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Stimulus orientation and the first-letter advantage

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ABSTRACT

A post-cued partial report target-in-string identification experiment examined the influence of stimulus orientation on the serial position functions for strings of five consonants or five symbols, with an aim to test different accounts of the first-letter advantage observed in prior research. Under one account, this phenomenon is driven by processing that is specific to horizontally arranged letter (and digit) strings. An alternative account explains the first-letter advantage in terms of attentional biases towards the beginning of letter strings. We observed a significant three-way interaction between stimulus type (letters vs. symbols), serial position (1–5), and orientation (horizontal vs. vertical) that was driven by a greater first-position advantage for letters than symbols when stimuli were presented horizontally compared with vertical presentation. These results provide support for the letter-specific processing account of the first-letter advantage, and further suggest that differences in visual complexity between letters and symbols play a minor role. Nevertheless, a first-position advantage for letters was observed in the vertical presentation condition, thus pointing to some role for attentional biases that operate independently of string orientation.

1. Introduction

Orthographic processing is the gateway to visual word recognition and reading (Grainger, 2018). A long tradition of research has thus explored the underlying mechanisms, such as the processes involved in encoding the identities and positions of letters in a word. Although there is a general consensus that letters are processed in parallel (e.g., Adelman, 2011; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Gomez, Ratcliff, & Perea, 2008; Perry, Ziegler, & Zorzi, 2010; Plaut, McClelland, Seidenberg, & Patterson, 1996), it is also generally acknowledged that letter processing efficiency varies as a function of the position the letters occupy within the written word (e.g., Rumelhart & McClelland, 1982). The present study addresses one specific aspect of such positional effects, the oft-reported advantage for processing of the initial letters of words – the so-called “first-letter advantage”.

Early letter identification processes involved in word recognition have been studied by briefly presenting strings of letters and asking participants to make a decision about the identity of a probed character at a specific location in the string. Results have consistently shown better accuracy for letters presented at fixation, as well as for the first and the last letters (e.g., Marzouki & Grainger, 2014; Merikle, Coltheart, & Lowe, 1971; Merikle, Lowe, & Coltheart, 1971; Mewhort & Campbell, 1978; Stevens & Grainger, 2003; Tydgat & Grainger, 2009). A similar pattern is found for strings of digits (e.g., Tydgat & Grainger, 2009; Ziegler, Pech-Georgel, Dufau, & Grainger, 2010), but interestingly a different pattern is found for strings of symbols or shapes (Grainger, Bertrand, Lété, Beyersmann, & Ziegler, 2016; Hammond & Green, 1982; Mason, 1982; Tydgat & Grainger, 2009; Winskel, Perea, & Peart, 2014; Ziegler et al., 2010). Additionally, the first position advantage for letters has been shown to be particularly robust, surviving in experimental conditions that, on the contrary, had a detrimental effect on processing of the final letter (Tydgat & Grainger, 2009). Furthermore, a special status of letters in first position has been demonstrated in paradigms focusing on whole word recognition (e.g., Scaltritti & Balota, 2013), and even in sentence reading (e.g., Johnson & Eisler, 2012; Jordan, Thomas, Patching, & Scott-Brown, 2003).

According to one account of the first-letter advantage, the modified receptive field (MRF) hypothesis (Chanceaux & Grainger, 2012; Grainger, Dufau, & Ziegler, 2016; Grainger, Tydgat, & Isselé, 2010; Tydgat & Grainger, 2009), reading acquisition involves adaptive changes in order to optimize orthographic processing within the highly crowded context provided by printed texts. More precisely, for written languages that use an alphabetic script, learning to read involves the development of an array of gaze-centered location-specific letter detectors (Grainger & van Heuven, 2003), and that the receptive fields of these location-specific letter detectors become progressively more finely tuned as reading expertise develops. This adaptive tuning is hypothesized to involve both a change in size and a change in shape of the receptive fields of location-

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specific letter detectors. The size and shape of receptive fields determines the precise region of the visual field for which changes in visual information cause changes in letter detector activity. Smaller receptive fields result in reduced visual interference from flanking letters, and therefore more efficient orthographic processing. Importantly, it is also hypothesized that the shape of receptive fields of letter detectors receiving information from the left visual field is modified, with a leftward elongation (for languages read from left-to-right) which, for a constant size, leads to a reduction in their rightward extent, thus reducing the interference exerted from rightward flanking letters. This provides a mechanism for prioritization of the processing of the leftmost letter in a word, that is, the initial letter, deemed crucial for word identification (Clark & O'Regan, 1999; Stevens & Grainger, 2003), and for orthography-to-phonology conversion (Perry, Ziegler, & Zorzi, 2007). The hypothesized change in shape of letter detectors in the left visual field led to the prediction that letter identification should be hampered more by leftward flankers than rightward flankers when target and flankers are presented in the left visual field, and that no such asymmetry should be seen for letters in the right visual field nor for symbol or shape stimuli in either visual field. Evidence that this is indeed the case has been provided in three studies that manipulated visual field and either the number (Chanceaux, Mathôt, & Grainger, 2013; Grainger et al., 2010) or the visual complexity (Chanceaux, Mathôt, & Grainger, 2014) of flanking stimuli located to the left or to the right of target stimuli.

However, two recent studies have challenged the MRF hypothesis (Aschenbrenner, Balota, Weigand, Scaltritti, & Besner, 2017; Castet, Descamps, Denis-Noël, & Colé, 2017). In the Aschenbrenner et al. study, words were presented (33 or 50 ms) between visual masks. Two alternative responses were then displayed, one corresponding to the target word and the other representing a distracter, for a recognition test. Crucially, the target and the distracter word differed by only a single letter, and the position of the mismatching character was manipulated (see Adelman, Marquis, & Sabatos-DeVito, 2010). The authors found that participants were faster and more accurate when the mismatching character for the distracter occurred in the first position. Importantly, this same first position advantage was found even when target words where displayed in a vertical orientation. This latter finding challenges the MRF hypothesis. As noted above, according to the MRF account, location-specific letter detectors are horizontally aligned, and capture letter identity at a given location with respect to fixation (Grainger & van Heuven, 2003). Only the receptive fields receiving input from left visual field, moreover, would feature the leftward elongation (Chanceaux et al., 2013, 2014; Grainger et al., 2010). It is thus not clear how a first position advantage should arise for words displayed vertically. Aschenbrenner and colleagues thus proposed an attentional account, where spatial attention is automatically shifted towards the first letter upon stimulus presentation independently of stimulus orientation, thus prompting a more efficient processing of the initial letter in both conditions. However, the use of word stimuli in the Aschenbrenner et al. study may have resulted in attention being drawn to the beginning of stimuli independently of their orientation. As a more stringent test of the MRF hypothesis, it is important to examine whether the same pattern would be observed with random consonant strings. This was the main aim of the present study.

The present experiment also provides a test of another explanation for differences in the processing of letter and symbol strings proposed by Castet et al. (2017). These authors found that such differences disappeared in conditions similar to those of the Tydgat and Grainger (2009) study when visual complexity was controlled for, and especially when using a pre-cued as opposed to a post-cued partial-report procedure.[1] Castet et al. therefore suggested that prior observations of differences between letters and symbols might be due to mechanisms involved in post-cued partial report, and more specifically, due to more efficient short-term memory storage for letter stimuli compared with symbols. A simpler explanation for the Castet et al. (2017) findings, however, would be that pre-cueing enables attention to be focused at the cued location, thus reducing effects of the surrounding context (for example, the classic word superiority effect disappears with a pre-cue procedure – e.g., Johnston & McClelland, 1974). Crucial, with respect to the present experiment, is that any potential effects due to short-term memory should not be influenced by stimulus orientation.

In the present experiment, we therefore tested target-in-string identification accuracy with a post-cued partial report procedure as used by Tydgat and Grainger (2009) among others, and with strings of five consonants or five symbols. Strings could be presented either horizontally or vertically, and in both cases centered on fixation. The MRF hypothesis predicts a first position advantage exclusively for horizontally displayed strings of letters. The attentional account (Aschenbrenner et al., 2017) predicts a first position advantage for both horizontal and vertical orientations, but whether the first position advantage for vertical displays selectively arises only for letter stimuli is an empirical question. The crucial comparison with symbols will shed light on the extent to which any observed first-position effects are related to orthographic processing, or are the result of generic processing mechanisms such as visual interference or memory scanning.

2. Method

2.1. Participants

Thirty-two participants (21 females; $M_{age} = 22.63$; $SD_{age} = 3.67$) took part in the experiment. Two participants performed at chance-level, and were thus replaced. Participants provided written informed consent before participating, and they were compensated with 5€.

2.2. Materials and design

Stimuli consisted of arrays of 5 characters. Two types of characters were used: consonant letters presented in uppercase (R, N, D, M, B, K, G, H, S), and symbols (%, /, ?, @, }, μ, £, §, and <). For each stimulus type, 180 different arrays of 5 characters were created. Each one consisted of a quasi-random sequence of characters, with each of the target characters being presented 4 times at each of the five target positions and 80 times at a non-target position. The arrays never contained a repeated character.

There were 3 experimental factors, all manipulated within participants. These were a) target type (letters vs. symbols), b) target position (positions 1 to 5), and c) orientation of the array (horizontal vs. vertical). Following Aschenbrenner et al. (2017) we used "marquee" style (i.e., stimuli remain upright) for the vertical presentation condition (see Fig. 1). For each stimulus type, the main set of 180 arrays was divided into two subsets of 90 arrays each. One set appeared in vertical orientation, the other in horizontal orientation. The presentation of the two sets in vertical and horizontal orientation was counterbalanced across participants.

2.3. Apparatus and procedure

The experiment and data acquisition were controlled by E-Prime 2 software. Participants were seated in front of a computer screen at a distance of approximately 60 cm. Stimuli were displayed in black on a light gray background in 21-point Courier New font. For both vertical and horizontal displays, the center-to-center distance between adjacent characters subtended a visual angle of approximately 0.6°.

Participants read the instructions and went through a practice phase of 20 trials. Each trial began with a fixation cross which remained on the screen for 506 ms, followed by a blank screen 506 ms. Target strings

[1] The only, albeit limited, evidence for a first-letter advantage in the Castet et al. (2017) study can be seen in the post-cued and standard spacing condition of their Experiment 1, where the size of the effect might have been limited by a number of participants performing at ceiling.

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