future-tense assertion like (1b). By rapidly, we mean within the time frame of processing the sentence itself.

The experiment is based on the following line of reasoning. If a comprehender takes a sentence such as (1a) to be true, but it then turns out that (1a) is merely the first clause of a disjunction, as in (2a) below, the comprehender will have to revise her beliefs to reflect the fact that (1a) may not be true. This belief revision may have a processing cost. But if the comprehender takes (1b) to be a prediction or statement of belief (i.e., not certainly true), then when it turns out that (1b) is merely the first clause of a disjunction, as in (2b) below, the processing cost associated with belief revision may be mitigated or absent altogether.

- (2) a. Sally ate an apple before lunch, or her mother gave her some carrots.
- b. Sally will eat an apple before lunch, or her mother will give her some carrots.

In order to assess the processing cost associated with belief revision in the two sentences, we compared reading times on sentences like (2a-b) with reading times on control sentences in which the word *either* was included at the beginning of the sentence, as in (3a-b), making clear to the reader early on that the initial clause is in fact a disjunct.

- (3) a. Either Sally ate an apple before lunch, or her mother gave her some carrots.
- b. Either Sally will eat an apple before lunch, or her mother will give her some carrots.

Thus, we are able to compare reading time on the critical material in (2a-b) with reading time on identical material in a context in which belief revision is unlikely. Any belief revision cost should take the form of inflated reading time on the second clause of the sentences in (2), compared to the corresponding sentences in (3).

## Method

### *Participants*

Forty-eight members of the University of Massachusetts community participated in the experiment, either for course credit or \$7. All were native speakers of English, and all were naïve to the purpose of the experiment.

### *Materials*

Twenty-four stimulus sets like that shown in (4) were constructed. Many of the items were based on the items used in Staub and Clifton (2006). This experiment

demonstrated a general facilitation from the word *either* on reading of a second disjunct, whether the sentence involved clausal disjunction or noun phrase disjunction; in the Discussion section below we comment on the relationship between the present study and this earlier study. Unlike in the Staub and Clifton (2006) study, a comma was always included between clauses in order to prevent an initial noun phrase disjunction analysis. This incorrect analysis would also have been highly implausible, as the subject of the second clause was always an implausible object for the verb of the first clause.

- (4) a. Either John will borrow a rake, or his wife will buy one. (either, future)
- b. Either John borrowed a rake, or his wife bought one. (either, past)
- c. John will borrow a rake, or his wife will buy one. (no either, future)
- d. John borrowed a rake, or his wife bought one. (no either, past)

The 24 experimental sentences were separated into four lists, with one version of each stimulus set appearing on each list, and each list containing six sentences in each of the four experimental conditions. Each participant read the sentences on one of the four lists. The experimental sentences were intermixed with 114 unrelated filler sentences and presented in an individually randomized order to each participant, after two practice sentences. The full set of materials is presented in the Appendix.

### *Procedure*

Participants were tested individually using a non-cumulative phrase-by-phrase self-paced reading paradigm (Just, Carpenter, and Wooley 1982). Stimuli were presented and responses were collected on an IBM compatible computer running the E-Prime software package (Schneider, Eschman, and Zuccolotto 2002). Each sentence was divided into four presentation regions, as shown below:

- 5. Either John\ will borrow a rake,\ or his wife\ will buy one.

At the beginning of each trial, all characters were represented as dashes on the screen, with the first two regions on one line and the final two regions on the subsequent line. When the participant pressed the space bar, the dashes corresponding to the first region were replaced by characters. When the participant pressed the space bar again, these characters reverted to dashes, and the dashes in the second region were replaced by characters. This process continued until the participant finished reading the sentence and pressed the space bar for a final time, at which point the sentence was replaced by a two-choice comprehension question. The participant responded to the comprehension question by pressing a key. The duration of the experiment was approximately thirty minutes.

### *Results*

The comprehension questions associated with the sentences in this experiment were answered correctly on 91% of trials, with no participant scoring below 75% correct.

The participant mean reading times for each region in each condition are displayed in Table 1. On region 1, reading times were longer when *either* was present, as would be expected based on the length difference ( $F_1(1, 47) = 202.05, p < .001$ ;  $F_2(1, 23) = 138.12, p < .001$ ). The effect of tense was not significant on region 1 ( $F_1(1, 47) = 2.59, p = .11$ ;  $F_2(1, 23) = 2.23, p = .15$ ), and the interaction effect was also not significant ( $F_s < 1.5$ ). On region 2, reading times were longer for the future tense conditions than for the past tense conditions, which is again attributable to length differences ( $F_1(1, 47) = 20.93, p < .001$ ;  $F_2(1, 23) = 21.01, p < .001$ ). The effect of *either* was not significant ( $F_1(1, 47) = 1.76, p = .19$ ;  $F_2(1, 23) = 3.16, p = .09$ ), and the interaction effect was also not significant ( $F_s < 1$ ). On region 3, reading times were 98 ms shorter when *either* was present than when *either* was absent, a difference that was highly significant ( $F_1(1, 47) = 36.26, p < .001$ ;  $F_2(1, 23) = 30.94, p < .001$ ). This main effect of *either* was modulated by a significant interaction with tense: for the future tense conditions, the presence of *either* reduced reading time by 68 ms, while for the past tense conditions, the presence of *either* reduced reading time by 129 ms ( $F_1(1, 47) = 7.48, p < .01$ ;  $F_2(1, 23) = 6.08, p < .05$ ). The main effect of tense was not significant on region 3. On the final region, there was once again an effect of tense, with longer reading times in the future tense conditions due to length differences ( $F_1(1, 47) = 11.82, p < .01$ ;  $F_2(1, 23) = 13.07, p < .01$ ). No other effects approached significance on the final region (all  $F_s < 1$ ).

Table 1. Participant mean reading times on each region, in milliseconds.

Condition	Region 1 ( <i>Either</i> ) <i>John</i>	Region 2 ( <i>will borrow/ borrowed</i> ) <i>a rake,</i>	Region 3 <i>or his wife</i>	Region 4 ( <i>will buy/ bought</i> ) <i>one.</i>
either, future	771	1015	691	951
either, past	810	911	662	865
no either, future	571	980	759	960
no either, past	583	894	791	896

### Discussion

We will confine our discussion to the results from region 3, as all other results are easily interpretable in terms of simple length differences. On region 3 reading times were significantly shorter when *either* was present, but this difference was significantly greater for the past tense sentences than for the future tense sentences.

The main effect of *either* obtained in the present experiment is a clear replication of one of the principal findings obtained by Staub and Clifton (2006), who used eyetracking to investigate the question of whether reading may be facilitated when a syntactic structure can be predicted in advance. In their experiment, participants read sentences containing clausal disjunction (which provided the basis for some of the

materials in the present experiment), as well as sentences involving noun phrase disjunction (e.g., *The team took the subway or the train to get to the game.*) In addition, the word *either* could be present or absent before the disjunction. There were two critical findings. First, reading time on the region consisting of the word *or* and the subsequent noun phrase was significantly reduced by the presence of *either*, as measured by both first pass time (the sum of the reader's eye fixation durations beginning with the first fixation on this region and continuing until the reader leaves the region for the first time, to the left or the right) and go-past time (the sum of the reader's eye fixation durations beginning with the first fixation on the region and continuing until the reader leaves the region to the right, i.e., including re-reading time). These effects were similar in size for the clausal disjunction and noun phrase disjunction sentences. Second, despite the fact that the clausal disjunction sentences were designed to render the incorrect noun phrase disjunction analysis highly implausible, there was some evidence of garden-pathing in these sentences when *either* was absent, in the form of an increase in regressive eye movements from the final region of the sentence. (Unlike in the present study, there was no comma at the clause boundary.) But when *either* was present, this garden path effect was eliminated entirely. On the basis of these results, Staub and Clifton argued that the word *either* enabled readers to predict the arrival of a disjunction, and that this prediction facilitated processing of the second disjunct when it ultimately arrived. Furthermore, the presence of *either* before a clausal disjunction eliminated any tendency to mistakenly analyze the structure as noun phrase disjunction (see also Staub 2007, for additional evidence bearing on this question).

The significant interaction effect on region 3 suggests that when *either* was absent, readers did in fact become more strongly committed to the truth of a past-tense assertion in the first clause than to the truth of a future-tense assertion. The cost of belief revision is reflected in the fact that it took 129 ms longer for participants to read region 3 in the *no either, past* condition than in the *either, past* condition; we assume that in the latter condition, no belief revision was necessary. The corresponding difference was only 68 ms for the future tense conditions. This may be interpreted as suggesting that there is some belief-revision cost for the future tense, as well. We think it is more likely, however, that the 68 ms benefit when *either* is present is a syntactic predictability benefit, consistent with the conclusions of Staub and Clifton (2006).

### Conclusion

The experiment presented here suggests that whether readers become committed to the truth of an assertion, while they are still reading the sentence, depends in part on tense. When the truth of a past tense assertion was called into question by the arrival of a disjoined second clause, there was significantly greater processing cost on this clause than when a future tense assertion was similarly called into question. We interpret this pattern as reflecting the fact that future tense assertions are likely to be regarded as only probably true; little if any belief revision is necessary if it becomes explicit, by means of disjunction, that a future tense assertion may or may not be true. As we mentioned in the introduction, the comprehender's tendency to withhold belief in the proposition expressed by a future tense sentence may be understood either in metaphysical terms (i.e., statements made at time  $t$  about events taking place at time  $t+1$  are neither true nor

false at time *t*), or in epistemic terms (i.e., past tense assertions are generally based on stronger evidence than future tense assertions, and comprehenders recognize this).<sup>1</sup>

On a more general note, this experiment is, to our knowledge, the first clear suggestion that belief revision has on-line processing costs that are distinct from other sources of processing difficulty such as syntactic revision. We think this may be a fertile area for future sentence and discourse processing research.

## References

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## Appendix

Experimental Materials. Future tense versions are shown below; past tense versions were constructed as in (4) above.

1. (Either) John will borrow a rake, or his wife will buy one.
2. (Either) Ms. Haywood will plan a picnic, or the kids will go swimming.
3. (Either) the Congress will pass the bill, or the President will issue an order.

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<sup>1</sup> Florian Schwarz has provided the following interesting example in support of the second account. Suppose an archeologist discovers an ancient skull with clear signs of damage. She reports, "He was killed in a fight or he fell from a cliff." Given the context, a listener is likely to recognize the somewhat shaky evidentiary base for the assertion in the first clause, despite the use of the past tense. This predicts that the disjunction should cause little or no processing difficulty associated with belief revision. Indeed, our own intuitions are that no processing difficulty is present in this case.

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4. (Either) Linda will buy the red car, or her husband will lease the green one.
5. (Either) Dr. Wendell will perform the surgery, or the nurse will make a splint.
6. (Either) Liza will sing her famous song, or the host will dance with a bear.
7. (Either) Rudolph will pull the sleigh, or the leader will organize a team.
8. (Either) the pitcher will throw a ball, or the slugger will hit a home run.
9. (Either) Igor will discover a cure, or the patients will continue to suffer.
10. (Either) Jones will win the battle, or the natives will keep their land.
11. (Either) Brown will defeat the space aliens, or the ship will be swallowed up.
12. (Either) Louise will punish the children, or the parents will decide to let it slide.
13. (Either) the director will fire the cameraman, or the caterers will issue a formal complaint.
14. (Either) the teenagers will leave the party, or the police will tell them to go home.
15. (Either) the acrobat will drop the baton, or the clown will make the children cry.
16. (Either) the waiter will serve the soup, or the cook will have to do it himself.
17. (Either) the distributor will forget to deliver the cookies, or the shoplifters will steal them all.
18. (Either) the investigator will solve the crime, or the victim will continue to wonder what happened.
19. (Either) George will smoke the cigar, or his friend will object to his habit.
20. (Either) the referee will call time out, or the players will get into a scuffle.
21. (Either) the drummer will start the song, or the conductor will tap his baton.
22. (Either) Leo will bring his tools, or the carpenter will make the repairs.
23. (Either) Barbara will organize the files, or the agency will send someone to do it.
24. (Either) Richard will write the paper, or his assistant will do some of the work.

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