



Word and line bisection in typical and impaired readers and a cross-language comparison



Yafit Gabay^{a,d,*}, Shai Gabay^{a,b}, Avishai Henik^c, Rachel Schiff^d, Marlene Behrmann^a

^a Department of Psychology, Carnegie Mellon University, Pittsburgh, PA, USA

^b Department of Psychology and The Institute of Information Processing and Decision Making, University of Haifa, Israel

^c Department of Psychology and Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel

^d School of Education and Haddad Center for Research in Dyslexia and Learning Disabilities, Bar-Ilan University, Ramat-Gan, Israel

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ABSTRACT

Observers exhibit larger leftward bias when bisecting words compared with lines. According to the *Attentional Scaling Hypothesis*, attempting to access lexical entries involves focusing attention on the initial letters of words to establish a cohort of potential matches with entries in the mental lexicon. We test this account by examining two predictions: (1) greater leftward bias for words should be evident in English readers in which the word beginning is on the left but not in Hebrew readers. (2) Dyslexics who have lexical impairments should show greater bias. Results reveal that word length modulated bisection bias differently for Hebrew and English readers, although the bias stays always leftward. Furthermore, dyslexics exhibited an exaggerated leftward bias than controls. We propose this effect arises from an interaction between reading and spatial attention rather than from the scaling of attention relative to the beginning of the word in the service of lexical access.

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1. Introduction

When participants are required to bisect a line, they typically do so slightly to the left of the true center, demonstrating what has come to be termed ‘pseudoneglect’ (Bowers & Heilman, 1980). Pseudoneglect is thought to reflect stronger activation of the right hemisphere (RH) than the left hemisphere (LH) in response to the visuospatial nature of the line bisection task (Bowers & Heilman, 1980; Kinsbourne, 1970). Interestingly, there are several factors that can modulate line bisection such as the hand used for the bisection (Jewell & McCourt, 2000), the manner of bisection such as paper and pencil versus computerized tests (Dellatolas, Vanluchene, & Coutin, 1996) as well as reading direction (Chokron & Imbert, 1993; Fagard & Dahmen, 2003; Gabay, Gabay, Schiff, Ashkenazi, & Henik, 2013). Several studies have demonstrated that participants also exhibit a leftward bias while bisecting words but, interestingly, this leftward bias is even greater in magnitude than the leftward line-bisection bias (Arduino, Previtali, & Girelli, 2010; Fischer, 1996; Fischer, 2000a, 2000b,

2004). This enhanced leftward bias for word bisection is replicable across a host of conditions and has been documented in the context of both paper and pencil bisection tasks as well as in a computerized version of the bisection task. Furthermore, the enhanced leftward bias is evident across different word classes (nouns, adjectives and verbs) and across different languages such as German and English (Fischer, 2000a). Finally, this bias emerges regardless of the font type or the font size in which the words are presented (Fischer, 2004), and is independent of the requirement to read the stimulus aloud (Fischer, 2000a).

1.1. Support for an attentional account of the leftward word-bisection bias

To account for the robustness and widespread manifestation of the leftward bias on word-bisection results as well as the disproportionate bias relative to line bisection, Fischer (1996) proposed the *Attentional Scaling Hypothesis*. On this account, the leftward bias in word-bisection reflects the participant’s attempts to access the mental lexicon. Lexical access is often conceived as starting from the beginning of the word and progressing toward its end (Marslen-Wilson, 1987). Thus, the attempts to access the lexical item may involve increased attentional focusing on the initial letters of a word to establish a cohort of potential matches with entries in the mental lexicon. Consistent with this idea, the

* Corresponding author at: Edmond J. Safra Brain Research Center for the Study of Learning Disabilities, Department of Learning Disabilities, Department of Communication Sciences and Disorders, University of Haifa, Mount Carmel, Haifa 31905, Israel.

E-mail address: yafitvha@gmail.com (Y. Gabay).

analysis of eye movements during reading reveals that readers fixate on a location to the left of true center when first looking at a new word and also tend to shift fixations further to the left of the midpoint as word length increases (O'Regan, 1990; Rayner, 1979). The critical role of word initial letters is well established, and the initial letters are recognized even when the word beginning is presented parafoveally (White, Johnson, Liversedge, & Rayner, 2008). The unintended consequence of this hypothesized attentional strategy for lexical access is that there is over-representation of the initial part of the word relative to its actual physical extent, and this results in systematic leftward bias when bisecting words (Fischer, 2004).

Considerable empirical evidence from bisection studies is also compatible with this Attentional Scaling Hypothesis. First, the misperception of the word center is reported for different types of orthographic stimuli (words, pseudowords, and symbol strings), but not for non-alphabetic stimuli such as bars, dashes, or boxes (Fischer, 2000b). Also, the enhanced leftward bias is abolished for letter string bisection, indicating that, in the absence of lexical and phonological information, there is no leftward scaling (Fischer, 1996; Exp. 5). Second, bisection errors tend to increase with the length of the stimuli (Arduino et al., 2010; Fischer, 2004) although, of note, it is the number of characters in a word and not the physical extent of the stimuli that determines the size of the error (Fischer (2000b)). This perceptual length sensitivity occurs for bisection of orthographic stimuli but not for bisection of lines indicating that the former undergoes additional processing. This is consistent with the idea that it is higher cognitive processes (lexical access) rather than physical properties of the stimulus per se that determine performance in bisection. Third, the word bisection bias differs as a function of one's linguistic skill: for example, bisection differs when the bisection task is performed on words in one's second language, compared with words from one's native tongue. That is, when Hebrew-American bilinguals bisected words in their second language (i.e. bisected English words) they revealed a stronger leftward bias (perhaps indicating increased difficulty in lexical access) compared with native readers (Fischer, 1996; Exp. 6). This result is compatible with the claim that extent of lexical access affects the strength of the bias.

Finally, the enhanced leftward bisection for words appears to be strongly dependent on the structure of the orthographic input. For example, Lee, Kang et al. (2004) and Lee, Kim et al. (2004) asked both healthy and neurologically impaired participants to bisect either long strings of letters from the Korean alphabet (letter-line bisection), nonlinguistic symbols (star line bisection) or solid lines. Specifically for both the letter and star line bisection tasks, participants were first instructed which character to find, then to identify an exemplar of the target letter, and, thereafter, to determine the midpoint of the linear array. Under these conditions, in the absence of real words, a rightward bias was observed for letter and star lines compared with solid lines. This same result was replicated in a further study conducted on both younger and older healthy participants (Lee, Kang et al., 2004; Lee, Kim et al., 2004) (for related results, see Mohr & Leonards, 2007). These authors suggested that the stronger rightward bias observed for letter lines may arise from left hemisphere activation due to (1) verbal information associated with individual letters and (2) local attention to letters as compared to global attention to lines.

As evident from the brief review above, there are at least two conflicting accounts having to do with spatial bias in line and word bisection. According to the hemispheric activation account (Bowers & Heilman, 1980; Kinsbourne, 1970), the leftward attentional bias observed during bisection tasks (pseudoneglect) arises from a stronger activation of the right than left hemisphere in response to the visuospatial aspects of the task. Accordingly, people who suffer from left-sided neglect exhibit a rightward bias

as the intact left hemisphere shifts attention toward the contralateral, right hemisphere (Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). By extension, this account would explain the leftward bias for bisecting words in the same way – it is the spatial pattern rather than the content per se that shifts the center to the left. This account, however, does not articulate an obvious mechanism for explaining the greater leftward bias for words over lines and thus, does not fully account for the data. The Attentional Scaling hypothesis, on the other hand, specifically addresses this word/line discrepancy and suggests that the enhanced word bisection bias reflects the participant's attempts to access the mental lexicon and the increased attentional activation associated with this process. The unintended consequence of this hypothesized attentional strategy for lexical access is that there is over-representation of the initial part of the word relative to its actual physical extent, resulting in systematic leftward bias when bisecting words (Fischer, 2004).

1.2. The current study

Here, we test several predictions of the Attentional Scaling Hypothesis. The first prediction is that, if the leftward bias for words arises as a result of lexical activation for the informative beginning of words, the leftward bias should only be evident for readers of languages where the word beginning is on the left (as in English) but not for readers of languages where the word beginning is on the right (Hebrew readers). To evaluate this, we compared the bisection performance of native Hebrew and English speakers on lines and words in their native orthography. If the Attentional Scaling Hypothesis holds, we would expect to see greater leftward bias for words than lines in English readers but greater rightward bias for words than lines in Hebrew readers. As an intermediate condition, we also included pseudowords in each language with the expectation that the bisection bias for these trials should be in the same direction as for words if the source of the bias is lexical albeit not as large. The second prediction concerns the impact of lexical access on the leftward word bisection bias; specifically, the Attentional Scaling Hypothesis predicts that individuals who have difficulties in lexical access and reading, such as those with developmental dyslexia (DD), might reveal even greater word bisection bias than in controls reflecting the additional effort required to activate lexical representations.

Third, the Attentional Scaling Hypothesis predicts that word bisection should be affected by the frequency of occurrence of the word. High frequency words are accessed faster than low frequency words (Morton, 1969) and are fixated for a shorter time in reading compared with low frequency words (Rayner, 1977). Thus, the *Attentional Scaling Hypothesis* would predict greater leftward bias when lexical access is more demanding as in the case of low frequency words (Raney & Rayner, 1995). Moreover, this pattern might potentially be disproportionately exaggerated in DD readers, in whom lexical access is disrupted and greater effort is required to activate lexical representations, relative to typical readers.

1.3. Bisection performance in developmental dyslexia

Thus far, the focus has been on lexical access as key in provoking the leftward bias for word bisection in both normal readers and DD readers. It is the case, however, that DD might not only be a consequence of difficulties in lexical access (largely resulting from problems in phonological processing) but might also reflect difficulties in spatial attention. As such, alterations in line bisection in these individuals might result from one or more than one underlying mechanisms.

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