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Structural prediction in aphasia: Evidence from *either*

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ABSTRACT

Young neurotypical adults engage in prediction during language comprehension (e.g., Altmann & Kamide, 1999; Staub & Clifton, 2006; Yoshida, Dickey & Sturt, 2013). The role of prediction in aphasic comprehension is less clear. Some evidence suggests that lexical prediction may be spared in aphasia (Dickey, Warren, Hayes, & Milburn, 2014; Love & Webb, 1977; cf. Mack, Ji, & Thompson, 2013), and there is even indication that structural prediction may be spared in some people with aphasia (PWA; e.g. Hanne, Burchert, De Bleser, & Vashishth, 2015). The current self-paced reading experiment manipulated the presence of *either* to examine structural prediction among PWA and a set of similar-aged neurotypical control participants. Consistent with intact structural prediction for both groups of participants, when *either* preceded a disjunction, reading times were faster on the *or* and second disjunct (cf. Staub & Clifton, 2006). For neurotypical controls, this effect of the presence vs. absence of *either* shrank reliably as more experimental items were encountered, whereas for PWA there was a non-significant trend for it to grow as more experimental items were encountered. These findings indicate that PWA and older neurotypical individuals can use a lexical cue to predict the structural form of upcoming material during comprehension, but that on-line adaptation to patterns in the local context may be different for the two groups.

Although the contribution of prediction to language comprehension in neurotypical populations was once debated (e.g. Hess, Foss, & Carroll, 1995), the past fifteen years have seen growing evidence that prediction is vital to comprehension (e.g. Federmeier, 2007; Kuperberg & Jaeger, 2015; Pickering & Garrod, 2013). Reading studies show that highly predictable words are fixated for shorter amounts of time and are more likely to be skipped than less predictable words (e.g. Rayner, Ashby, Pollatsek, & Reichle, 2004). Event Related Potential (ERP) studies show that comprehenders predict semantic features and the phonological form of upcoming words (e.g., DeLong, Urbach, & Kutas, 2005; Laszlo & Federmeier, 2009; Wlotko & Federmeier, 2007). Visual world studies have shown that comprehenders anticipate probable upcoming referents based on verb information, world knowledge, shared context, case marking, etc. (e.g. Altmann & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003).

This literature indicates that comprehenders routinely engage in lexical or referential prediction. But there is also evidence that neurotypical comprehenders make predictions about the form of upcoming sentence structure. The fact that syntactic surprisal is a good predictor of reading times (Hale, 2003; Levy, 2008) suggests that comprehenders keep track of which syntactic forms are most likely to appear next in a sentence. Research shows that comprehenders predict upcoming structure in sentences with parasitic gaps, ellipsis, and sluicing (Lau, Stroud, Plesch, & Phillips, 2006; Phillips, 2006; Yoshida, Dickey, &

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Sturt, 2013). Some of the most direct evidence of structural prediction comes from work investigating the processing consequences of the word *either*. Upon encountering the word *either*, comprehenders know that a disjunction is likely to follow. Staub and Clifton (2006) looked for processing consequences of this by comparing reading times for sentences with disjunctions that were or were not preceded by the word *either*. When *either* was present, reading times on the second disjunct were faster than when it was not. Reading times were also faster when the structure of the second disjunct matched the structure of the first disjunct (see Warren & Dickey, 2011 for production evidence of this expectation for parallelism). These findings suggest that neurotypical comprehenders use the presence of *either* to predict an upcoming disjunction and use the structure of the first disjunct to predict the structure of the second.

There is considerably less evidence regarding the role of prediction in aphasic comprehension. It has long been known that strongly predictive sentence contexts can facilitate lexical retrieval and production in aphasia (Love & Webb, 1977). Recent work shows that people with aphasia (PWA) read words more quickly in contexts that make them highly predictable (Dickey, Warren, Hayes & Milburn, 2014). This suggests that in strongly supportive contexts at least, predictive mechanisms may be maintained. However, in a 2013 paper testing verb-argument prediction in aphasia, Mack, Ji, and Thompson's participants with aphasia showed only limited (if any) prediction. Mack et al. measured the eye movements of PWA as they simultaneously heard a sentence and looked at a set of images. In the restrictive condition, the sentence's verb limited the set of possible direct objects to only one of the images, but in the unrestrictive condition, the verb could accept any of the images as its direct object. For example, participants might have heard “Sam will open the jar” or “Sam will break the jar” while looking at images of a jar, a pencil, a plate, and a stick. All of these objects are breakable, but only one of them is openable (the target object). In a similar experiment, Altmann and Kamide (1999) found that neurotypical college students began to gaze at the target in the restrictive but not the unrestrictive condition starting at the end of the verb or during the determiner *the*, even before the target was encountered in the speech stream. In Mack et al.'s study however, neither the participants with aphasia nor their age-matched controls (who were older than Altmann and Kamide's participants) showed anticipatory looks to the target before hearing it named. Nonetheless, both groups did look more to the target towards the end of the trial in the restrictive condition.

These findings provide no evidence of prediction, but they do suggest that integration of the target may have been facilitated by the verb's restrictions. However, the window for observing prediction in this study was very short: there was less than 150 ms between the offset of the verb and the onset of the target noun. To allow more time for predictive processing to develop and be observed, in a second study Mack and colleagues truncated the sentences before the last noun, so the target was never encountered in the speech stream. With this modification, the control participants showed increased looks to the target in the restrictive condition quickly after the verb, and the participants with aphasia showed the same pattern considerably downstream from the verb. These results suggest that verb-argument prediction is slowed or impaired by aphasia. These findings, in combination with those from Love and Webb (1977) and Dickey et al. (2014), could be interpreted to suggest that: (1) PWA only make strongly supported predictions, and (2) those predictions may be slowed.

The research discussed above focuses on lexical and referential prediction in aphasia, rather than purely structural prediction. Given that aphasia often involves syntactic impairment (e.g. Goodglass, 1993) and syntactic computation may be important for structural prediction, one might expect PWA not to engage in structural prediction, at least not PWA with marked syntactic impairments (Goodglass, 1976; Kean, 1977; Menn & Obler, 1990). However, Hanne, Burchert, De Bleser, and Vashishth (2015) suggest that PWA might make structural predictions under certain conditions. Hanne et al. tracked the eyes of PWA ($N = 8$) with sentence-comprehension deficits while they listened to reversible subject-verb-object (SVO) and object-verb-subject (OVS) sentences in German, in a sentence-picture matching task. Hanne et al. manipulated case and number marking to disambiguate the sentences' structure. Gazes to an OVS or SVO picture during the unfolding of a sentence were assumed to indicate prediction of the structure congruent with that picture. According to this measure, the PWA's structural prediction was impaired compared to controls, but they did successfully predict upcoming structure when morphosyntactic cues were strong and unambiguous. Hanne, Burchert, and Vasishth (2015) used the same paradigm to test PWA's processing of subject- and object-extracted wh-questions, and found similar evidence of slowed but extant prediction based on strong morphosyntactic cues. These findings are consistent with the picture emerging from aphasic lexical prediction above, according to which PWA only make strongly supported predictions.

These results are interesting and suggestive, but not conclusive. One issue is whether an increase in gazes to one of two pictures during the sentence necessarily reflects syntactic prediction or could possibly reflect some other comprehension process. For example, it is possible that participants assigned a structure only to the words they had already heard (e.g., assigning an agent role to the first NP after hearing an NP-V sequence) and then gazed at whichever picture was consistent with that assignment, without making any predictive commitments regarding upcoming material. Detailed evidence presented by Hanne, Burchert, and Vasishth (2015) regarding gazes at the different event participants in the images make this interpretation of their results less likely. However, converging evidence from other tasks would be helpful in strengthening the case that PWA engage in structural prediction.

A second possible issue is that the presence of visual representations of two potential interpretations for the sentences in these experiments could have supported the participants' language processing and thus boosted their prediction. The pictures provided participants with the set of referents and relations that were relevant to understanding, and could have facilitated processing. Converging evidence, from tasks and structures that provide fewer external supports to comprehension and fewer external constraints on the structures and interpretations that participants may assign during comprehension, would again be useful in establishing whether PWA predict upcoming structure.