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Effects of syntactic and semantic predictability on sentence comprehension: A comparison between native and non-native speakers

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Abstract

Prediction is pervasive during sentence comprehension among native speakers of a language. But whether non-native speakers predict to the same extent as native speakers remains an open question. To examine the effects of semantic and syntactic predictability in native and non-native speakers, we conducted a self-paced reading and an acceptability judgement task. The results suggest that the effects of semantic and syntactic predictability are unequivocally robust among native speakers during sentence comprehension. However, the effects of syntactic predictability seem to be more robust for native speakers than for non-native speakers who are largely sensitive to semantic predictability.

Keywords: syntactic predictability; semantic predictability; sentence comprehension; native speakers; non-native speakers

Introduction

It is well established that native speakers and adult second language (L2) learners are both adept at processing sentences in a highly incremental fashion (Juffs & Rodríguez, 2014; Marslen-Wilson, 1973). A long-standing debate over L2 sentence processing concerns whether L2 learners can reach nativelikeness with respect to the mechanisms employed for incremental sentence processing (e.g., Clahsen & Felser, 2006; Cunnings, 2017). A large body of evidence has shown that adult monolingual speakers do not only passively integrate information with prior context, but also proactively predict upcoming materials based on existent linguistic evidence (Altmann & Mirković, 2009; Pickering & Garrod, 2013). Prediction in native speakers can take place at different linguistic representations ranging from phonology to syntax (e.g., DeLong et al., 2005; Lau et al., 2006). For example, Altmann and Kamide (1999) reported that English listeners readily used semantic and pragmatic information extracted from the verb in a clause (The boy will eat/move the cake) to anticipate what happened next in the input by predictively restricting their attention to the plausible referents displayed in the visual context.

The evidence for prediction in non-native speakers is mixed (Dussias et al., 2013; Hopp, 2015). Despite evidence that non-native speakers can use semantic information for predictive processing (Foucart et al., 2014; Köhne Crocker 2010), evidence for L2 prediction in morphosyntax seems to be sporadic (e.g., Grüter et al., 2012; Lew-Williams & Fernald, 2010). Grüter et al. (2017) argued that non-native speakers, compared to native speakers, may have reduced capacity in generating prediction even though their ability to engage in integrating information to evolving representations may not differ from native speakers. Kaan (2014) instead claimed that the mechanisms involved for predictive processing are not fundamentally different between L1 and L2 speakers. According to Kaan (2014), factors that account for potential differences in predictive processing between L1 and L2 speakers also explain differences in anticipatory processing among native speakers. Those factors include verb frequency, competing information, quality of lexical representations and so forth.

Among others, the predictability of a linguistic context is a critical factor influencing incremental and predictive processing (Levy, 2008). For example, given the context, *He went to the library to borrow a_*, *book* would be a more likely candidate than *table* if we were asked to complete the sentence because *book* is more predictable than *table* in this context. In the psycholinguistic literature, it has been found that more predictable words tend to induce shorter reading times (RTs) than less predictable ones during processing (Smith & Levy, 2013). In this case, the expectations for a particular word are generated based on the likelihood of how that word among others semantically fits the given context.

Besides semantic expectations at the word level, expectations also extend to more abstract levels of linguistic representations such as syntax. For instance, when English speakers read a sentence like *the old man remembered (that) the famous singer had been-*, if not followed by an overt complementizer *that*, they would be garden pathed upon encountering *remember* because it could take either a sentence (S) or a noun phrase (NP) as the complement. Misanalysis can be recovered by disambiguating information available from the language input. If the complementizer *that* were present, such a misanalysis would not arise because the parser expects a sentence complement to appear downstream. Therefore, the fact that the presence of this complementizer facilitates processing can be interpreted as comprehenders being engaged in making syntactic expectation during sentence processing. In other words, the size of garden path effects can be argued to depend on the predictability of syntactic structures (Kuperberg & Jaeger, 2016). Most previous L2 studies regarding the effects of predictability primarily considered how semantic predictability at the word level affects prediction during incremental processing. (e.g., Foucart et al., 2014). In the current study, we extend the investigation of both the effects

of semantic and syntactic predictability on sentence processing to non-native speakers. Specifically, following Slevc et al., (2009), we manipulated two different types of contextual predictability: semantic predictability (predicted semantics vs. unpredicted semantics) and syntactic predictability (predicted syntax vs. unpredicted syntax). To this end, we examine the relationship between linguistic predictability and reading times during L2 sentence processing. If participants are sensitive to the predictability information relevant to semantics and syntax, their processing of sentences containing such information should be facilitated.

Methods

Participants. Two groups of participants were recruited. Fifty-one English speakers (38 female and 13 male; mean age = 20.3 years, *SD* =2.63) and 63 Chinese-speaking learners of English (52 female and 11 male; mean age = 20.2 years, *SD* =2.5) participated in this study. The LexTALE test was implemented among L2 learners to assess their vocabulary knowledge as a proxy for their overall proficiency in English (Lemhöfer & Broersma, 2012). The test was administered as an untimed lexical decision task where participants were asked to decide whether each item was a true English word or not. Language proficiency will be treated as a continuous variable rather than a categorical variable with the purpose of maximally keeping statistical power (Cohen, 1983) and minimizing rates of Type I error (Preacher, Rucker, MacCallum & Nicewander, 2005).

Stimuli. Adapted from Brothers and Kuperberg (2020) and Slevc et al. (2009), twelve pairs of sentences were constructed of syntactic predictability, and another 12 pairs of semantic predictability. In the syntactic predictability condition, syntactic interpretation was either predictable or not depending on whether there is an overt complementizer *that* following the verb. For example, in sentences such as *the man who wore the red hat remembered (that) the recipe* ***would*** *require using white sugar*, when *that* occurs after the main verb *remember*, the modal verb *would* which serves as the critical region was syntactically expected; otherwise, local ambiguity between an NP and an S complement arises as the verbs examined in the current study could either take an NP or an S as their complements . Therefore, *would* in the case of 'remembered that . . . ' should incur a longer reading time than in the case of 'remembered . . . '. Even though all verbs used for this condition can subcategorize for either NP or S, they are statistically biased toward NPs based on the results from Sturt et al. (1999) where garden path effects occurred in clauses involving such verbs. Moreover, those verbs are of high frequency (mean lemma frequency being 165 per million words determined by the SUBTLEX corpus from the English Lexicon Project (Balota et al., 2007)), and thus should be familiar to participants. In the semantic predictability condition, semantic interpretation was either predictable or not given the probability that the critical word can be predicted from the preceding context. For instance, *neck* relative to *tail* was highly predictable in the *boy noticed the giraffe with the long neck/tail at the zoo yesterday*. In this case, *neck* as the critical region should take a shorter reading time than *tail*. For the semantic predictability condition, we adapted the experimental sentences from Brothers and Kuperberg (2020) and Slevc et al. (2009) where the predictable words were much more likely than those unpredictable ones in a given context.

Design & Procedure. The experiment comprises two types of predictability, namely syntactic and semantic predictability. The type of predictability is a between-item factor. As such, items of both conditions were created and analyzed separately even though they appeared in the same experiment as a whole. Sentences from each factor has two possibilities, being either a predictable one or unpredictable one. Accordingly, there were four conditions out of which 48 experimental items were constructed. These items were evenly distributed into four counterbalanced lists using a Latin Square design such that an individual participant saw a given item from each condition only once. In addition to the experimental items, another 65 distractor sentences of unrelated structures were created. Therefore, each subject saw a totality of 77 test sentences. To avoid cross-task priming effects, the self-paced reading (SPR) task was administered prior to the acceptability judgement task (AJT)[1] as they shared the sentence stimuli. Sentences were presented on a segment-by-segment basis. Each trial started with a fixation cross signaling the position of the first segment, and participants self-controlled the presentation of each segment by pressing the spacebar. After the SPR task, participants were asked to rate the acceptability of the sentences that were tested in the SPR task along a 7-point Likert Scale (1-completely unacceptable; 7-completely acceptable) in the AJT. Each experimental session began with five practice trials to familiarize participants with the tasks.

Analysis. Responses to AJT and SPR were analyzed separately. We conducted analyses of the ratings and reading times on sentences with different types of linguistic predictability to examine how native and non-native speakers understand and process those sentences. To this end, we implemented a set of linear mixed effects regressions modelling the variation of the judgements and reading times to relevant critical regions depending on different fixed effects including syntactic predictability, semantic predictability and language proficiency. Maximal random effects structure were justified by the experimental design - by-participant random slopes for semantic and syntactic predictability and a by-item random slope for language proficiency (Barr et al., 2013), and were simplified wherever necessary. All categorical factors were

[1] A reviewer asks why we conducted an additional off-line acceptability judgement task besides the self-paced reading task. This is to substantiate how participants understand the sentences under no time pressure that will be used in the self-reading task.

sum coded and continuous factors were centered and standardized prior to their respective analysis. In the following section, we reported results of ratings and reading times by sequence.

Results

Ratings. To reduce skewness and mitigate potential scale bias, we converted raw ratings from all items into z-scores by participant (Spinner & Gass, 2019). Figure 1 shows the mean ratings of experimental stimuli by condition in native speakers. We observed main effects of semantic and syntactic predictability such that both semantically and syntactically predictable sentences were more acceptable than their unpredictable counterparts among native speakers (β=-1.13, SE=0.33, $p<.01$; β=-0.62, SE=0.22, $p<.01$).

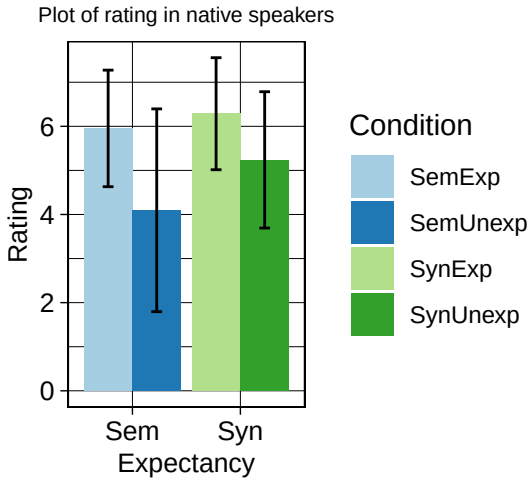


Figure 1: Results of the acceptability judgement task with native speakers. Error bars indicate standard error of the mean.

Figure 2 illustrates the mean ratings of experimental stimuli by non-native speakers. The results revealed a main effect of semantic predictability regardless of language proficiency (β =-0.62, SE=0.28, $p<.05$) such that semantically predicted sentences were more acceptable than unpredicted ones. We obtained a marginal main effect of syntactic predictability (β =-0.55, SE=0.28, $p=.0506$) such that syntactically predictable sentences were slightly more acceptable than their unpredictable counterparts for non-native speakers. No interaction between syntactic predictability and L2 proficiency was obtained in any case.

Response times. Prior to statistical analysis, participants with accuracy on comprehension questions lower than 80% were excluded, resulting in an removal of 7 English speakers and 7 Chinese speakers. The RTs beyond 2.5 standard deviations of the mean for individual participants were further dropped. This affected 2% and 2.4% of all trials for English and Chinese speakers respectively. To reduce skewness, the

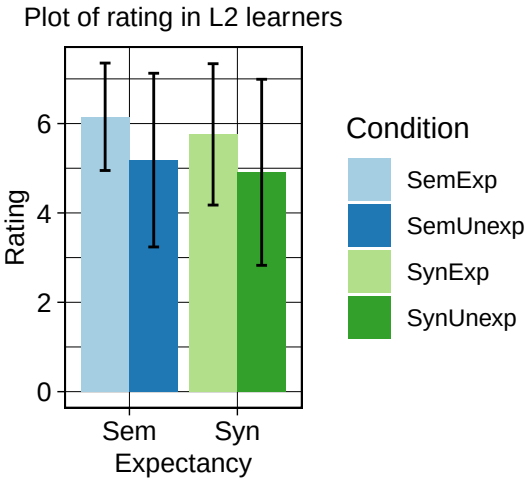


Figure 2: Results of the acceptability judgement task with L2 learners. Error bars indicate standard error of the mean.

remaining data were submitted to log transformation. Residualization was then applied to the log-transformed data with the aim of adjusting the variability of region length and individual processing speed. Figure 3 illustrates the distribution of mean RTs by condition in native speakers. We found a main effect of semantic predictability such that the critical region was read faster in the semantically predictable context than in the semantically unpredictable context (β=0.09, SE=0.04, $p<.05$). The main effect of syntactic predictability was marginally significant (β=0.06, SE=0.04, $p=0.0926$. These results suggested that sentence comprehension was largely facilitated by contextual predictability at semantic and syntactic levels among native speakers.

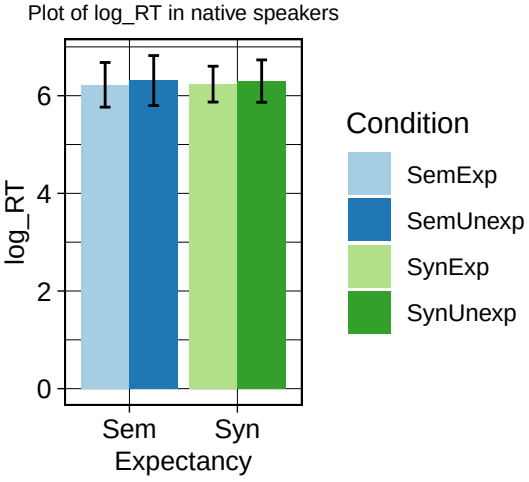


Figure 3: Mean reading times of the critical region by condition in native speakers. Error bars indicate standard error of the mean.

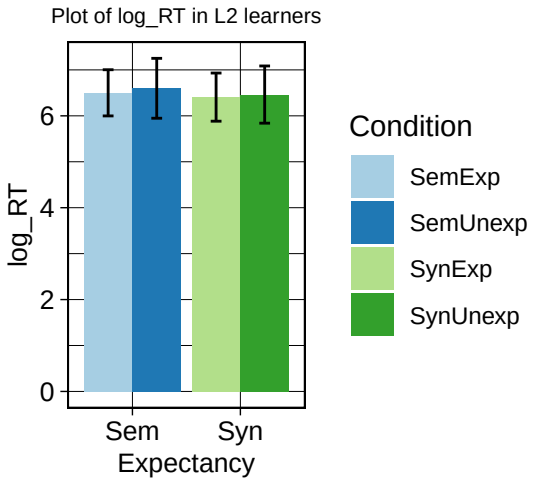


Figure 4: Mean reading times of the critical region by condition in non-native speakers. Error bars indicate standard error of the mean.

Figure 4 demonstrates the distribution of the mean log RTs by condition across language proficiency in non-native speakers. The main effect of semantic predictability suggests the critical region was read faster in the semantically predictable context than in the semantically unpredictable context (β=0.11, SE=0.05, $p<.05$). No interaction between semantic predictability and language proficiency was detected.

For the syntactic predictability condition among non-native speakers, there were no main effects of syntactic predictability (β=0.4, SE=0.28, p=0.15) and language proficiency (β=0.002, SE=0.003, p=0.46) for reading times of the critical region. There was no interaction between the two factors (β=-0.005, SE=0.004, p=0.21).

General discussion

The results show that, different from native speakers whose incremental and predictive processing were driven by semantic and syntactic predictability, non-native speakers seemed to be less sensitive to syntactic predictability during sentence processing even though they showed more or less differential acceptability of syntactically predictable and syntactically unpredictable sentences. The effects of semantic predictability were robust in non-native speakers. Results of non-native speakers contrast with some previously reported studies such as Ito et al.(2017) where they did not obtain N400 components indexing semantic pre-activation in non-native speakers, but were consistent with Foucart et al. (2014) and Köhne and Crocker (2010) where word prediction was found to be semantically guided by highly constraining contexts.

As for the effects of semantic predictability in both groups of participants, we do not necessarily attribute them to evidence demonstrating prediction unless pre-activation of semantic aspects of upcoming words was explicitly detected over the time-course of processing. In fact, it remains an open question as to whether predictability effects arise from pre-activation of upcoming materials, or from information integration that is facilitated by contextual predictability (Smith Levy, 2013). The manifestation of semantic predictability effects during sentence processing at least reflects a fact that readers try to combine top-down information from the sentence context and bottom-up information from words encountered from the language input to constrain sentence comprehension in an incremental manner.

The same account holds for the effects of syntactic predictability on native speakers. The effects of syntactic predictability being relatively less robust in non-native speakers than in native speakers may be due to various reasons. One reason is that non-native speakers did not efficiently activate and use information encoded in complementizers predictively signaling syntactic structures and may have failed to integrate cues from complementizer and main verbs to arrive at a correct interpretation. This may be due to the fact that Chinese lacks complementizer, and thus this cue was not strong enough for learners to be used predictively. The other possible reason is that resources allocated for processes responsible for information integration have been taken up with little left for generating prediction (Grüter et al., 2017). Hence, non-native speakers relative to native speakers are less likely to be engaged in making prediction driven by the constraining contexts that would otherwise trigger prediction for comprehenders. It is also possible that the range of proficiency in our L2 participants is not wide enough for us to detect the strong effects of syntactic predictability. It remains to be seen whether non-native speakers would be sensitive to the manipulation of syntactic predictability especially when they are of near-nativelike proficiency in English.

Conclusion

Taken together, we have presented experimental evidence that native and non-native speakers use top-down information particularly from semantic predictability at the word level and bottom-up information available in the language input for sentence processing. The effects of syntactic predictability on non-native speakers appear to be less robust than those on native speakers. Various reasons have been proposed to account for this discrepancy. These findings suggest that linguistic predictability of different types may exert influences in different ways among non-native speakers, presumably due to the fact that semantic and syntactic predictability are operated differently at the linguistic level thus leading to varying processing consequences. The extent to which adults are sensitive to word predictability has been found to highly correlate with their abilities in implicit learning (Conway, Bauernschmidt, Huang & Pisoni, 2010). Further research is therefore desired to examine the influences of linguistic predictability of various kinds on statistical learning in both native and non-native speakers. It is well accepted that context-independent word frequency and word predictability interactively influence reading times among natives (see Staub, 2015 for a

review). The investigation of the relationship between contextual predictability and frequency effects extending to non-native speakers will be also necessary.

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