STUDYING THE DYNAMICS OF LEXICAL ACCESS USING DISFLUENCIES

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ABSTRACT

Faced with planning problems related to lexical access, speakers take advantage of a major function of disfluencies: buying time. It is reasonable, then, to expect that the structure of disfluencies sheds light on the mechanisms underlying lexical access. Using data from the Switchboard Corpus, we investigated the effect of semantic competition during lexical access on repetition disfluencies. We hypothesized that the more time the speaker needs to access the following unit, the longer the repetition. We examined the repetitions preceding verbs and nouns and tested predictors influencing the accessibility of these items. Results suggest that speed of lexical access negatively correlates with the length of repetition and that the main determinants of lexical access speed differ for verbs and nouns. Longer disfluencies before verbs appear to be due to significant paradigmatic competition from semantically similar verbs. For nouns, they occur when the noun is relatively unpredictable given the preceding context.

Keywords: Repetition, lexical access, semantic competition, sentence planning, lexicalization.

1. INTRODUCTION

Several studies have suggested that disfluencies are used by speakers to buy time until the selection and planning of upcoming items is completed [9, 26]. This claim is supported by studies that show an increase in the rate of disfluneices as a result of utterance length [28] and difficulties in planning [21]. But more specifically, it is supported by the fact that disfluencies appear in production before words that are hard to access. Words may be hard to access because they are unpredictable [8, 2] or infrequent [17, 2], or because there are many semantically similar words that compete with them for selection [14, 25]. This difficulty in access is especially severe if the competitors are more frequent than the target word [27] or have been made highly accessible through priming [18]. The stronger the competition, the more time is needed for the lexical selection process. Disfluencies may therefore be longer in highly competitive contexts, as the speaker needs to buy more time to plan the upcoming material.

In the current paper, we examine this hypothesis for repetition disfluencies preceding nouns and verbs. Theories of sentence production differ on whether verbs and nouns are selected at the same time during planning. On the one hand, both are lexical rather than functional items and therefore might be expected to be selected at the same time following the building of the sentence's structural frame [6]. On the other hand, verbs have been suggested to project the sentence's argument structure into which nouns (or noun phrases) are then slotted or, in constructionist approaches to syntax, to be tightly fused with the sentence's argument structure construction, which again is selected early in sentence planning [10]. If verbs are selected before nouns, we expect to see predictors of accessibility vary with lexical category of the target, as nouns are selected in the context of verbs while verbs are selected in a more context-independent manner. Differences in predictors of accessibility for nouns vs. verbs, as reflected in lengths of repetition disfluencies preceding these items, may therefore shed light on the time course of sentence planning.

2. METHODS

2.1. Repetition disfluencies

Repetition disfluencies are interruptions in the flow of speech followed by repetition of one or more of the items preceding the interruption point. We limited our study to instances of one-word and two-word repetitions preceding main verbs and nouns in the Switchboard Corpus [7]. Some data were excluded. Repetitions that were within one word of the preceding clause boundary were excluded. This is due to the fact that repetitions never span clause boundaries, so in these cases, the speaker would be limited to produce a one-word repetition only. Cases in which another disfluency immediately preceded or followed the repetition disfluency were also excluded. Our data included 2858 verbs and 1899 nouns following one-word repetitions and 776 verbs and 452 nouns following two-word repetitions. Examples of one-word and two-word repetitions are shown in (1) and (2). The '+' indicates the

interruption point and the '[]' mark the disfluency boundary.

1) I think it gets them prepared [to, + to] learn how to volunteer as they get older.
2) Now I'm probably [going to, + going to] upset you.

Henceforth, we use the following templates to refer to the structure of repetitions in the preceding and following context of the interruption point. 'W' stands for 'word' and the subscriptions denote the distance from the interruption point. The word(s) within the brackets on either side of the interruption point is (are) the same words. W_1 is either a noun or a verb and immediately follows the repetition.

- One word repetitions
  $W_{-3}\ W_{-2}\ [W_{-1}+\ W_{-1}]\ W_1$
- Two-word repetitions
  $W_{-3}\ [W_{-2}\ W_{-1}\ +\ W_{-2}\ W_{-1}]\ W_1$

2.2. Cohesion and interruptibility

Besides accessibility, the length of a repetition disfluency may be influenced by characteristics of the preceding context. In particular, studies have shown that production tends not to restart from the middle of a cohesive unit [5]. Words, as the paradigm examples of cohesive units in language, are impervious to restarts: following an interruption, production always restarts from at least as far back as the preceding word boundary, in (3) and (4), and never from the middle of the word, hence the ungrammaticality of (5).

3) I [had a similar, + a similar] health plan.
4) I [had a similar, + similar] health plan.
5) * I [had a similar, + -milar] health plan.

But not all words are the same when it comes to interruptibility. Less frequent words are more susceptible to interruption than frequent ones. Logan [15] shows that in stop-signal tasks, it is more difficult to stop typing the word *the* compared to other less frequent words such as *thy*. There is also evidence that frequent words are less likely to be interrupted prior to completion than infrequent words [12, 23]. Likewise, cohesion of a unit bigger than a word may result from a high degree of co-occurrence between words rather than being completely determined by syntactic constituency. For example, sentence comprehension is sensitive to frequencies of compositional four-word strings that are not syntactic constituents (e.g. *in the middle of* vs. *in the side of*) even when frequencies of the component units are controlled [29]. This is in line with usage-based linguistic theory, which claims that "units used together fuse together" [4].

According to Levelt [13], speech production is restarted from the nearest major syntactic constituent boundary. However, the restart location is also influenced by co-occurrence, more specifically backward transitional probability: the probability of a word given the following word [11]. Speakers tend not to restart speech from transitions of high backward transitional probability. This observation is illustrated in (6) and (7). The probability of *of* before *the* is higher than the probability of *for* before *the*. While the speaker has an overall tendency to repeat as little as possible, thus interrupting the fairly cohesive *for the*, they do not interrupt the even more cohesive *of the* despite the nearest constituent boundary being before *the* in both cases.

6) That place is known for [the, + the] rudest waitresses.
7) The crime level is not as high as it is in other areas [of the, + of the] city.

High cohesion between words preceding the interruption point may therefore cause speakers to repeat more than one word, avoiding interrupting a cohesive unit. Thus, we need to take into account characteristics of the context preceding the disfluency before arguing that repetition length is affected by accessibility of the following word.

2.3. Independent measures

2.3.1. Accessibility

Influences on lexical accessibility include the frequency of the upcoming word [19], the number of semantic competitors (synonyms) of the word, and their frequencies [27]. Words that are infrequent relative to their competitors and that have many competitors are expected to be harder to access [16] and therefore be preceded by longer repetitions. A machine-readable version of Roget's Thesaurus [24] was used to retrieve and count the number of synonyms for verbs and nouns following disfluencies, but the synonyms were limited to the ones found in the Switchboard Corpus. Frequencies of verbs and nouns and their synonyms were then retrieved from the Switchboard Corpus. So, the predictors for measuring accessibility include: Frequency of the verb or noun following the disfluency; probability of the word following the disfluency given the word that precedes it (i.e., forward transitional probability or FTP) – $p\ (W_1|W_{-1})$; and competition index (the product of number of synonyms for the noun or verb and mean frequency of the synonyms).

2.3.2. Cohesion

Based on the findings of previous work on repetiion repair [11], backward transitional probability (BTP) was used in the model as the best index of cohesion

as it impacts repetition length. If BTP of W_{-2} or p (W_{-2} | W_{-1}) is high, sequence $W_{-2}W_{-1}$ is cohesive, so speakers should avoid restarting the speech from the middle of it, which would result in a longer (two-word) repetition. On the other hand, if BTP of W_{-3} or p (W_{-3} | W_{-2}) is high, sequence $W_{-3}W_{-2}$ is highly cohesive, which should prevent the repetition of W_{-2} because repetition of W_{-2} would require interruption of the cohesive sequence $W_{-3}W_{-2}$.

2.4. Analysis

Multimodel inference with logistic regression [3] was used to assess the predictors (MuMIn package in R [1]). In this method, models containing all possible subsets of predictors are built from a complex regression model. Coefficients are then derived by averaging across models, weighting each model in proportion to its predictiveness. There were no random effects in the model, as models with random effects (of speaker and following word) would not converge given the small number of observations per speaker and per following word. Note that to reduce skew, predictors were scaled using log, rank, and square root transformations. Therefore, the magnitudes of coefficients of the various predictors within a model cannot be directly compared.

3. RESULTS

The results of the analysis for verbs are summarized in Table 1. High BTP of W_{-2} resulted in longer repetitions, and high BTP of W_{-3} resulted in shorter repetitions (*p*s < .001). Thus, speech production tends not to restart from transitions with high backward transitional probability. In addition, there was an effect of accessibility of the upcoming verb: verbs with higher frequency tend to follow shorter (one-word) repetitions ($p < .001$) and verbs that face high competition tend to follow longer (two-word) repetitions ($p = 0.0139$).

Table 1: Model averaged coefficients for verbs.

Predictors	Estimate	z value	Pr(>|z|)
(Intercept)	2.986	6.794	< 2e-16
Verb Frequency	-0.1548	4.103	4.08e-05
BTP($W_{-2}W_{-1}$)	0.7702	15.90	< 2e-16
BTP($W_{-3}W_{-2}$)	-0.00066	8.655	< 2e-16
Competition	0.001935	2.459	0.0139
FTP(W_1|W_{-1})	-0.0128	0.470	0.6384

The results of the analysis for nouns are summarized in Table 2. Comparable to verbs, high BTP of W_{-2} resulted in longer repetitions, and high BTP of W_{-3} resulted in shorter repetitions (*p*s < .001). Thus, speech production tends not to restart from transitions with high backward transitional probability. In addition, there is an effect of accessibility: nouns with higher predictability (forward transitional probability) tend to follow shorter repetitions ($p = 0.0142$).

Table 2: Model averaged coefficients for nouns.

Predictors	Estimate	z value	Pr(>|z|)
(Intercept)	-0.351	0.535	0.5924
Noun Frequency	0.068	1.059	0.2898
BTP($W_{-2}W_{-1}$)	0.421	9.289	< 2e-16
BTP($W_{-3}W_{-2}$)	-0.002	8.231	< 2e-16
Competition	0.062	1.032	0.3020
FTP(W_1|W_{-1})	-0.129	2.451	0.0142

4. DISCUSSION

For both verbs and nouns, disfluency length was significantly influenced by both accessibility of the upcoming word and cohesion of the preceding string. Cohesive word sequences preceding hard-to-access nouns or verbs are likely to be repeated as a unit. However, the best predictors of accessibility were different for nouns and verbs. For verbs, accessibility was best captured by context-independent measures: frequency and the cumulative strength of semantic competitors. For nouns, accessibility was best captured by probability of noun given the preceding context. In other words, longer disfluencies before verbs happen when the verb is facing significant paradigmatic competition from semantically similar verbs. Longer disfluencies before nouns appear to occur when the noun is relatively unpredictable given the preceding context. This is consistent with the idea that sentence planning consists of selecting a grammatical frame / argument structure construction first, followed by filling in the content words during lexicalization [6] as long as verbs are considered to be tightly fused with the argument structure construction [10]. After verbs are specified during the selection of argument structure construction, nouns are selected and filled in during lexicalization, rendering the choice of noun a more context dependent process.

Why is backward transitional probability a reliable predictor for the length of repetition? Our current interpretation is that BTP is indexing cohesion in the sense of co-occurrence. Studies of statistical learning show learners to be sensitive to BTP in segmenting units out of a continuous speech stream [22]. However, BTP in pre-posing languages such as English is highly correlated with syntactic constituency [11, 20]. So, it is possible that BTP acts as an index of constituency rather than an independent influence on it.

5. CONCLUSION

We investigated factors that predict the lengths of repetition disfluencies based on the preceding and following context. We found that cohesive units preceding interruption point are less likely to be interrupted when restarting production. Additionally, speed of lexical access of verbs or nouns following the disfluency negatively correlates with the length of repetition. However, the best predictors of accessibility differ across lexical category. Frequency and semantic competition are best predictors of the length of repetition before upcoming verbs while the best predictor of repetition length for nouns is contextual predictability. This difference may be due to differences in the timecourse of planning, namely that accessing nouns occurs at a later stage than accessing verbs. The results also corroborate the hypothesis that repetition disfluencies are used to buy time for lexical access.

6. REFERENCES

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