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How struggling adult readers use contextual information when comprehending speech: Evidence from event-related potentials

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ABSTRACT

We investigated how struggling adult readers make use of sentence context to facilitate word processing when comprehending spoken language, conditions under which print decoding is not a barrier to comprehension. Stimuli were strongly and weakly constraining sentences (as measured by cloze probability), which ended with the most expected word based on those constraints or an unexpected but plausible word. Community-dwelling adults with varying literacy skills listened to continuous speech while their EEG was recorded. Participants, regardless of literacy level, showed N400 effects yoked to the cloze probability of the targets, with larger N400 amplitudes for less expected than more expected words. However, literacy-related differences emerged in an earlier time window of 170–300 ms: higher literacy adults produced a reduced negativity for strongly predictable targets over anterior channels, similar to previously reported effects on the Phonological Mapping Negativity (PMN), whereas low-literacy adults did not. Collectively, these findings suggest that in auditory sentence processing literacy may not notably affect the incremental activation of semantic features, but that comprehenders with underdeveloped literacy skills may be less likely to engage predictive processing. Thus, basic mechanisms of comprehension may be recruited differently as a function of literacy development—even in spoken language.

1. Introduction

Language comprehension is multifaceted. Decoding skills are required to rapidly translate acoustic signals into linguistic units during listening or to extract visual word information from print during reading. Regardless of modality, comprehension involves the ongoing construction of a message-level representation of semantics and situations, which, in turn, can be used to resolve ambiguity and make predictions about the language stream as it unfolds. While decoding skill is well understood as a contributor to reading difficulties, less is known about the role of "higher level" comprehension abilities, such as making sense of word sequences. One of the most well-studied higher level comprehension skills is the use of context to facilitate word processing. Less-skilled decoders have been shown to use contextual information to assist word reading in some circumstances (e.g., Stanovich, 1980). However, if poor decoders are also poor language comprehenders (e.g., Landi, 2010), this pathway—bootstrapping from the larger context to enable word recognition on the fly—may be less available. We have recently shown deficits among less-skilled readers in using contextual information during reading (Ng et al., 2017). The present investigation focused on understanding the extent to which similar problems also arise in spoken language comprehension—conditions under which deficits in print decoding are not a barrier to comprehension.

In fact, reading and listening comprehension often show moderate to high correlations in studies of both children and adults, suggesting that the ability to achieve a message-level interpretation from linguistic units may be a common thread across modality (e.g., Palmer et al., 1985). In Smiley et al. (1977), for example, seventh graders read and listened to stories and then recalled their gist. The skilled readers were able to distinguish the importance of different idea units better than the less skilled readers, and this difference did not interact with the modality of story presentation. In a sample of adult literacy learners, Mellard et al. (2010) observed a moderate correlation between reading and listening comprehension, although listening comprehension lagged behind other factors, such as vocabulary knowledge, reading fluency, and word reading ability, in predicting reading comprehension.

Given that domain-general language understanding is ultimately the sum of many processes, online studies that can reveal how processing unfolds moment by moment are especially valuable in identifying the process that may contribute to fluency and success in understanding

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language. For example, in the visual world paradigm, eye movements are monitored while participants prepare to select a target object based on a spoken sentence. Mishra et al. (2012) used this paradigm to investigate the impact of literacy differences on the ability to use context information to predict likely upcoming words. High- and low-literacy adult speakers of Hindi in India listened to sentences with a prenominal adjective that matched in grammatical gender with the name of one of the objects displayed. High-literacy adults moved their eyes to the target object before the noun was heard; low-literacy participants, however, did not fixate on the target object until the noun was presented, suggesting that they were not making use of the gender cues to predict likely upcoming nouns. Similarly, in Huettig and Brouwer (2015), dyslexic adults showed a delayed use of gender information to anticipate target objects, compared to adults with typical reading abilities. Such findings suggest that adults without intact reading skills, regardless of etiology, may not be able to take full advantage of the morphosyntactic features in language—even when spoken—to prepare to process upcoming words.

Measurements of brain electrical activity, in the form of event-related potentials (ERPs), provide an especially sensitive means of tracking language comprehension over time. ERPs are the electrophysiological response of the brain time-locked to the onset of an event, typically a word in language studies. The excellent temporal resolution afforded by ERPs allows a fine-grained examination of multiple neurocognitive processes in language comprehension as they occur. Most importantly, ERPs have been used to study visual and auditory language processing for several decades, thereby producing a set of functionally well-specified indices of language subprocesses that can be used to make specific inferences about the nature and success of the processes unfolding during comprehension.

One of the most well-studied ERP components is the N400, a negative-going voltage deflection that peaks approximately 400 ms after stimulus onset. The N400 indexes the ease of accessing semantic information linked to a stimulus (Kutas and Federmeier, 2011). Thus, less expected words in a context produce larger N400s than more expected words, because the semantic features of an expected word have already become activated in the course of processing the prior context. This contextual congruency effect has been observed in both visual and auditory modalities (e.g., Kutas et al., 1987), indicating that these mechanisms are similarly engaged in reading and listening.

Studies using ERPs, primarily with samples of college-aged readers with well-developed literacy skills, have shown that at least some of this context-based facilitation can arise through predictive processing mechanisms (e.g., Kutas and Federmeier, 2011). This prediction-based N400 effect is most clearly observed in response to unexpected target words that share semantic, phonological, or orthographic features with a predicted word. Words with similar features as the predicted words elicit a smaller N400 than those with dissimilar features, even in cases wherein both types of words are semantically incongruent with the context. This suggests that prediction afforded by context activates relevant semantic and linguistic features of upcoming words, thereby facilitating the processing of words that share those features (Federmeier and Kutas, 1999; Laszlo and Federmeier, 2009). Among literate college-aged adults, this context-based pre-activation of semantic features on the N400 has been observed in both reading and listening and, thus, is modality-independent (Federmeier and Kutas, 1999; Federmeier et al., 2002). Prediction has also been linked to other ERP effects observed when predictable or unpredictable words are encountered, such as modulations of sensory components to predictable words and a post-N400 frontal positivity to unpredictable words (e.g., Federmeier et al., 2007), as well as effects observed in advance of a predictable target, based on gender match/mismatch at articles or adjectives preceding an expected target noun (Van Berkum et al., 2005; Wicha et al., 2003).

An ERP component that has provided evidence for predictive processing in listening is the Phonological Mismatch Negativity, also called the Phonological Mapping Negativity (PMN; Connolly and Phillips, 1994; Connolly et al., 1992). Linguistic or not, sounds whose features mismatch versus match the immediately preceding auditory context have been associated with a relatively early, frontally distributed effect known as the Mismatch Negativity (see review by Naatanen, 1995; Naatanen et al., 2007). Specifically in the context of speech, when auditory language context engenders an expectation for a particular word, a target whose initial sounds do not match those of the expected word elicit more negative-going ERPs than inputs that match with this expectation in their initial phonemes (McCallum et al., 1984). This PMN tends to occur between 150 and 300 ms post-stimulus onset with a broad, fronto-central scalp distribution, and has been argued to reflect prediction of the (sub)phonemic features of an incoming word (Archibald and Joanisse, 2011; Newman and Connolly, 2009; Newman et al., 2003). It is often taken to reflect phonological processing, although overlap in timing and distribution with the N400 component can make the separation and identification of these two components difficult, so, historically, some have argued that this could be an earlier onset of the N400, or the reflection of an early lexical selection process. However, results from more recent research lend support to the notion that the PMN and N400 represent different aspects of language processing, the former of which is specific to phonological processing. Importantly, regardless of the precise underlying process(es) that engender this effect, it clearly reflects expectations for likely upcoming words (Connolly and Phillips, 1994; Connolly et al., 1992; D'Arcy et al., 2004; Hagoort and Brown, 2000; van den Brink et al., 2001; van den Brink and Hagoort, 2004; Van Petten et al., 1999).

The focus of the current investigation was to use these ERP indices of context use and prediction to assess variability in semantic access and predictive processing as a function of literacy skill. Adapting the stimuli from Federmeier et al. (2007), we recently examined this issue in the print modality (Ng et al., 2017). Community-dwelling adults read sentences that provided strong or weak constraint for a target word (based on cloze probability norms). Contextual constraint was crossed with expectancy of the sentence-final target, such that the context sentence was completed with either the most expected word or a plausible but unexpected word. Readers self-paced the presentation of the text word-by-word (cf. Payne and Federmeier, 2017), so as to accommodate the range of reading rates in this sample. Importantly, stimuli were selected so as to only include items within the reading level of the sample. As shown in the upper panel of Fig. 1, participants with well-developed literacy skills showed an ERP pattern very similar to that of the college-aged adults in Federmeier et al. (2007), with N400 amplitudes graded by cloze probability (strongly constrained-expected < weakly constrained-expected < unexpected in both constraint conditions). This pattern indicates that proficient readers use contextual information in a graded manner to facilitate processing of incoming words. However, the pattern was different for low-literacy participants. Although this group showed an N400 effect of target word expectancy in the strongly constraining condition that was comparable to the high-literacy group, they showed no N400 expectancy effect at all in the weakly constraining condition. Moreover, among the more literate readers, the cost of prediction disconfirmation manifested in longer reading times for the unexpected word in strongly, compared to weakly, constraining contexts, but such a cost was not observed for the lower literacy adults. Collectively, these data suggest two sources of difficulty for low-literacy adults in reading: they do not take advantage of the full range of sentence constraint to facilitate semantic access, and they do not appear to engage in predictive processing.

These results raise the question of whether this reduced sensitivity to context and the failure to use prediction among lower literacy adults is restricted to the visual domain, in which demands on print decoding may draw resources away from semantic processing (Gao et al., 2012; Gao et al., 2011), or whether these adults have a domain-general deficit in integrative and predictive processing that spans across modality of input. Thus, in the present study, we examined the impact of constraint