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Research Report

The strong, the weak, and the first: The impact of phonological stress on processing of orthographic errors in silent reading

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ABSTRACT

In auditory speech processing, phonological stress functions as an attention holding cue, which facilitates detection of mispronunciations and phonetic deviants in strong syllables as compared to weak ones. Whereas silent reading involves activation of phonological information including word stress, it is not clear whether it has any functional relevance for visual language processing. We investigated whether phonological stress impacts orthographic processing such as detection of misspellings in silent reading. In an ERP experiment, participants silently read intact and misspelled German words. We manipulated the strength of the misspelled syllable (strong vs. weak) as well as its position (word-initial vs. word-middle). No effect of stress was observed for misspellings occurring in a word-initial position suggesting that misspellings in word-initial position disrupt visual word processing regardless of the phonological strength of the first syllable. In contrast, phonological strength modulated the ERPs when misspellings occurred in the middle of the word: misspellings embedded in strong syllables enhanced the P600 and the N400-like component compared to misspellings in weak syllables. In this case, i.e., when misspellings occur in the middle of a letter string, lexical access may be hindered more when errors occur in strong syllables, as reflected in the enhanced N400 in strong compared to weak syllables. This in turn may facilitate active reanalysis as mirrored in the increased P600 in the strong condition. The findings are discussed in the context of the relatively late activation of phonological form in visual word recognition and its interaction with other perceptual visual information. Overall, the results demonstrate the functional significance of phonological stress in visual word processing.

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1. Introduction

Silent reading often involves some kind of inner voice speaking in our heads (Huey, 1908/1968; Perrone-Bertolotti et al., 2012; Abramson and Goldinger, 1997). Even when not overtly producing language, we activate phonemes (Rastle and Brysbaert, 2006; Frost, 1998), sub-phonemic features, e.g., vowel duration or voicing (Abramson and Goldinger, 1997; Lukatela et al., 2001; Ashby et al., 2009) and higher phonological features such as phonological stress (Ashby and Clifton, 2005) while reading. Against this background, the current study investigated whether activating phonological stress in silent reading is functionally relevant for orthographic processing, in particular with regard to orthographic error detection.

Listeners do not perceive speech as a monotonous stream of acoustic input, but rather as a sequence of alternating relatively more and less prominent units. These alternations occur at different phonological levels, i.e., at the level of a phonological phrase (intonation) as well as at the lower levels of phonological words and syllables. In languages like English or German stressed syllables acoustically differ from unstressed ones in fundamental frequency, duration and intensity and, depending on the linguistic background of the listener, are typically perceived as higher in pitch, longer in duration, louder and differing in vowel quality (Fry, 1955; Zhang and Francis, 2010; Chrabaszcz et al., 2014). Strong syllables – relative to weak syllables – more clearly retain their acoustic properties in noisy environments thereby appearing as "islands of reliability" to comprehenders (Pitt and Samuel, 1990). These qualities ensure the perceptual salience of stressed syllables.

Different patterns of alternations of stressed and unstressed syllables are termed metrical feet. A trochee is a metrical foot that starts with a stressed syllable followed by unstressed ones, whereas an iamb is a sequence of unstressed syllables preceding the stressed syllables. The regularity of alternations of metrical patterns helps listeners to anticipate upcoming information (Schmidt-Kassow and Kotz, 2008) and rapidly shift their attention to the next stressed syllable. According to the attentional bounce hypothesis (Pitt and Samuel, 1990), when listening to speech the attention of the listener travels from one stressed syllable to the next facilitating, for instance, the detection of mispronunciations (Cole and Jakimik, 1980), phonetic deviants (Wang et al., 2005) or target phonemes in stressed syllables (Pitt and Samuel, 1990), albeit with differences between the salience of mispronunciations/deviants at word onset and word medial positions.

Whilst phonological stress is indubitably critical for the processing of auditory input, its impact on visual language processing is less apparent. Recent experiments suggest that word stress information may be activated and interacts with other processes during visual word recognition. A recent eye-tracking study by Breen and Clifton (2011) also Breen and Clifton (2013) reported that if the metrical structure of a word does not conform with the reader's expectations, revising this structure leads to increased processing costs as manifested by longer reading times. Arciuli and Cupples (2006) and Colombo (1992) observed that when asked to read words aloud, participants were faster and made fewer errors when words followed a typical metrical pattern as compared to an atypical one[1]. Effects of metrical typicality in these studies were also observed in error rates in lexical decision tasks, i.e., even when participants were not required to overtly pronounce the words. This finding suggests that the influence of stress in reading occurs prior to the stage of articulation. An eye-tracking experiment conducted by Ashby and Clifton (2005) demonstrated that when silently reading words participants gazed longer and had more fixations on words with two stressed syllables as compared to words with only one stressed syllable. Thus, later processing of words in silent reading is influenced by the metrical properties of the words. However, earlier stages of processing, as indexed by first fixations on words, were not similarly affected by the number of stressed syllables. This suggests that that phonological stress information does not critically impact early word processing in silent reading and is more influential at later stages of lexical access.

While the research reviewed above indicates that word stress is activated in silent reading, its functional significance in orthographic processing remains somewhat unclear. Here we asked whether stressed syllables may hold the attention of readers in visual language processing in the way they do in auditory speech perception. In particular, if stressed syllables are more salient relative to weak syllables even in silent reading, it is possible that detection of orthographic errors in stressed syllables may differ from unstressed syllables and it should be possible to index these differences by means of the event-related brain potential technique (ERP).

ERPs provide an excellent marker of on-line processing at various levels of linguistic analysis. Of special interest here are two ERP components, the N400 and the P600, that have been repeatedly shown sensitive to orthographic manipulations. The N400 is a negative-going component with a broad distribution that peaks between 200 ms and 500 ms after the stimulus onset (for a review see Kutas and Federmeier, 2000, 2011). The N400 indexes a complex of processes related to various aspects of meaning processing such as accessing and selecting conceptual representations from semantic memory and integrating them with the existing contextual information (for reviews see Lau et al., 2008 and Kutas and Federmeier, 2011). The amplitude of the N400 is modulated by the ease of semantic processing and increases when meaningful processing is hindered, as is the case, for example, with pseudowords. For instance, Bentin et al. (1999) conducted an oddball experiment in which participants had to read a list of words and respond to occasionally occurring abstract concepts. The authors then compared ERPs elicited by non-target concrete words and pseudowords and observed that the N400 was modulated by the meaningfulness of the stimuli and was more negative for pseudowords compared to words. A recent study by Laszlo and Federmeier (2009) manipulated the resemblance of pseudowords to real words that were appropriate continuations of highly predictive sentences. Whilst sensitive to the lexical status of the words

[1] Advantage in naming times was observed for low but not for high frequency words (Colombo, 1992).