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The Optimal Viewing Position effect in the lower visual field

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ABSTRACT

The Optimal Viewing Position (OVP) effect shows that word identification is best when the eyes first fixate near the centre of words. While this effect has been extensively studied in normal reading conditions, it has not been much investigated for words in the periphery. Here, we compared, in a perceptual identification task, the OVP effect for words presented either on the line of sight or in the lower visual field. Results confirmed the existence of an OVP effect for both central and vertically-shifted words but this effect was significantly weaker in the lower visual field. This finding provides further evidence for an important role of letter visibility in determining the shape of the OVP phenomenon. It also indicates that aligning the eyes with the centre of words is not as critical for vertically-shifted words. Implications for patients with central field loss who are forced to read in the periphery are discussed.

1. Introduction

Due to the drastic decrease of visual acuity on either side of the central, foveal part of the retina and the interference from adjacent stimuli, or visual crowding (Bouma, 1970), visual performance deteriorates very rapidly from the centre of the fovea towards the periphery. In normally sighted readers, poor resolution in the periphery is compensated for by the execution every about 200–250 ms of very brief saccadic eye movements. Although there is great variability in the eyes' landing position, saccades most often bring the fovea near the centre of peripheral words or slightly left of it (i.e. the preferred viewing position; Rayner, 1979); this allows words to be processed optimally during the intervening eye-fixation periods (i.e. the Optimal Viewing Position or OVP effect; O'Regan et al., 1984). However, in patients with central field loss as in Age-related Macular Degeneration (AMD) or Stargardt's juvenile macular disease, word processing can no longer proceed in the fovea, and it relies instead on information extracted in various parts of the remaining intact peripheral field (or Preferred Retinal Locus, PRL). Interestingly, while the position of the PRL of patients is not predictive of their reading performance (Fletcher, Schuchard, & Watson, 1999), processing in the lower visual field seems to be more advantageous, at least after training (Fine & Rubin, 1999; Nilsson, 1990; Petre et al., 2000). This suggests that there might also be an optimal locus for peripheral words to be recognised most efficiently. To provide further insight on this issue, but also in an attempt to better understand the origin of the OVP phenomenon, the present study tested whether words presented in the lower visual field benefit, just as foveal words, from being horizontally centred on the retina.

The OVP effect, investigated in a number of studies, tells how the initial horizontal placement of the eyes in a word constrains its identification and the subsequent eye movement pattern (for reviews see Brysbaert & Nazir, 2005; Rayner, 1998). Originally found during the reading of isolated words presented at variable horizontal locations relative to a previously displayed fixation point, and for limited vs. unlimited durations, the phenomenon was later found to generalise to natural reading, though being somewhat weaker (Vitu, O'Regan, & Mittau, 1990). The classical finding is that performance is best with the eyes near the centre of a word, or slightly left of it; the likelihood of correctly reporting a word is higher, and naming latency as well as lexical decision time are shorter when the eyes initially fixate near the centre of the word than when they start fixating the beginning or the end of the word. In a relative manner, the likelihood of refixating a word (i.e. of making an additional fixation on the word) is lower and the gaze duration (i.e. the total time the eyes remain on a word before moving to another word) is shorter when the eyes first fixate near the centre of the word than when they start fixating one of the word's ends.

The typical OVP curve is a U- or inverted-U shaped curve depending on the dependent variable; it is U-shaped for naming latency, lexical decision time, refixation probability and gaze duration, and inverted U-shaped when the probability of correct identification is measured. Irrespective of the dependent variable, the OVP curve has two main characteristics; the location of its minimum/maximum and its slope (i.e. how fast performance increases

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or decreases as the eyes fixate away from the optimal location). As revealed in isolated-word studies, the slope is relatively invariant. Reaction times (i.e. naming latency, lexical decision time and gaze duration) increase by about 20 ms per letter deviation from the optimal position. Reciprocally, when words are presented for a very short duration or for the time of a single fixation, the likelihood of correct identification, which is maximal near the centre of words drops by at least 10% per letter deviation from the optimal position (Nazir, O'Regan, & Jacobs, 1991; O'Regan, 1990; Stevens & Grainger, 2003). As reported by Brysbaert, Vitu, and Schroyens (1996), this also holds beyond the word boundaries that is even when words are displayed in the parafovea. The location of the minimum/maximum of the OVP curves is often slightly shifted to the left of the words' centre irrespective of their length. Still, the asymmetry of the curves tends to increase as words get longer which results in gradually steeper slopes for the right compared to the left half of the curves.

Different factors have been proposed to account for the shape and/or the asymmetry of the OVP effect observed in central vision: letter visibility, lexical constraints, reading habits and interhemispheric differences. These four factors are not necessarily mutually exclusive and may contribute jointly to word identification performance (for a review see Brysbaert & Nazir, 2005). The hypothesis that *letter visibility* plays a major role in the OVP effect is based on the drastic decrease of visual acuity, and reversely the strong increase of crowding when retinal eccentricity increases; given these, more letter information accumulates when the eyes' initial fixation falls near the centre of words. In accordance with this hypothesis, it has been shown that the bowl shape of the OVP effect, and possibly the asymmetry of the curves, can be captured by simply summing or multiplying the visibility from a given eye fixation location, of each of a word's individual letter. In a model first proposed by McConkie et al. (1989), letter visibility was derived from a linear visual acuity function which attributed an information value of 1 to the fixated letter, and an arbitrary drop-off rate of information of 0.1 for each additional letter deviation from fixation. This accurately predicted maximal word identification for fixations near the centre of words, but failed to reproduce the typical rightward bias of OVP curves. In a revised model, Nazir, O'Regan, and Jacobs (1991) proposed that the asymmetry of the effect arises from visual constraints specific to letter strings, thus suggesting that visual crowding, visual attentional processes and/or reading habits are also involved. In a letter discrimination task, they found in line with several other authors (Bouma, 1973; Legein & Bouma, 1977; Legge, Mansfield, & Chung, 2001 but see Stevens & Grainger, 2003), that the likelihood of correctly identifying a letter embedded in a string of homogeneous letters, decreases faster in the left compared to the right visual field. Based on these letter visibility scores, they successfully predicted typical OVP curves, with a steeper slope in the right compared to the left half of the words and a slight shift of the optimum of the curves to the left of the words' centre.

The hypothesis that *lexical factors* play a greater role in the OVP effect was proposed by Clark and O'Regan (1999). Their word identification model incorporates minimal letter visibility principles, but does not attribute the OVP effect to the amount of letter information which accumulates from various fixation locations. Rather, this is the level of lexical information carried by the set of extracted letters which is at the origin of the effect. If the centre of words is an optimal location for word identification, it is not because more letters can be extracted from this location, but it is because the extracted letters are shared by a smaller number of words in the lexicon (see also Stevens & Grainger, 2003). In their model, Clark and O'Regan (1999) computed a measure of lexical ambiguity for various theoretical fixation locations in words of variable length and frequency. Lexical ambiguity was defined as the number of words, in the French or the English vocabulary, which were compatible with only four letters of a given word, the ones a priori extracted during a fixation irrespective of its location (i.e. the two letters at fixation, which benefit from being centred on the fovea and the two most extreme letters of the word, which are less subject to visual crowding). The curves representing lexical ambiguity as a function of fixation location predicted the empirical OVP curves quite accurately; they were U-shaped, with a minimum slightly to the left of the words' centre and a steeper slope for the right compared to the left part of the words. Several findings further corroborated the lexical hypothesis by revealing slight variations of the location of the optimum of OVP curves with the informativeness of the words' initial letter sequence (Holmes & O'Regan, 1987; see also Farid & Grainger, 1996).

As originally proposed by Nazir (2000), reading habits, and more precisely *perceptual learning* may also contribute to determine both the shape and the asymmetry of OVP curves (see also Mishkin & Forgays, 1952; Nazir et al., 2004). According to her hypothesis, the variations of word identification performance with retinal location would be a consequence of the preferred viewing position effect or the tendency, in languages read from left to right, for the eyes to land more frequently near the centre of words or slightly left of it (Rayner, 1979). Left-to-right adult readers would be better at identifying words within the central, or right-to-central part of their visual field because they would have been adapted to visualise words in that part of their visual field while learning to read. In line with this hypothesis, it was found that unknown visual patterns presented repeatedly in one given part of the visual field can be recognized only at the learned retinal location but not at others (e.g. Nazir & O'Regan, 1990 but see Chung, Legge, & Cheung, 2004). In addition, it was shown that the OVP effect does not generalise to pseudo-words (i.e. pronounceable, non-word, string of letters) and that the right visual field advantage, which remains greater for words than pseudo-words, and for letters compared to symbols, is specific to left-to-right readers (Grainger, Tydgat, & Isselé, 2010; Nazir et al., 2004). Still, there is no clear leftward asymmetry of the OVP effect in languages read from right to left (e.g., Arabic or Hebrew native readers; Farid & Grainger, 1996; Nazir et al., 2004) as would be predicted by the perceptual learning hypothesis. This may be due to *inter-hemispheric differences*, the fact that the left cerebral hemisphere generally plays a greater role in language processing (Brysbaert, 1994, 2004). Indeed, Brysbaert (1994) showed a significant effect of cerebral dominance on the OVP effect, with more symmetrical OVP curves for participants with right-hemisphere language dominance.

Although lexical constraints, perceptual learning and inter-hemispheric differences certainly contribute to the OVP effect, some findings suggest a predominant role of visual constraints. First, neither the slopes nor the location of the optimum of OVP curves varies with word frequency (O'Regan & Jacobs, 1992; see also O'Regan & Lévy-Schoen, 1987; Vitu et al., 2001), while some variations would be expected at least under lexical and possibly perceptual-learning hypotheses. On the other hand, in line with the visual hypothesis, it has been demonstrated that the shape of OVP curves varies with the visual characteristics of the stimuli. Nazir, Heller, and Sussmann (1992) varied inter-letter spacing and showed that the slopes of the curves became gradually greater as spacing, and hence the eccentricity (or the visibility) of each letter increased (decreased). Nazir, Jacobs, and O'Regan (1998) scaled letters in words proportionally to their distance to the fixation location, and found flatter OVP curves. However, the weakening of the effect was found only for short, 5-letter words, but not for longer words of 9 letters, thus violating the predictions of the visual model in that specific case. This finding can be reconciled with the visual account only if, as proposed by the authors, perceptual