Ambiguity Advantage Effect in Wh-Questions*

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Abstract

An Ambiguity Advantage Effect occurs when a globally ambiguous sentence is processed faster than its unambiguous counterparts. This has been observed in PP attachment height and pronominal reference (Traxler et al., 1998; Grant et al., 2020). This study tests for an ambiguity advantage in filler-gap dependencies with wh-questions. We hypothesize that multiple gap-sites in ambiguous sentences will lead to faster processing times due to the viability of all possible parses. A lack of effect would entail that multiple analyses create competition. We find a statistical trend towards an ambiguity advantage, which is more pronounced in ungrammatical sentences and interpret the results under the Unrestricted Race Model, a serial stochastic parsing mechanism (van Gompel et al., 2000).

1 Introduction

The ambiguity advantage effect, first observed by Traxler et al. (1998), is a phenomenon where a globally ambiguous sentence is processed faster than its unambiguous counterparts. Originally observed for the ambiguity of attachment for prepositional phrases and relative clauses (1), this finding has been extended to attachment ambiguities for adverbs, VPs and NPs as well (Van Gompel et al., 2001; Van Gompel et al., 2005). Recent studies have also found the ambiguity advantage for pronominal reference (Grant et al., 2020).

(1) PP Attachment Ambiguity (Traxler et al., 1998, p.563)

a. The **son** of the **driver** with the moustache was pretty cool (AMBIG)

b. The **driver** of the car with the moustache was pretty cool (HIGH)

c. The car of the **driver** with the moustache was pretty cool (LOW)

The ambiguity arises in (1a) from the optionality of attachment for the PP *with the moustache*; modifying either *the driver* or *the son*. In (1b) and (1c), the attachment is forced to be either HIGH or LOW. Traxler et al. (1998) and subsequent replications (e.g. Van Gompel et al., 2001; Grant et al., 2020) found that the globally ambiguous

*Many thanks to Matt Wagers for extensive comments and feedback throughout this project. This paper formed from a class project with Shaya Karasso and Sophie Green. I am grateful to them for brainstorming and piloting this study.

sentence (1a) had faster reading times than the unambiguous (1b) & (1c) and concluded that globally ambiguous sentences are easier to process.

The ambiguity advantage effect poses a problem for models of parsing where multiple potential parses in an ambiguous sentence causes competitive inhibition and thus a slowdown in processing (e.g. MacDonald et al., 1994). To remedy this van Gompel et al. (2000) proposed the Unrestricted Race (URM), a serial stochastic parsing mechanism where weights are probabilistically assigned to competing parses. In temporarily ambiguous sentences these weights can be assigned such that one parse is initially favored over the other. However, in the cases where the ambiguity advantage is present, weights are essentially equal[1] and the acceptability of either reading (HIGH or LOW attachment in (1)) means the parser never needs to re-analyze the initial parse. The comparable slowdown in unambiguous conditions is explained by the small proportion of times where the incorrect attachment site is chosen and thus re-analysis is necessary to derive a well-formed syntactic output. In the case of (1b), the most plausible parse is one where the driver has the moustache and thus if the parser initially attaches the PP *with the moustache* to *the car*, a re-analysis may occur, resulting in a small slowdown in processing times. The prediction under the URM then is that structurally ambiguous sentences, when all parses are acceptable, will exhibit a speed up compared to those where not all parses are acceptable.

2 Current Study

The present study investigates the ambiguity advantage effect from a new lens: filler-gap ambiguities in WH-questions. We take advantage of the lexical properties of certain embedding verbs to create structurally ambiguous sentences. We find some evidence for an ambiguity advantage in grammatical sentences. These results are interpreted under the Unrestricted Race Model and future pathways are explored for the implicit prosody associated with the parsing of questions.

2.1 Background

2.1.1 Dependencies

Dependencies in the grammar have been the subject of much psycholinguistic research. A dependency is formed between two elements and can be either local or non-local. These dependencies can compete with one another to aid or hinder the parser. An example of a local dependency is subject verb agreement:

(2) The children$_{3pl}$ are$_{3pl}$ causing trouble

The parser must form a dependency between the subject *the children* and the verb *be* so that they both have 3PL agreement. These types of local dependencies have been shown to exhibit competition when there are multiple

[1] The equality of the weights will be variable based on language-internal considerations. A language with a low-preference for attachment will assign more weight to the low reading and vice versa for high attachment preference.

possible elements to satisfy the dependency (Wagers et al., 2009)

The current study is concerned with long-distance dependencies, specifically the relation between a ‘filler’ and its ‘gap’ (Fodor, 1978). This is shown in (3). A wh-element *who* is the ‘filler’ for the ‘gap’ after the verb *meet*:

(3) Who$_1$ did you meet __$_1$ on the street?

This dependency must be resolved to have a well-formed parse of the sentence. To resolve a long-distance dependency the parser must first predict that a gap will be present. Fodor (1978) argued that the parser is sensitive to fillers and that the moment a filler is seen, the parser already predicts a gap. Numerous follow-up studies have shown that there is an active process of predicting and filling gaps (e.g. Frazier et al., 1983; Crain and Fodor, 1985; Stowe, 1986 a.o.). Stowe (1986) found that when the parser predicts a gap but that gap is already filled, a slowdown in reading times occurs. This was done by comparing minimal pairs with and without a *wh*-dependency. When a dependency was present but the first possible gap was already filled a large slowdown in reading times was found (4a). This same slowdown was not present for sentences without *wh*-dependencies (4b):

(4) *Active Gap Filling* (Stowe, 1986)

a. My brother wanted to know **who**$_1$ Ruth will bring *us* home to __$_1$ at Christmas

b. My brother wanted to know **if** Ruth will bring *us* home to Mom at Christmas

These findings of active gap-filling have been further corroborated in a wide-range of paradigms with measures of reading times, ERPs and eye-tracking (Traxler et al., 1998; Kaan et al., 2000; see Phillips and Wagers, 2007 for an overview). A recent study by Omaki et al. further supported these claims, finding that the parser immediately posits the presence of a gap upon encountering a filler, not waiting for any additional information from verbal material. The present study takes advantage of this strategy to see if multiple gaps in a sentence which both result in a grammatical parse will aid or hinder the parser.

2.1.2 Control

We build our design from Frazier et al. (1983) who manipulated the control properties of the embedding verb (*want/decide/force*) to obtain various possible gap sites for the filler, *the girl*. *Want* is ambiguous between subject control and exceptional case marking (a flavor of object control). *Decide* is obligatorily subject control and *force* object control. Previous literature on filler-gap dependencies has primarily focused on processing gaps in declarative sentences (Frazier et al., 1983; Stowe, 1986 a.o.). This is illustrated by the paradigm in (5):

(5) Filler-Gap Dependencies (Frazier et al., 1983, p.197)

a. This is the girl the teacher wanted __ to talk to __ (LONG)

b. This is the girl the teacher wanted __ to talk (SHORT)

c. This is the girl the teacher decided __ to talk to __ (LONG)

d. This is the girl the teacher forced __ to talk (SHORT)

Frazier et al. (1983) hypothesized that sentences with subject control, where the initial gap is closer to a potential filler (5a)/(5c) would exhibit faster reading times than sentences where there was local competition for the gap site between two potential fillers (5b)/(5d). This was guided by the Most Recent Filler hypothesis, where gaps are preferably filled by the most recently encountered potential filler. In the case of (5b), the most recent possible filler is *the teacher* but the grammatically correct filler is *the girl*. Frazier et al. (1983) found a slowdown in SHORT conditions compared to LONG and took this as support for the Most Recent Filler hypothesis.

2.1.3 Transitivity

The difference between gap sites for (5a) and (5b) were forced with the presence or absence of the preposition *to*. Transitivity alternations can create a local syntactic ambiguity that interacts with filler-gap dependencies. (6) has a local ambiguity after the verb *play*: there is a potential gap site for the filler *what* but then the preposition *beside* introduces the true gap site. This arises from *play* being ambiguous between a transitive or intransitive verb:

(6) What$_1$ did the little children **play** beside __$_1$?

2.2 Experiment

The present investigation looks at paradigms similar to (5) and uses wh-questions instead of declaratives. We chose to use questions due to their underrepresented status in the sentence processing literature. We further utilized optionally transitive verbs like *play* which are ambiguous between transitives and intransitives to create multiple possible gap sites.

Consider the sentence (7):

(7) Who did the teacher want to draw? (AMBIG)

This sentence has two possible parses. One is a question about who will be drawn (8a). The other is a question about who will be drawing (9a).

(8) a. Who did the teacher want to draw __ ? (LONG)

b. The teacher wanted to draw **Sally**.

(9) a. Who did the teacher want __ to draw? (SHORT)

b. The teacher wanted **Sally** to draw.

This structural ambiguity arises from the optional transitivity of the embedded verb *draw*[2] along with the variable control properties of *want*. When the LONG dependency is formed, *want* functions as a Subject Control verb, where

[2]All Experimental Stimuli are in Appendix A

who is interpreted as the object of *draw*. When SHORT, *want* is an Exceptional Case Marking verb where the subject of draw receives its case from *want* (in this case the filler *Who*).

These ambiguous sentences were then compared to sentences with obligatorily subject (10b) and object (10c) control verbs, which are unambiguous

(10) WH-Question Filler-Gaps

a. Who did the teacher want __ to draw __ ? (AMBIG)

b. Who did the teacher agree to draw __ ? (LONG)

c. Who did the teacher tell __ to draw ? (SHORT)

Following the URM, the possibility of two parses in (10a) where *want* is either ECM or Subject Control, we predict that the acceptability of both sentences will lead to an analogous ambiguity advantage; (7) will be processed faster than the unambiguous sentences (10b)/(10c). Between the unambiguous sentences, we predicted that LONG sentences would have faster processing (Frazier et al., 1983). To test our hypothesis we implemented a Speeded Acceptability Judgment study which has been previously used to robustly show the ambiguity advantage effect (Dillon et al., 2019).

2.2.1 Participants

Forty-three participants were recruited from University of California Santa Cruz. 12 participants completed the study in the lab and the other 31 completed the study online after receiving instructions from the experimenter over Zoom. Participants were compensated for their time with course credit. All participants were over 18.

2.2.2 Materials

We used a factorial design of Dependency Type (AMBIG, LONG, SHORT) x Grammaticality (GRAMMATICAL, UNGRAMMATICAL). Ungrammatical sentences were created by filling all possible gaps in a sentence:

(11) Ungrammatical Foil WH-Questions

a. Who did the teacher want <u>the student</u> to draw <u>the model</u>? (foil to AMBIG)

b. Who did the teacher agree to draw <u>the model</u>? (foil to LONG)

c. Who did the teacher tell <u>the student</u> to draw <u>the model</u>? (foil to SHORT)

Due to the optional transitivity of the embedded verb, two gaps are filled in AMBIG and SHORT conditions but only one in LONG conditions. The second filled gap is necessary in (11c) because *draw* is forced to be transitive. This was done to ensure that the ungrammaticality uniformly arose after the embedded verb *draw*. We had no specific hypotheses about the ungrammatical conditions but conjectured that the sentences with ambiguous verbs would see a slowdown due to exhaustive parsing[3]; the need to rule out multiple potential parses. These ungrammatical sentences were primarily included to run the acceptability task and have foils to the grammatical sentences in (10).

Using the above design, we created 36 experimental items and combined these with 108 filler sentences. The study was balanced for grammatical and ungrammatical sentences. All sentences presented were questions. Fillers were either yes/no questions, wh-questions regarding adjuncts or wh-questions of subjects/objects. (10) and (11) constitute a full item set. Another example item set is given below:

(12) Example Item Set

a. Who did the mother need __ to drive __? (AMBIG)

b. Who did the mother offer to drive __? (LONG)

c. Who did the mother convince __ to drive? (SHORT)

d. Who did the mother need <u>the kids</u> to drive <u>the guest</u>? (UG Foil to AMBIG)

e. Who did the mother offer to drive <u>the guest</u>? (UG Foil to LONG)

f. Who did the mother convince <u>the kids</u> to drive <u>the guest</u>? (UG Foil to SHORT)

AMBIG sentences have 2 potential gap sites, either the subject or object of the embedded verb. LONG and SHORT have 1 potential gap site which is forced by the control properties of the embedding verb. All UNGRAM sentences have 0 potential gap sites.

2.2.3 Procedure

The above items were coded into lists using PcIBEX (Zehr and Schwarz, 2018) and distributed using Latin Square. Sentences were presented in a speeded acceptability judgment study using Rapid Serial Visual Presentation (Potter, 2018). Experimental trials began with a fixation cross in the center of the screen. Participants were presented sentences one word at a time. Each word remained on the screen for 250ms with a 100ms pause between words. At the end of each sentence, participants were immediately prompted to give an acceptability judgment, pressing *f* for 'Yes' and *j* for 'No'. Participants had a 2-second (2000ms) response window to provide a judgment. No feedback was given on whether a response was correct or incorrect.

Experimental trials began with participants filling out an informed consent form and demographic survey. Participants were then told that they would be reading sentences and providing acceptability judgments based on whether a sentence sounded natural/grammatical. Practice sentences were given prior to the experimental stimuli to acclimate participants to the RSVP reading style. Participants were debriefed after the experiment. In-person participants filled out a brief questionnaire.

[3] A pilot study with the same research question but different material resulted in a speed-up in ambiguous grammatical conditions and a slow-down in ambiguous ungrammatical conditions.

2.2.4 Results

Overall we found some evidence for an ambiguity advantage effect in structurally ambiguous wh-questions. There is a small speed-up in response times for AMBIG sentences compared to LONG and SHORT. Figure 1 plots the average reading times for all conditions. Among the grammaticals the ambiguous sentences are judged the fastest. We replicated the findings of Frazier et al. (1983) for LONG and SHORT. LONG are judged faster than SHORT in grammaticals but vice versa in ungrammaticals. We also found an unexpected speed-up in response times for ungrammatical sentences with ambiguous verbs. Ungrammatical sentences were responded to faster overall.

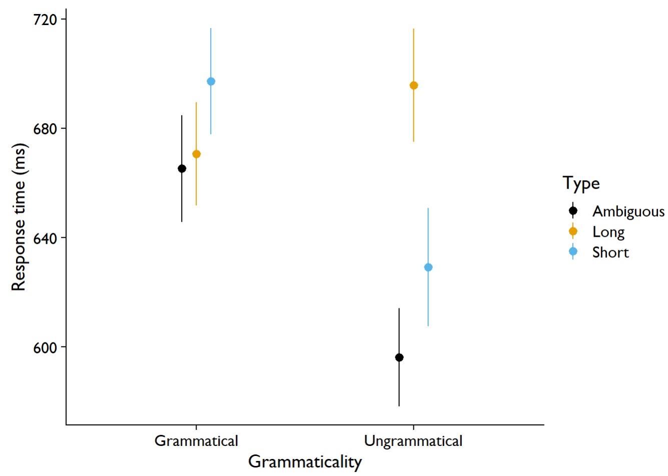

Figure 1: Average Response Times

We fit a Linear Mixed Effects Model with Log-transformed RTs as the dependent variable with Helmert coding to represent the distinction between Ambiguous and Unambiguous conditions (LONG + SHORT); and the Long v. Short contrast between Unambiguous conditions. Responses were filtered to only include correct judgments (i.e. *Yes* for grammatical and *No* for ungrammatical) two standard deviations from the mean ($>$1500ms). We found a significant effect of Ambiguity (β = 0.062, (0.012,0.11); p = .012) and Grammaticality (β = -0.063, (-0.11,-0.017); p = .0073). Ambiguous sentences had faster response times than unambiguous sentences and ungrammatical sentences were responded to faster than grammatical ones. An interaction was found for Grammaticality x Length (β = 0.15, (0.037, 0.26); p = .0088). This is present as a crossover effect for SHORT and LONG replicating the results of Frazier et al. (1983); LONG grammatical sentences are responded to faster than SHORT grammaticals but in ungrammaticals, SHORT are responded to faster than LONG. No significant interaction was found for Ambiguity x Grammaticality (β = 0.645; (-0.034, 0.163) p =0.19). These results are visualized in Figure 1 and summarized in Table 1.

We further computed pairwise comparisons for: AMBIG x SHORT, AMBIG x LONG and SHORT x LONG. In the ambiguous comparisons we found a significant effect for LONG (β =.0804, (0.026, 0.13); p = .0033) but not SHORT (β = 0.043; (-0.015, 0.101); p= 0.14). There is no significance for SHORT x LONG (β =-0.045, (-0.1, 0.12); p = .13)). AMBIG sentences as compared to LONG sentences show a significant speed-up but this same effect does not

Grammatical	Correct		Incorrect	
Dependency	Mean RT	Count	Mean RT	Count
AMBIG	665ms	81%	805ms	19%
LONG	670ms	82%	838ms	18%
SHORT	697ms	83%	848ms	17%
Ungrammatical	Correct		Incorrect	
Dependency	Mean RT	Count	Mean RT	Count
AMBIG	596ms	80%	729ms	20%
LONG	696ms	79%	717ms	21%
SHORT	629ms	80%	836ms	20%

Table 1: Average RTs for Correct and Incorrect responses

hold when comparing AMBIG directly to SHORT.

Accuracy across participants was around 80% and did not vary with condition. A χ^2 test yielded no significant differences (p = 0.13).

3 Discussion

Reaction times to acceptability judgments across conditions lend support to an Ambiguity Advantage Effect being present in WH-Questions. Ambiguous sentences had faster response times than unambiguous sentences resulting in a main effect of AMBIG. We interpret this as a trend towards the ambiguity advantage effect in Grammatical conditions. Contra our expectations, there is a pronounced speed-up in sentences with two filled gaps.

Interpreting these results under the Unrestricted Race Model, the pattern in grammatical sentences is expected. AMBIG sentences with two possible gap sites have two potential parses which are both acceptable. In any scenario, the parse that is chosen will be well-formed. LONG and SHORT sentences only have one potential gap site and thus on some amount of trials, the parser will incorrectly fill a gap and have temporary re-analysis when they reach the second gap site. This leads to the slight slowdown for LONG and pronounced slow down for SHORT.

We replicated the findings of Frazier et al. (1983), a crossover effect for LENGTH and GRAMMATICALITY: grammatical LONG had faster response times than SHORT and vice versa in ungrammatical conditions. The grammar is faster at integrating control properties of the verb than resolving dependencies. This explains why AMBIG patterns with LONG for grammaticals.

In the case of the ungrammatical sentences, the grammar's preference for LONG becomes a hindrance; re-analysis is necessary for the parser as a gap is expected but instead the parser sees a gap filled by a DP. The considerable speed-up for SHORT sentences comes from the parser already having found a gap for the filler, the wh-item *who*, and when the parser comes across the unexpected final DP, there is still a re-analysis, but this re-analysis is not as costly due to there not being any interference with the grammatical parse. AMBIG patterned with SHORT but exhibited an even further speed-up in response times

4 Implications in Implicit Prosody

The puzzle is the major observed speed-up for sentences with ambiguous verbs but zero potential gap sites. We did not expect to find any result in this condition so the interpretation is *post hoc*.

4.1 Repairing Ungrammaticals with Prosody

In the debrief questionnaire, an overwhelming majority of participants indicated that the ungrammatical sentences would have been grammatical with a comma, creating an echo question:

(13) Temporary Repair of Ungrammaticals

a. Who did the teacher want the student to draw, the model? (AMBIG)

b. Who did the teacher agree to draw, the model? (LONG)

c. Who did the teacher tell the student to draw, the model? (SHORT)

This tendency to attempt a repair of ungrammaticals could be what is driving the slowdown for LONG sentences. A temporary repair leads to a slowdown in overall judgment times. To respond correctly, that is respond '*No*' to the ungrammatical condition, the parser must first rule out the prosodic ambiguity of the question as an echo question. This attempt at repair is dependent on the parser's implicit prosody; how a given parser analyzes the intonational contour of a sentence (Fodor, 2002; Breen, 2014). For LONG sentences, this temporary repair occurs right before the parser is asked for a judgment resulting in a slowdown in response times. There is the remaining difficulty of explaining the difference between SHORT and AMBIG. Even though they pattern together, there is a pronounced speed-up for AMBIG.

4.2 Ambiguous Verbs have multiple parses

We interpret this difference as directly related to the ambiguous nature of the verbs in the AMBIG sentences. Dillon et al. (2019) found evidence that parsers retain information from multiple potential parses in globally ambiguous sentences. In the responses to the ungrammatical AMBIG sentences, the parser has one parse running that is equivalent to LONG and one that is equivalent to SHORT. When the parser reaches the second filled gap, re-analysis is not as costly as the parser has already 'bookmarked' the SHORT version as ungrammatical. Recall that SHORT sentences are instantly ungrammatical with the first gap filled:

(14) SHORT with first gap filled:

*Who did the teacher agree the student to draw __?

Thus in the AMBIG condition the parser is entertaining both of the following parses prior to the second filled gap:[4]

[4]There is the additional ambiguity of the optional transitivity of the embedded verb. For simplicity's sake we will assume that once the first gap is filled the parser is expecting transitive *draw*. Future work should run further norming tests to determine the transitivity preferences of the embedded verbs.

(15) AMBIG parses with first gap filled:

a. * Who did the teacher want the student to draw? (Subject Control; SHORT)

b. Who did the teacher want the student to draw __? (ECM; LONG)

The parser is already preparing to reject a parse like (15a) on the basis that there is a DP, *the student*, where a gap was expected for the subject controller. The parser is still considering a grammatical parse (15b) where *want* is an *Exceptional Case Marking* verb, which mechanically is very similarly to Object Control verbs. We hypothesize then, that even though a temporary repair is available for the ECM parse, the already available ungrammatical parse of (15a) allows for a *No* judgment to be given much faster. The parser is already prepared to judge one potential outcome of the string as ungrammatical and so no re-analysis is necessary to provide a *No* response.

This is further supported by incorrect *Yes* responses for the ungrammatical condition. When the parser incorrectly judges an ungrammatical AMBIG sentence as grammatical, they are doing so with the verb in its ECM form. Table 2 shows this descriptively: AMBIG and LONG pattern alike with an even larger slowdown for SHORT.

Dependency	Mean RT	Count
AMBIG	729ms	20%
LONG	717ms	20%
SHORT	836ms	20%

Table 2: Average RTs for Incorrect Ungrammatical Judgments

This provides support for an interpretation that when the parser incorrectly judges an ungrammatical sentence as grammatical, the grammatical parse is being analyzed with a LONG dependency (most likely from an echo question repair (13)). Table 2 shows that the RTs for AMBIG and LONG are almost identical. Taking the correct grammatical judgments into account (Table 1), where AMBIG patterns with LONG, this pattern is not unexpected.

4.3 Summary

An analysis of the speed-up in sentences with ambiguous verbs and zero potential gap sites (i.e. UG AMBIG) can be explained by the parser already having an active ungrammatical parse, which is similar to the SHORT sentence. The further speed-up in response times from SHORT to AMBIG comes about from temporary prosodic repair not being attempted for the short parse of AMBIG sentences leading to a faster '*No*' response. The parser will attempt a prosodic repair for SHORT sentences as there is only one potential parse. To correctly respond '*No*' for the ungrammatical parse, a grammatical parse must have already been ruled out. This bears on our implicit bias to form grammatical parses for sentences. The parser wants to attempt repair when there is a way to grammaticality but sometimes there is no way out and the ungrammatical parse is readily accepted.

5 Conclusion

This study set out to investigate the ambiguity advantage effect in Wh-Questions. An effect whereby a globally ambiguous sentence has faster processing times than related unambiguous sentences. We found a trend towards an ambiguity advantage in sentences with two potential gap sites and an unexpected speed-up in response times for sentences with zero potential gap sites and ambiguous verbs. We explained this unexpected result under the Implicit Prosody Hypothesis (Fodor, 2002): participants assigns a prosodic structure to a sentence as they are silently reading it. Ambiguous sentences have multiple possible prosodic parses, some of which are ruled out early on. The parser then does not need to undergo a temporary repair and costly re-analysis to correctly judge a sentence as ungrammatical.

Future research on the nature of the ambiguity advantage effect in wh-questions could focus in more on the implicit prosody of these sentences. There is a growing but small body of work on the implicit prosody associated with questions and the constructions presented in this study could provide valuable insight into the nature of implicit prosody. Additionally, the present study was done with an offline judgment immediately following presentation of the sentence. Future work will benefit from also testing the nature of this ambiguity advantage in online methods like the Maze task (Sloggett et al., 2020) or eye-tracking.

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6 Appendix A

All stimuli and fillers can be found here