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The importance of the first and last letter in words during sentence reading

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ABSTRACT

Previous research suggests that the first and last letters of words are more important than the interior letters during reading. A question that has yet to be fully studied is why this is so. The current study reports four experiments in which participants read sentences containing words with transposed letters occurring at the beginning of the word, near the middle of the word, or at the end of the word. Experiments 1 and 2 also included some sentences where the spaces were removed and replaced with hash marks (#) to equate all letters on their degree of lateral interference from adjacent letter positions. In Experiment 3, equating was done by adding an additional space between all of the letters, so that no letter position received lateral interference from any letter. In Experiment 4, readers read sentences from right to left so that word-initial letters were presented furthest into the parafovea. The results indicate that although the first letter of a word has a privileged role over interior letters regardless of the degree of lateral interference it receives or its location in the parafovea (suggesting that it is intrinsically related to how we process, store, or access lexical information), the last letter of a word is more important than interior letters only when it receives less lateral interference or when its parafoveal location was close to the fovea (suggesting that it is privileged only due to low-level visual factors). These findings have important implications for current theories and computational models regarding the roles of various letter positions in reading.

1. Introduction

In identifying a written word, readers must first identify the constituent letters within that word. Past research has looked at the relative importance of specific letter positions within a word and found that letters in certain positions in words are actually privileged when it comes to recognition; that is, letters in certain positions in words are more important for recognition than other letters in the word. Specifically, these studies indicate that the first and last letters of a word are more important than the interior letters.

An e-mail that circulated around the internet about 7 years ago claimed that this is true by stating "Aoccdrnig to rseaerch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a ttoal mses and you can sitll raed it wouthit a porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe." It turns out that many of the claims that are made in this e-mail are false; readers *do* display reading difficulties when reading jumbled text (Rayner, White, Johnson, & Liversedge, 2006; White, Johnson, Liversedge, & Rayner, 2008) and no such research has been conducted at Cambridge University. However, the assumption that the exterior letters are more important than interior letters in lexical processing does seem to hold up in a laboratory setting.

1.1. The importance of exterior letters

Many previous studies have looked at the relative importance of various letter positions within words and found that the first and last letters of a word are more crucial in word recognition than interior letters. Support for this conclusion comes from a variety of isolated word studies utilizing a number of different experimental paradigms. For example:

(1) Priming studies indicate that lexical decision times (e.g., Forster & Gartlan, 1975, cited in Forster, 1976) and naming latencies (e.g., McCusker, Gough, & Bias, 1981) are shorter when participants are first primed with the word's exterior letters (e.g., *st____ly* for *steadily; t__p* for *trap*) than when primed with the word's interior letters (e.g., *__eadi__* for *steadily*; *_ra_* for *trap*). Furthermore, recall for briefly presented words is greater when participants are primed with their exterior letters than with two interior letters (Humphreys, Evett, & Quinlan, 1990; Humphreys, Evett, Quinlan, & Besner, 1987).

(2) The exterior letters of briefly-presented letter strings are reported more accurately than letters in interior positions (e.g., Averbach & Coriell, 1961; Butler & Merikle, 1973; Estes, Allmeyer, & Reder, 1976; Haber & Standing, 1969; Merikle,

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1974; Merikle & Coltheart, 1972; Merikle, Coltheart, & Lowe, 1971, Mewhort & Campbell, 1978). Importantly, these effects are also found when words are used as target stimuli (e.g., Carr, Lehmkuhle, Kottas, Astor-Stetson, & Arnold, 1976; Jordan & Bevan, 1996; Jordan, Patching, & Milner, 2000; Jordan, Patching, & Thomas, 2003).

(3) Responses to exterior letters are faster and more accurate than responses to interior letters on letter search tasks where participants are asked to detect whether or not a cued letter is within a letter string (e.g., Hammond & Green, 1982; Mason, 1975, 1982; Mason & Katz, 1976; Pitchford, Ledgeway, & Masterson, 2008). Furthermore, when participants are asked to determine whether a presented word matches a pre-specified target word, search latencies for detecting differences are faster for changes at the first and last letter position than for changes at interior locations (Bradshaw, Bradley, Gates, & Patterson, 1977)

(4) Individuals with Letter-Position Dyslexia make more migration errors at interior letter positions than at exterior letter positions (e.g., Friedmann & Gvion, 2001).

(5) Orthographic and transposed-letter (TL) neighborhood effects differ as a function of letter position. Specifically, orthographic neighborhood effects are weaker at external letter positions than at internal positions (Grainger & Seguí, 1990; Perea, 1998), and transpositions that involve the first or last letter of the word cause more disruption to word recognition processes than transpositions of interior letters (Bruner & O'Dowd, 1958; Chambers, 1979; Holmes & Ng, 1993; Perea & Lupker, 2003; Schoonbaert & Grainger, 2004).

The differential importance of exterior vs. interior letter positions has also been found in the context of reading sentences, increasing the external validity of these previous findings. Specifically, these studies indicate:

(1) Readers successfully extract useful information about the first (e.g., Briihl & Inhoff, 1995; Johnson, Perea, & Rayner, 2007; Lima & Inhoff, 1985; Rayner, McConkie, & Zola, 1980) and last (e.g., Inhoff, 1989a, 1989b; Johnson et al., 2007) letters of a word when they are located in the parafovea and reading processes are disrupted to a greater degree when readers are denied correct parafoveal preview information about these letters than when information about interior letters is denied.

(2) During sentence reading, fixation durations are longer when the beginning letter sequence of a word is more constraining (e.g., dwarf) than less constraining (e.g., clown; Lima & Inhoff, 1985) and the frequency of the word initial letters can affect the initial landing position on long words (Hyona, 1995; Radach, Inhoff, & Heller, 2004; Vonk, Radach, & van Rijn, 2000; White & Liversedge, 2004, 2006a, 2006b; but see White, 2008, for evidence of a different pattern for short words). Furthermore, orthographically illegal word-initial trigrams presented in the parafovea can influence landing positions on words once they are fixated (where fixations land closer to the beginning of the word than when initial trigrams are orthographically legal) in both short and long words (Plummer & Rayner, 2012).

(3) Text that is manipulated at the fovea during sentence reading in the first or last letter positions leads to greater reading difficulty than text manipulated at interior letter positions. This has been shown when manipulations involve letter substitutions (Rayner & Kaiser, 1975), visual degradations (Jordan, Thomas, Patching, & Scott-Brown, 2003), and letter transpositions (Rayner et al., 2006; White et al., 2008). Interestingly, similar effects arise when Chinese characters are manipulated. Yan et al. (2012) found that characters with their beginning or ending strokes removed were more difficult to identify than characters with an "internal" stroke removed that retained the configuration of the character.

Important for the current set of experiments, White et al. (2008, see also Rayner et al., 2006) investigated the role of exterior vs. interior letter positions by recording the eye movements of participants as they read sentences that contained some words with letter transpositions at various positions. Although some of the sentences contained no transpositions, others contained words that had transpositions at the beginning of the word (e.g., *rpoblem*), near the middle of the word (e.g., *porblem*, *probelm*), or at the end of the word (e.g., *problme*). All words in the sentence that were at least 5 characters in length included such transpositions. They found that all transpositions disrupted the normal pattern of eye movements, resulting in an increase in the number of fixations made on the sentence and in the total time spent on the sentence relative to the normal sentences. Readers also had increased first fixation durations, gaze durations, and total times on a predetermined target word when it was transposed than when it was not. Furthermore, White et al. found differences in processing difficulty as a function of the location of the transposition. Across several dependent measures, they found word-initial transpositions to be more disruptive than transpositions at any other location, and that word-final transpositions were more disruptive than internal transpositions, especially in later measures of processing (e.g., total sentence reading time, gaze duration, total time). These findings, then, support previous research which suggests that some letter positions are more important for processing than others; specifically, the first letter in a word is the most critical in word recognition, but the last letter is also more important than the interior letters.

1.2. Outline of the current experiments

Therefore based on the prior research, it has been thoroughly established that the first and last letters in a word play an important role in visual word recognition and in the processing of text. A question that has yet to be studied more thoroughly is why that is so. Some researchers (e.g., Forster, 1976; Grainger & Seguí, 1990; Jordan, 1990; Jordan, Thomas, et al., 2003) argue that exterior letters are intrinsically related to how we process or access lexical information. That is, exterior letters are important because they are related to how the mind either organizes lexical information or retrieves that lexical information. This is a very high-level cognitive explanation. Other researchers, however, (e.g., Bouma, 1970, 1973; Chambers, 1979; Estes, 1972; Estes et al., 1976; Haber & Standing, 1969; McCusker et al., 1981; Van der Heijden, 1992) believe that exterior letters may be more important than interior letters in reading simply because they are easier to extract from the visual stimuli because they suffer less lateral interference or crowding effects (e.g., Grainger, Tydgat, & Issele, 2010; Levi, 2008; Pelli et al., 2007) from other letters. That is, it could be the case that the importance of the first and last letters comes from perceptual salience; in normal sentence reading, these letters are always located next to a space, and as such are subjected to less lateral interference or less crowding than interior letters making them easier to extract from the text. The exterior letter benefit, then, would come down to the fact that while interior letters are flanked by 2 letters (e.g., the *b* in the word *problem* is flanked by both an *o* and an *l*), exterior letters are only flanked by 1 letter (e.g., the *p* or *m* in the word *problem* are flanked by only an *r* or an *e*, respectively).

The present study explored whether exterior letters are more important in sentence reading for either intrinsic or perceptual reasons by implementing reading tasks that teased apart these two possible explanations. Based on the methodology and stimuli of White et al. (2008), participants read sentences with transposed letters occurring at different letter positions. In addition to these transposition manipulations, in half of the sentences we equated the letter positions on the degree of lateral interference they received. In Experiments 1 and 2, this was done by removing the spaces naturally occurring between the words and replacing them