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Investigating the time-course of phonological prediction in native and non-native speakers of English: A visual world eye-tracking study

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ABSTRACT

We report a study using the "visual-world" paradigm that investigated (1) the time-course of phonological prediction in English by native (L1) and non-native (L2) speakers whose native language was Japanese, and (2) whether the Japanese participants predicted phonological form in Japanese. Participants heard sentences which contained a highly predictable word (e.g., *cloud*, following *The tourists expected rain when the sun went behind the* ...), and viewed an array of objects containing a *target* object which corresponded to the predictable word [*cloud*; Japanese: *kumo*], an *English competitor* object whose English name was phonologically related to the predictable word [*clown*; *piero*], a *Japanese competitor* object whose Japanese name was phonologically related to the Japanese translation of the predictable word [*bear*; *kuma*], or an object that was *unrelated* to the predictable word [*globe*; *tikyuugi*]. Both L1 and L2 speakers looked predictively at the target object, but L2 speakers were slower than L1 speakers. L1 speakers looked predictively at the English competitor object, but L2 speakers did not do so predictively. Neither group looked at the Japanese competitor object more than the unrelated object. Thus, people can predict phonological information in their native language but may not do so in non-native languages.

Introduction

People predict aspects of upcoming words during language comprehension, including meaning or syntax (Altmann & Kamide, 1999; Staub & Clifton, 2006). Other studies suggest they predict phonological or orthographic word forms (DeLong, Urbach, & Kutas, 2005; Laszlo & Federmeier, 2009), but much less is known about when these predictions occur or the extent to which they depend on the availability of cognitive resources (Huettig, 2015). In this paper, we investigate the nature of phonological form prediction by tracking the eye movements of native (L1) and non-native (L2) speakers as they listen to English sentences and see pictures whose names are phonologically related to highly predictable words.

In this "visual world" paradigm, fixations to objects are driven by lexical activation (Tanenhaus, Magnuson, Dahan, & Chambers, 2000). We can therefore investigate when phonological information relevant to highly-predictable words becomes available. L2 language comprehension involves more resources than L1 language comprehension (Clahsen & Felser, 2006), and so we use a comparison of L1 and L2 comprehension to investigate whether phonological prediction is resource-intensive. Moreover, L2 comprehension is of course difficult in general, and one reason may be that L1 is not fully suppressed (e.g., Thierry & Wu, 2007). For this reason, we also tested whether L2 speakers predictively activate phonological information in their L1 by presenting them with objects whose L1 names were related to the L1 translation of the predictable word.

Prediction of phonological information in L1

Studies of word-form prediction have tended to conflate phonology with orthography, because of the close relation between the two in Western languages. For ease of exposition, we refer throughout the present paper to phonology (on the basis that the materials in our experiments are presented auditorily) but we would not be able to fully exclude an account of our evidence rooted in orthography.

Evidence about the prediction of phonological form comes exclusively from event-related potential (ERP) experiments in which participants read highly constraining sentences – that is,

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sentences with a context that is very likely to be followed by a particular predictable word. There are two types of study. In the first, the predictable word is replaced by a word or nonword with a similar form to the predictable word. This stimulus elicits a smaller N400 than a word or nonword that is dissimilar to the predictable word (Ito, Corley, Pickering, Martin, & Nieuwland, 2016; Kim & Lai, 2012; Laszlo & Federmeier, 2009). In a representative study, participants read contexts such as "*The student is going to the library to borrow a*...", followed by the predictable word (*book*), an unpredictable word whose form was related to the predictable word (*hook*), or an unpredictable word whose form was unrelated to the predictable word (*sofa*). The unpredictable words *hook* and *sofa* both showed larger N400s compared to the predictable word *book*, but the N400 was reduced for the form-related word *hook* compared to the unrelated word *sofa* (Ito, Corley et al., 2016). These findings suggest that readers pre-activate the forms of predictable words. However, it is also possible that readers activated the form of the predictable word (*book*) after they encountered the form-related word (*hook*). For instance, readers might have encountered *hook* and combined it with the predictable sentence context to activate *book*.

The second type of study investigates whether form is predicted before the target stimulus is encountered. DeLong et al. (2005) found that people can predict phonological aspects of highly predictable words during reading comprehension. In their study, participants read sentence contexts that predicted a specific noun (e.g., *kite* in "*The day was breezy so the boy went outside to fly*..."). These contexts were followed by the expected noun phrase (*a kite*) or an unexpected but plausible noun phrase (*an airplane*). Unexpected nouns (*airplane*) elicited larger N400 amplitudes than expected nouns (*kite*). This N400 for expected versus unexpected nouns could indicate that participants predicted the expected noun, but could also indicate that expected nouns were easier than unexpected nouns to integrate into the context. Importantly, the authors also found a correlation between the N400 amplitudes for the preceding articles (*a*/*an*) and the cloze probabilities of these articles. The authors argued that this graded N400 for articles could not be explained by integration, and indicated that people probabilistically pre-activate an element of the phonological form of predictable words (whether it began with a vowel or a consonant).

But the reliability of this effect is under dispute. One study used the same *a*/*an* manipulation and found a larger N400 for unexpected articles compared to expected articles (Martin et al., 2013; we discuss this study in the following section *Prediction of phonological information in L2*). However, this effect of condition (expected vs. unexpected articles) was not found in DeLong et al. (2005), and Martin et al. (2013) did not report the article correlation that DeLong et al. reported. Thus, the findings from the two studies are not fully consistent. Furthermore, using materials adapted from Martin et al., another study failed to replicate Martin et al.'s effect of condition and also did not find any graded effect of article cloze probability on article N400 (Ito, Martin, & Nieuwland, 2016a). It is possible that comprehenders are not always confident that the noun (e.g., *kite*) will be the next word (e.g., the sentence could continue *an impressive kite*). But for whatever reason, it appears that N400 effects on the article do not consistently occur. It is therefore particularly important to investigate phonological prediction using another paradigm.

Even assuming prediction, a limitation of these studies is that they cannot straightforwardly reveal when the predictions occurred, because the test point occurs at, or one word before, the predictable word. So they are compatible with two accounts. On one account, comprehenders predict as soon as they are confident that the word will occur at some point downstream. In other words, they predict word form as a consequence of predicting other aspects of a word (e.g., semantics). In Ito, Corley et al. (2016), comprehenders who encountered *The student is going to the library to borrow a*..." may have predicted the form *book* after encountering *library* (or even *student*); in DeLong et al. (2005), they may have predicted *kite* after encountering *breezy day*. On the other account, they predict form immediately before the upcoming word, presumably in order to make comprehension of that word as straightforward as possible. In Ito, Corley et al., they may have predicted *book* after encountering the form-related word *hook*. In DeLong et al., they may have predicted *kite* after encountering the immediately preceding article *a*.

In a visual world experiment, eye movements are continuously recorded as participants listen to a sentence. If the scene contains an object whose name is related in form to the predictable word (e.g., a hook in Ito, Corley et al., 2016), then participants who preferentially look at that object must have predicted the form of the predictable word (because the form-related word is not related to the predictable word or to the context in any other way). These prediction-driven fixations may therefore occur much earlier than the predictable word. Thus, we expected that our study would provide more information about the time-course of prediction than previous ERP studies.

Our experimental logic is based on one used by Rommers, Meyer, Praamstra, and Huettig (2013) who investigated the prediction of physical aspects (shape) of the referents of upcoming words. Their participants heard highly constraining sentences (e.g., "*In 1969 Neil Armstrong was the first man to set foot on the moon*") while viewing a scene containing a picture representing the predictable target object (the moon), an object of a similar shape to the target object (a tomato), or an unrelated object (rice). The scenes also contained three unrelated distractor objects. If participants pre-activated the shape of the target word, they would be expected to fixate the similar-shaped object, as a result of their shape-related similarity (competitor effect). Participants fixated the similar-shaped object more than the unrelated objects before the target word could be processed (assuming a 200 ms delay to initiate eye movements; Saslow, 1967). Thus, these findings support pre-activation of shape information.

The present study was closely modelled on the design used by Rommers et al. (2013). To investigate pre-activation of phonological information, we used phonologically related, rather than shape-related, competitors. We did not present a predictable target object when its competitor object was present. The primary advantage of this design is that it should prevent looks to the competitor object being swamped by looks to the target object. In other words, the absence of the predictable object should give participants more opportunity to fixate on the competitor object.

Prediction of phonological information in L2

The resources available to L2 speakers are more limited than the resources available to L1 speakers. Compared to L1 speakers, L2 speakers may be slower to access lexical information or have weaker semantic networks (e.g., Ivanova & Costa, 2008). They may also be less good at using syntactic information (Clahsen & Felser, 2006), or may comprehend less automatically (Segalowitz & Hulstijn, 2009). Thus, we expected that L2 speakers would predict to a lesser extent than L1 speakers.

There is evidence that L2 speakers can predict some features of upcoming words, including semantic (Chambers & Cooke, 2009; Ito, Corley, & Pickering, 2017) or syntactic information (Foucart, Martin, Moreno, & Costa, 2014; Foucart, Ruiz-Tada, & Costa, 2016). However, it is less clear whether L2 speakers predict phonological information. As we have noted, Martin et al. (2013) used DeLong et al.'s (2005) paradigm, and found that L1 speakers showed a larger N400 for pre-nominal articles that were incompatible with