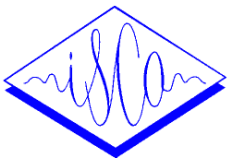

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Do non-word disfluencies affect syntactic parsing?

Karl G. D. Bailey and Fernanda Ferreira

Department of Psychology and Cognitive Science Program
Michigan State University
karl@eyelab.msu.edu

Abstract

Although disfluencies such as *uh* are generally not treated as linguistic items, our results suggest that they can affect syntactic parsing. Using a grammaticality judgment task, we demonstrate that disfluencies are able to affect the syntactic parse of a sentence in two ways. First, disfluencies can make syntactic reanalysis more difficult by coming between an ambiguous constituent and a disambiguating item. Second, the pattern of disfluencies in spontaneous speech may be used by the listener to guide the parse of a sentence. Thus, although disfluencies have often been viewed as pragmatic phenomena, they can affect the language comprehension by influencing its parsing procedures.

1. Introduction

Comprehension of spontaneous speech is not a simple as it might initially seem. A comprehender must break down a continuous speech stream into component parts, then build a syntactic structure and determine the meaning that the speaker intended to convey. Models of language comprehension ~~all~~ attempt to describe this process. However, our models of speech comprehension also assume that the utterances that make up spontaneous speech are ideal deliveries [1], that is, the kind of language that we see in grammatical polished writing. In theory, disfluencies could be filtered by some component of the language comprehension system before syntactic parsing occurs; however, our data strongly suggest that utterances with disfluencies are parsed differently from those without disfluencies.

In this series of experiments, we examine whether a filled pause disfluency, *uh*, that is generally believed not to be a word or syntactic constituent [2] can have the same effect on syntactic reanalysis as linguistic material. We then examine two possible explanations to account for how disfluencies could affect parsing.

The syntactic reanalysis effect examined in this series of experiments is known as the head noun position effect. The head noun position effect [3] occurs in garden path sentences such as (1).

(1) While the boy scratched the (A) **dog** (B) *yawned* loudly.

A garden path sentence is one which is temporarily ambiguous. The ambiguity can be resolved in one of two ways, one of which is preferred. If the parser incorrectly assumes the more preferred structure, as in (1), the parser is forced to reanalyze this structure. Reanalysis is not always successful, and when it fails the subject will call the sentence ungrammatical. A baseline garden path sentence like (1) is rated as grammatical 61% of the time in reading studies [3]. In this sentence the ambiguous noun is in bold and the disambiguating verb is in italics. If modifiers such as *big and hairy* are placed at position (A), the proportion of sentences rated grammatical falls (non-significantly) to 50%. However, if a modifier such as *that was hairy* is placed at position (B), only 29% of sentences are judged grammatical. The increase in reanalysis failure that occurs when material intervenes between ambiguous head noun and disambiguating verb is the head noun position effect.

In Experiment I, we demonstrate that filled pause disfluencies (*uh*) also produce the head noun position effect. In Experiment II and III, we examine two possible reasons why the disfluency elicited the head noun position effect: one is that the disfluency delays the onset of the disambiguating verb, and the other is that the listener uses the locations of disfluencies to predict particular types of syntactic constituents.

2. Methods

2.1. Stimuli

Two garden path structures were used in this study. The first is the subordinate main structure shown in (1). The head noun position effect has been replicated several times in this structure using reading paradigms. The second structure is the coordination ambiguity structure in (2).

(2) Sandra bumped into the (C) busboy and the (A) **waiter** (B) *told* her to be careful.

The head noun position effect has never been described in the coordination ambiguity structure. Some models of parsing (e.g. [4]) suggest that the coordination ambiguity structure should not show a head noun position effect because it is reanalyzed by a different mechanism than the subordinate main structure, and therefore a comparison of (1) and (2) is of considerable theoretical interest. 30 subordinate main structures and 20 coordination ambiguity structures were created for these experiments.

Five versions of each experimental sentence were created for Experiment I: a plain ambiguous NP baseline condition, two modifier conditions with a modifier at either position (A) or (B), and two disfluency conditions with a disfluency cluster (*uh uh*) at either position (A) or (B). Material at position (A) is referred to a prenominal and material at position (B) is referred to as postnominal. For Experiment II, the disfluencies were replaced with extraneous noises that are not produced by speakers as part of spontaneous speech. The stimuli for Experiment III consisted of the baseline condition, in addition to disfluency and modifier conditions at positions (A) and (C). In the context of Experiment III position (A) will be referred to at consistent and position (C) will be referred to as inconsistent.

All of the experimental sentences were non-preferred (i.e., garden-path) structures, and were produced as a single intonational contour in order to achieve neutral prosody [5]. The sentences were normed using a prosodic acceptability task

and a sentence completion task. 50 unambiguous grammatical and 50 ungrammatical fillers were included in Experiments I and II and 20 unambiguous grammatical and 20 ungrammatical fillers were included in Experiment III.

3. Experiment I

Experiment I was an auditory analogue of the grammaticality judgment task used previously to describe the head noun position effect [3].

3.1. Procedure

Subjects were seated in front of a computer and told that they would hear sentences sampled from natural speech and that they were to judge whether the sentence that they heard was grammatical or ungrammatical. The subject indicated their judgment by pressing either a button marker "Grammatical" or a button marked "Ungrammatical". The subjects completed eight practice sentences, four grammatical and four ungrammatical, to assure that they understood the procedure. The subject pressed a button to begin each trial. The subject's judgment of grammaticality was recorded for each sentence.

The results were analyzed as a 2x2 ANOVA, with material (disfluency or modifier) and position (prenominal or postnominal) as independent variables. The subordinate-main and coordination structures were analyzed separately.

3.2. Results

Experiment 1 replicated the head noun position effect with spoken sentences. In the subordinate main structure (Fig. 1), the prenominal modifiers (80% judged grammatical) were more likely to be judged grammatical than the postnominal modifiers (59%). In addition, for the coordination ambiguity (Fig. 2), prenominal modifiers (93%) were more likely to be judged grammatical than the postnominal modifiers (78%), thus demonstrating the head noun position effect in a novel structure.

The disfluency conditions showed the same pattern. The subordinate main prenominal disfluencies (85%) were judged grammatical more often than the postnominal disfluencies (60%). Likewise, the coordination ambiguity prenominal disfluencies (93%) were judged grammatical more often than the postnominal disfluencies (80%).

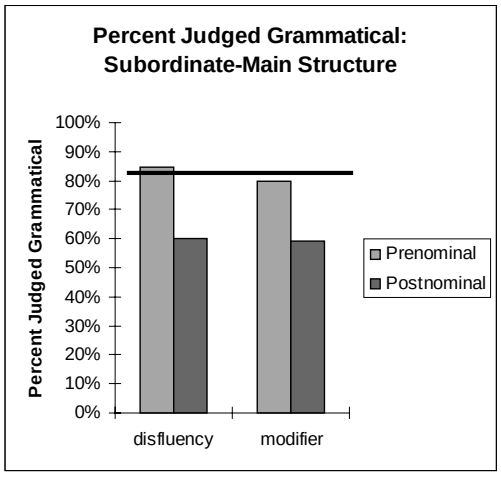

Figure 1: Percent of sentences judged grammatical for each condition of the subordinate main structure. The black line denotes the baseline condition.

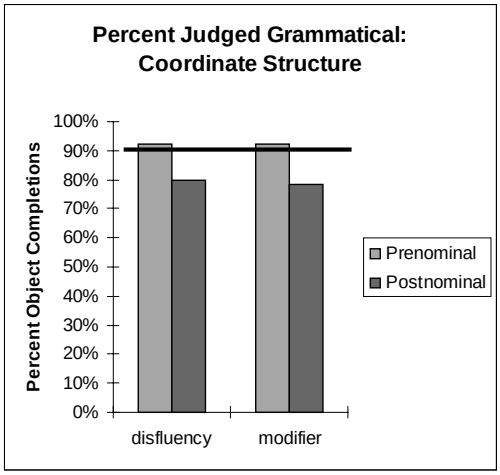

Figure 2: Percent of sentences judged grammatical for each condition of the coordination ambiguity structure. The black line denotes the baseline condition.

The main effect of position was significant (subordinate main: $F_{1,29} = 44.43$, $p<0.01$; coordination ambiguity: $F_{1,29} = 18.19$, $p<0.01$) for this experiment. The main effect of material and the interaction between material and position were non-significant for both structures.

3.3. Discussion

Experiment I shows that the head noun position effect described in reading studies also occurs in spontaneous speech. In addition, the head noun position effect has for the first time been demonstrated in the coordination structure. Thus, the head noun position effect seems to be very robust, and determining the cause of the head noun position effect could thus shed some light on the process of syntactic reanalysis.

Experiment I also indicates that disfluencies can affect the syntactic parse of a sentence. The presence of a disfluency between the ambiguous head noun and the disambiguating verb can elicit the head noun position effect. However, it is not clear from Experiment I why disfluencies might cause the head noun position effect. There are two possibilities.

The head noun position effect could be due to a delay introduced between the ambiguous head noun and the disambiguating verb. During this delay, decay in memory traces might make retrieval of the correct structure more difficult. This assumption would predict that the postnominal conditions would result in a lower proportion of sentences judged grammatical since material in the postnominal position delays the onset of the disambiguating verb. This is, of course, exactly what was found in Experiment I.

However, it is also possible that the head noun position effect elicited by disfluencies and the head noun position effect elicited by modifiers occur for different reasons. The modifier head noun position effect might be due to some process related to syntax, while the disfluency head noun position effect might be due to some special property of disfluencies. One such property might be the patterns of co-occurrence between disfluencies and syntactic constituents. Several researchers have noted that disfluencies tend to cluster around clause boundaries (e.g. [6], [7], [8]). Thus, listeners might be able to take the presence of a disfluency at a possible clause boundary as evidence of a clause boundary

and thus guide their syntactic parse accordingly. This hypothesis predicts that the postnominal disfluency condition should be judged grammatical less often than the prenominal disfluency condition, a prediction which matches the results of Experiment I.

Obviously, then, Experiment I is not sufficient to disentangle the two hypothesis. Experiments II and III were run in order to remove this confound.

4. Experiment II

Experiment II was identical to Experiment I, with one important change. In all of the experimental and filler stimuli, disfluencies were replaced with extraneous noises (cats meowing, dogs barking, telephones and doorbells ringing, people coughing and sneezing) that were not under the control of the speaker. The noises introduced a delay between the ambiguous head noun and the disambiguating verb that could not be interpreted as intentional on the part of the speaker (as an unfilled pause could be). In addition, the extraneous noises have no pattern of clustering at clause boundaries, and so the listener could not make any use of distributional information.

4.1. Procedure

The procedure was identical to the procedure in Experiment I. An additional instruction was added, indicating to the subjects that the speaker might be interrupted by an extraneous noise and that this had no bearing on the grammaticality of the sentence.

4.2. Results

Once again, the modifier conditions in both structures showed a head noun position effect. As in Experiment I, for both the subordinate main structure (Fig. 3; $F_{1,34} = 37.8$, $p<0.01$) and the coordination ambiguity structure (Fig. 4, $F_{1,34} = 4.39$, $p<0.05$) significant main effects of position were

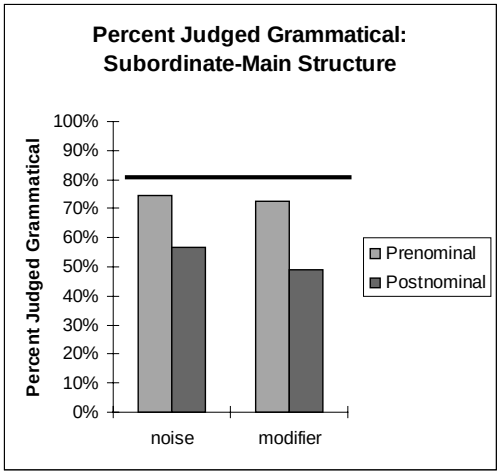

Figure 3: Percent of sentences judged grammatical for each condition of the subordinate main structure. The black line denotes the baseline condition.

observed. The main effect of material and the interaction between material and position were non-significant.

The extraneous noise conditions also showed a head noun position effect. In the subordinate main structure, the prenominal noise condition (74%) was judged grammatical more often than the postnominal noise condition (57%). In the coordination ambiguity structure, the same result was

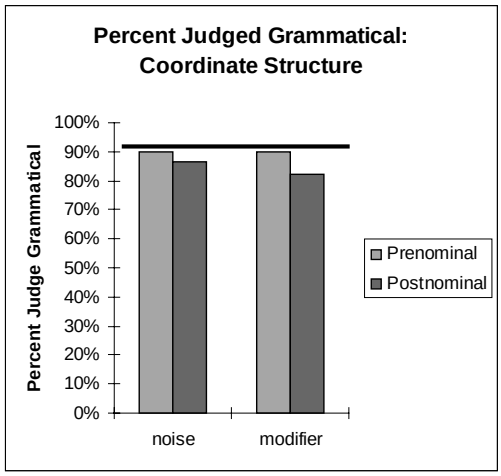

Figure 4: Percent of sentences judged grammatical for each condition of the coordination ambiguity structure. The black line denotes the baseline condition.

found, with the prenominal noise condition (90%) being judged grammatical more often than the postnominal noise condition (86%).

4.3. Discussion

The results from this experiment suggest that the head noun position effect may occur because postnominal modifiers cause the parser to be committed to the wrong analysis for a longer time period, and the longer the parser is committed to the wrong analysis, the more difficult it is to recover the correct one.

Thus, we can conclude that one way in which disfluencies can affect the syntactic parser is by delaying the appearance of a disambiguating item. Therefore, if the disfluency occurs at a place in the syntax where there is no ambiguity about the upcoming structure, the disfluency will have little effect on the parser. If, however, the disfluency occurs in a temporarily ambiguous region of a sentence, and the parser has built incorrect structure, the delay caused by the disfluency will make reanalysis more difficult.

However, we still have not ruled out the possibility that listeners could be using the distributional patterns of disfluencies found in normally produced language. The third experiment examines whether listeners make use of the tendency of disfluencies to cluster around clause boundaries in order to guide their syntactic parse.

5. Experiment III

Experiment III examined whether listeners use the presence of a disfluency to predict a upcoming clause rather than a simple noun phrase. Disfluencies or modifiers were placed at either position (A) or position (C). If disfluencies could be used to guide the parse of a sentence, then it was expected that the consistent disfluencies at position (A) would lead to a higher proportion of sentences judged grammatical, while the inconsistent disfluencies would lead to a lower proportion of sentences judged grammatical.

5.1. Procedure

The procedure for this experiment was the same is in Experiment I, with the exception that only one structure was used, and that t-tests were used to compare the two disfluency

conditions and the two modifier conditions, in addition to 2x2 ANOVA (consistency x material).

5.2. Results

Neither main effect was significant in this experiment; however there was a significant interaction between the material (disfluency or modifier) and the consistency (position (A), which was consistent with the syntactic structure, or position (C), which was not) variables (Fig. 5; $F_{1,29} = 8.53$, $p<0.01$). The t-test on the modifier conditions revealed that although the inconsistent modifier (95%) was judged grammatical more often than the consistent modifier (90%), the difference was not significant ($t_{1,29} = 1.53$, n.s.) . However, difference between the consistent disfluency (98%) and the inconsistent disfluency (90%) conditions was significant ($t_{1,29} = 6.37$, $p<0.02$).

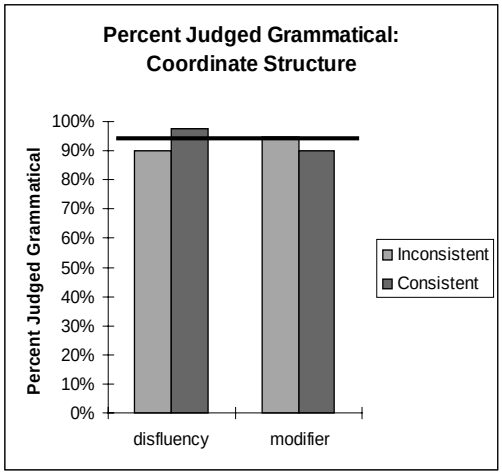

Figure 5: Percent of sentences judged grammatical for each condition. The black line denotes the baseline condition.

5.3. Discussion

The results of Experiment III indicate that the presence of a disfluency at the possible site of a clause boundary is information that can be used to guide the parse of a sentence. The presence of a disfluency at position (A) resulted in a higher proportion of grammatical judgments; thus, subjects were able to avoid the garden path more often. Thus, the head noun position effect elicited by disfluencies is probably a result of two factors working together. One is that disfluencies can cause the parser to be committed to the wrong analysis for a longer period of time, thus making recovery of the correct structure more difficult. The second is that disfluencies correlate with more complex syntactic structures, and the parser appears to be able to use the co-occurrence information to predict a more complex clausal structure and therefore to avoid being garden-pathed.

6. Conclusions

Based on these three experiments, it seems clear that filled pause disfluencies can affect the syntactic parse of a sentence. They can do so by introducing delay during the ambiguous region of a sentence, or by guiding the parse of the sentence when they co-occur with possible clausal boundaries. This suggests that models of parsing must take the effects of disfluencies into account, and that models of disfluency in spontaneous speech must account for syntactic effects in addition to pragmatic effects. The data also seem to rule out the idea that disfluencies are simply filtered from spoken utterances prior to parsing. Instead, disfluencies systematically influence the parser's basic parsing operations.

7. Acknowledgments

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