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Testing the flexibility of the modified receptive field (MRF) theory: Evidence from an unspaced orthography (Thai)

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ABSTRACT

In the current study, we tested the generality of the modified receptive field (MRF) theory (Tydgat & Grainger, 2009) with English native speakers (Experiment 1) and Thai native speakers (Experiment 2). Thai has a distinctive alphabetic orthography with visually complex letters (ฝ ฟ or ผ พ) and nonlinear characteristics and lacks interword spaces. We used a two-alternative forced choice (2AFC) procedure to measure identification accuracy for all positions in a string of five characters, which consisted of Roman script letters, Thai letters, or symbols. For the English speakers, we found a similar pattern of results as in previous studies (i.e., a dissociation between letters and symbols). In contrast, for the Thai participants, we found that the pattern for Thai letters, Roman letters and symbols displayed a remarkably similar linear trend. Thus, while we observed qualified support for the MRF theory, in that we found an advantage for initial position, this effect also applied to symbols (i.e., our data revealed a language-specific effect). We propose that this pattern for letters and symbols in Thai has developed as a specialized adaptive mechanism for reading in this visually complex and crowded nonlinear script without interword spaces.

1. Introduction

The initial position enjoys an advantage in different paradigms involving words and letter strings when participants are fixating at the central position with the Roman script (see Hammond & Green, 1982; Mason, 1975, for early evidence). This initial-position advantage does not occur with strings of symbols, where accuracy is greatest for the central letter position, but performance declines as the distance from the central letter position increases (e.g., Mason & Katz, 1976; see also Mason, 1982; Hammond & Green, 1982). This letter/symbol dissociation can be readily explained in terms of the modified receptive field (MRF) theory (Tydgat & Grainger, 2009). Tydgat and Grainger (2009) proposed that as children learn to read, they develop a specialized system that is custom-built to handle the very specific nature of letters—keep in mind that letters (but not symbols) activate the putative "visual word form area" in the brain (e.g., see Dehaene et al., 2010).

According to the MRF account, there is a change or expansion in shape of receptive fields of initial letters to optimize processing at the first position in strings of letters, which gives an initial position advantage (see Fig. 12 in Tydgat & Grainger, 2009; see also Grainger & Dufau, 2012). This would not occur with strings of symbols, in which the pattern of data merely reflects a drop in visual acuity. Consistent with this idea, Tydgat and Grainger (2009) conducted a series of two-alternative forced choice (2AFC) experiments with skilled adult readers and found a different serial position function for Roman letters (with a W shape in percent correct) when compared to symbol stimuli (with an inverted V function) (see also Ziegler, Pech-Georgel, Dufau, & Grainger, 2010, for a replication of this pattern with 8–13 year olds—both dyslexics and controls).

Traditionally, letter and word recognition research has focused on Roman script and a small number of European languages, in particular English. However, more recently a growing interest in investigating a broader range of languages and scripts has emerged, which is essential if we are to delineate between universal and orthography-specific processes as well as build more comprehensive and representative universal models of reading (see Frost, 2012, for a recent review). In the current study, we aim to test the generality of the MRF account by using Thai, a language with a distinctive alphabetic orthography, which makes interesting comparisons with other languages that use Roman script. Leaving aside that Thai script is visually complex (e.g., it has many letters that closely resemble each other and share common visual features, e.g., ฝ ฟ or ผ พ, to cite two examples), its vowels have a nonlinear configuration in that they can be written above, below, or to either side of the consonant as full letters or diacritics, and commonly

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combine across the syllable to produce a single vowel or diphthong. The orthographic order of vowels also does not necessarily correspond to the phonological order (e.g., แบน <ɛ:bn> ‘flat’ is spoken as /bɛ:n/; see Winskel, 2009) (a characteristic it shares with other Brahmi-derived scripts). Tone markers occur above the initial consonant of the syllable or word (e.g., ข้าว /k^hâ:w/ ‘rice’). Furthermore, Thai does not normally have interword spaces (similar in this respect with Chinese, Japanese, Lao, Khmer, Tibetan, and Burmese), which implies that during normal reading there is a degree of ambiguity in relation to which word a given letter belongs to (e.g., คุณพ่อของฉันชอบรับประทานอาหารที่มีรสจัด). Thus, the reader has to use other cues besides interword spaces to segment the text into words, such as frequently occurring or salient initial letters or combinations of letters and diacritics (Winskel, Radach, & Luksaneeyanawin, 2009). Due to these combined characteristics, Thai script is relatively dense or crowded and exerts distinct challenges to the child learning to read and spell Thai (Winskel & Iemwanthong, 2010).

There is empirical evidence that shows that the encoding of letters during reading in Thai may not be the same as in the Roman script. In a recent study on Thai, Winskel, Perea, and Ratitamkul (2012) examined whether the position of transposed letters (internal, e.g., *porblem* vs. initial, e.g., *rpoblem*) within a word influences how readily those words are processed when interword spacing and demarcation of word boundaries (using alternating**bold** text) was manipulated. Eye movements were recorded while participants read sentences silently. Unlike the parallel experiment in English—in which the reading cost was greater when the disruption affected the initial letter position (see White, Johnson, Liversedge, & Rayner, 2008), there was no apparent difference in the degree of disruption caused when reading initial and internal transposed-letter nonwords. Thus, the findings of Winskel et al. (2012) point to script-specific effects operating in letter position encoding in visual-word recognition and reading. Importantly, support for a lateral masking hypothesis was not found, as the magnitude of the transposed-letter effects was not modulated by the spacing manipulation: there was no significant difference between initial and internal transposed letter effects in the spaced condition—in which there is less lateral masking on initial letters than on internal letters. We expected to find that when spaces were inserted, there would be a reduction in lateral masking on initial letters, resulting in shorter reading times in spaced in comparison to unspaced text with initial transposed words than with internal transposed words. However, there was very little empirical support for this. We also expected the alternating**bold** manipulation to have a facilitatory effect on word segmentation similar to the spaced condition (as occurred in the study of Perea & Acha, 2009with Spanish sentences). However, we found that this manipulation was more similar to the normal unspaced condition than the spaced condition, and it even had a slight deleterious effect on reading in comparison to the spaced condition in the global sentence reading times. The fact that alternating**bold** did not facilitate reading in the same way that spaced text, in contrast to what happens in Indo-European languages (see Perea & Acha, 2009), indicates that there are different processes occurring when reading Thai and Roman script. Winskel et al. (2012) hypothesized that it could be that the alternating**bold** demarcation of the text is disrupting the habitual segmentation patterns and cues used by experienced readers to read Thai—as occurs when reading Chinese sentences (see also Bai, Yan, Liversedge, Zang, & Rayner, 2008).

In the current study, we used a similar two-alternative forced choice procedure as Tydgat and Grainger (2009), to measure identification accuracy for all positions in a string of five characters, which consisted of Roman script letters, Thai letters, or symbols. Participants were English native speakers (Experiment 1) and Thai native speakers (Experiment 2)—note that the Thai participants were also very familiar with reading Roman script. Thai children begin to learn the letters of the Roman alphabet either in Kindergarten (private school) or Grade 1 (public school). Based on prior research, we can predict that the English native speakers will demonstrate a similar quartic W-shaped identification pattern for the Roman letters, as the Tydgat and Graingers' French participants (i.e., in particular, an advantage for the initial position over the second position). In addition, the response to the symbols and Thai letters should reveal an advantage for the central letter position, and no advantage for the initial letter position—note that Thai letters will be perceived as unfamiliar symbols.

But the critical issue in the present study is the outcome for the Thai participants (Experiment 2). If the pattern of responding in the English experiment is related to a universal process, regardless of the participants' reading experience, then results for Thai letters and English letters should be similar to those found in Roman script (i.e., a W function with an advantage of the initial position), whereas results for symbols will deviate (i.e., an advantage of the middle position, in terms of an inverted V function). Alternatively, based on prior research on Thai, which has shown divergent results, different language- or script-specific patterns may emerge. There are two basic scenarios. On the basis that letter position coding in Thai seems to have a similar level of flexibility of the initial and internal letter positions during reading (Winskel et al., 2012), one possibility is that due to the unspaced nature of Thai script, we can envisage that the elongation of receptive field for the initial letter position, as hypothesized to occur for the Roman script, does not occur in Thai; instead, the receptive fields for initial and internal letter positions can be visualized as being similar in shape and size. This would lead to the prediction that we won't find an initial letter advantage and we could, for example, find a similar response to letters as we do for symbols (i.e., an advantage of the middle position; i.e., an inverted V function). Another possibility is that due to the importance of segmenting this unspaced crowded script into lexical components, using less salient cues than interword spaces, there could be a general heightened attentional response to initial letter position (i.e., a W function with a strong linear component). This would arise as an adaptive mechanism to reading in this extremely crowded nonlinear script without interword spaces, and this would be consistent with the lack of parafoveal-on-foveal effects during sentence reading in Thai (i.e., a marker of serial word-by-word reading rather than parallel reading; Winskel & Perea, 2014). As indicated earlier, in the MRF theory (Tydgat & Grainger, 2009), the advantage of the initial position arises to optimize the very specific nature of letter strings. Tydgat and Grainger hypothesized that a change in size and shape of the receptive fields of retinotopic letters or numbers underlies this adaptive process. This is an adaptive mechanism that has been developed to optimize processing in crowded conditions associated with reading words in the spaced, Roman script, and its role may even be more generalized in Thai—it may be important to note here that keyboard symbols may also be used in conjunction with Thai script similarly to how they are used in Roman script.

2. Experiment 1 (English readers)

2.1. Method

2.1.1. Participants

Thirty-nine individuals took part in the experiment. All of them were English-speaking participants recruited through Southern Cross University, Coffs Harbour, Australia. Participation was voluntary. None of the participants were familiar with Thai script. All participants had normal or corrected to normal vision.

2.1.2. Stimuli and design

The method and procedure used here is based on Tydgat and Grainger (2009). All stimuli consisted of horizontal arrays of five characters, which were either Roman consonant letters presented in uppercase (B, D, F, G, K, N, L, S, and T), Thai consonant letters (ก, ด, น, ล, ษ, ข, ห, ย, and ธ), and symbols (%, /, ?, @, }, <, £, §, and µ). The Roman letters and symbols were displayed in 18-point Courier New font and the Thai letters were displayed in 26-point Courier Thai Proportional font, so that the size of characters was the same. Thai letters can be visually similar,