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VISUAL SEARCH FOR LETTERS IN THE RIGHT VS. LEFT VISUAL HEMIFIELDS: THE ROLE OF PERCEPTUAL LOAD AND SET

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VISUAL SEARCH FOR LETTERS IN THE RIGHT VS. LEFT VISUAL HEMIFIELDS: THE ROLE OF PERCEPTUAL LOAD AND SET

The aim of the study was to better understand interconnection of visual attention, word processing and visual field asymmetries. Three experiments investigated visual search for a prespecified letter in displays containing 6-letter words or nonwords placed 7 degrees left and right to the fixation, with a variable target letter position within word and nonword strings. In Experiment 1, two letter strings of the same type (either words or nonwords) were presented to both sides of the visual field. In Experiment 2, there was only one letter string presented right or left to the fixation. In Experiment 3, two letter strings presented to both sides of the visual field were of different type (one word and one nonword). RT and accuracy data were collected. The results of Experiment 1 provide evidence for serial search for a letter within a word in the left visual field (LVF) and within a nonword in the right visual field (RVF) and parallel search for a letter within a nonword in the LVF and within a word in the RVF. The results of Experiment 3 were similar except for serial search for words in RVF. In Experiment 2, where perceptual load was twice lower, the search within both types of letter strings in both hemifields was serial. These results demonstrate the influence of the perceptual load and readiness to process a certain type of letter string, on the observers' choice of search strategy.

JEL Classification: Z.

Keywords: visual search, visual attention, left/right visual field asymmetry, perceptual load, word superiority effect

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Introduction

Among the important issues in the studies of high-level processes in human vision are the mechanisms of reading and processing of lexical stimuli. On the one hand, in this research domain there is an area of investigations grouping around the role of attention in the processing of embedded visual stimuli, such as letters within words (e.g. Johnston & McClelland, 1974; Salvemini et al., 1998; Fine, 2001; Falikman, 2011) and words within sentences (Potter, Nieuwenstein, & Strohminger, 2006; Barber, Ben-Zvi, Bentin, & Kutas, 2011). On the other hand, experimental studies of visual word processing might lead to new insights into the mechanisms of dyslexia (e.g. Grainger, Bouttevin, Truc, Bastien, & Ziegler, 2003). What's also interesting about lexical stimuli is functional specialization and functional asymmetry of human brain creating visual field asymmetry for spatially distributed stimuli.

Visual field asymmetries refer to differences in the processing of stimuli presented in different parts of visual field. There are three types of visual field asymmetries reported in the literature: left/right visual hemifield asymmetries, temporal/nasal visual hemifield asymmetries and upper/lower visual hemifield asymmetries (e.g. Michael & Ojeda, 2005). Left/right asymmetry is the most relevant to the studies of lexical information processing. According to Bever (1975), left-to-right cerebral asymmetries of mental functions are due to the two kinds of processes in the brain: analytic and holistic. Analytic processing is mostly lateralized to the left hemisphere and unfolds successively (e.g. letter-by-letter reading). Holistic processing is mostly lateralized to the right hemisphere and is simultaneous for all elements to be processed (e.g. whole-word reading). Although in both auditory and visual language processing both kinds of processes and both hemispheres are involved (Lindell, 2006), specialized language processing zones, starting from the visual word form area (VWFA) and finishing with Broca's and Wernicke's areas, are located in the left hemisphere in the majority of right-handed population.

Left/right visual hemifield asymmetry has been investigated in a number of studies on different perceptual phenomena. One of the most important questions is whether both hemispheres participate in selective attention and whether they contribute alike. The first PET studies (Corbetta, Miezin, Shulman, & Petersen, 1993, 1995), together with the analysis of attentional deficits in patients with unilateral visual neglect (Husain, Shapiro, Martin & Kennard, 1997), suggest the dominance of the right hemisphere as a substrate of visual attention, the idea further supported by fMRI studies (Woiciulik & Kanwisher, 1999). At the same time, bilateral attentional advantage was found for multiple object tracking (Alvarez & Cavanagh, 2005), crowding (Chakravarthi & Cavanagh, 2009) and elementary visual tasks (Reardon, Kelly, & Matthews, 2009). These results provide evidence for independent attentional resources for the left and right hemispheres, a hypothesis supported by transcranial magnetic stimulation study of multiple object tracking in healthy observers (Battelli, Alvarez, Carlson, & Pascual-Leone, 2009).

Nevertheless, taken together, the data on the independence of attentional systems for the right and left hemispheres are quite controversial. Bilateral attentional advantage was not found for visual search in healthy subjects (Luck, Hillyard, Mangun, & Gazzaniga, 1989). A recent study by Alvarez, Gill and Cavanagh (2012) showed hemifield independence in visual search task for location-based selection but not for feature-based selection. In addition, unilateral field advantage was found for detecting repeated elements (Butcher, Cavanagh, 2008) and for detecting matched motion paths (Butcher, Cavanagh, 2005).

Of special importance is a question of RVF/LVF asymmetry in the visual perception and attention to different categories of stimuli. There is an established fact that verbal stimuli are identified more easily when presented in the right visual hemifield (left hemisphere) and nonverbal stimuli are identified more easily when presented in the left visual hemifield (right hemisphere) (e.g. Levine & Koch-Weser, 1982). RVF (left hemisphere) advantage was found for word naming (Scott & Hellige, 1998), word recognition under random spatial frequency sampling (Tadros, Dupuis-Roy, Fiset, Arguin, & Gosselin, 2013), and other visual-verbal tasks.

Lexical decision experiments usually show word length effects for words presented in the LVF but not for words presented in the RVF. Recognition is affected more by word length for words in the LVF than for words in the RVF (e.g. Ellis, Young, & Anderson, 1988; Whitney & Lavidor, 2004). In contrast, Jordan, Patching and Milner (2000) found identical serial position effects for both visual fields in the Reicher-Wheeler task in which a participant has to identify a letter either embedded in a backward-masked word or in a random letter string or presented separately using a 2-AFC procedure (Reicher, 1969; Wheeler, 1970). In a recent study by Lavidor and Bailey (2005) serial position and word length effects were compared in two different tasks – lexical decision and visual search. For the visual search task, performance in both hemifields showed similar effects of serial position. In the lexical decision task, response times to RVF words were not affected by the amount of letters, but the amount of letters had a significant effect on LVF performance. These results indicate that the effects of serial position and of a number of letters in the two visual fields are modulated by the task. Whereas letter-level processing (visual search and the Reicher-Wheeler tasks) may be similar in both hemifields, the whole-word processing (lexical decision task) reveals qualitative differences between the hemifields.

A recent study by Madrid, Lavie and Lavidor (2010) showed that the effect of lexicality on distractor processing in letter search task was stronger for words presented to the left compared to the right hemifield. According to N. Lavie's Perceptual Load Theory of attention (Lavie, 1995), the selection occurs earlier when the load is high and later when the load is low. There is a body of evidence from previous research (e.g. Rees, Frith, & Lavie, 1997; Lavie & Cox, 1997) demonstrating that irrelevant distractors can be ignored in tasks with high perceptual load, but not in tasks with low perceptual load. A study by Brand-D'Abrescia and Lavie (2007) showed that the number of letters in a search task raises perceptual load and reduces irrelevant distractor effects for search within nonwords but not within words. Thus the results of Madrid, Lavie and Lavidor support the attentional load hypothesis as regards visual word recognition and RVF/LVF asymmetry. Previous studies have demonstrated that visual attention interacts with word processing and, in particular, with the word superiority effect, using a number of perceptual and attentional paradigms, such as lateral masking (Fine, 2001), metacontrast masking (Luiga, Bachmann, & Põder, 2002), the attentional blink (Falikman, 2002; Gorbunova, Falikman, 2010), simultaneity judgements (Pechenkova & Sinitsyna, 2009), spatial cueing (Gorbunova & Falikman, 2012), although not in all tasks presumably involving visual attention (for a motion-induced blindness study see Devyatko & Falikman, 2008). Using the spatial cueing paradigm, study we presented words, pseudowords and nonwords left and right to the fixation and asked participants to shift attention to the letter string following the central cue which was correct 75% of trials. The observers were instructed to identify a letter in a letter string using a 2-AFC paradigm (Reicher, 1969; Wheeler, 1970). Our study didn't reveal any differences in processing between left and right hemifields, although there were differences in the word and pseudoword processing after valid and invalid cues. Whereas valid cues led to both word and pseudoword superiority, thus emphasizing the role of orthographic regularity in the word superiority effect, invalid cues provided for word superiority only, revealing the role of the word familiarity under inattention. At the same time, none of these studies manipulated attentional load (e.g. the total amount of stimuli in the entire visual field), whereas one might expect its contribution to the word superiority effect, given that the attentional load influences multiple stages of visual processing (Lavie, Beck et al., 2014).

The word superiority effect has previously been obtained for letter search in word strings (Krueger, Keen, & Rublevich, 1974; Johnson & Carnot, 1990). However, earlier we failed to find a pronounced word superiority effect in the study of letter search in words and nonwords among other words or nonwords distributed over the display (Pantyushkov, Horowitz & Falikman, 2008). What we did observe where a somewhat faster search within a word, a finding supporting earlier results by Johnson & Carnot (1990), and a faster word rejection as a distractor string not containing a target letter.

The discrepancies in the letter search data, not providing a clear answer whether visual search for an embedded letter might be efficient, together with a remaining controversy in the data about

RVF/LVF asymmetry in the letter search in various types of letter strings (words and nonwords) containing a target letter, prompted us to investigate into the interaction of search strategies, visual hemifields and perceptual load. We manipulated these factors in three experiments.

Experiment 1

In the first experiment we investigated visual search for letters within words and nonwords in the right and the left visual hemifields. In each trial two letter strings were presented – one in the RVF and one in the LVF. The participants were instructed to search for a single letter prespecified in the beginning of each trial, while maintaining central fixation. We hypothesized that search for letters in words will be more efficient compared to nonwords. We also expected a left-right visual hemifield asymmetry in this task.

Method

Participants

27 right handed volunteers, students and graduates of Lomonosov Moscow State University and other universities in Moscow participated in the study. Results of 5 participants were excluded due to the extremely slow RTs (more than M + SD). The final data set included results from 22 participants, 3 male and 19 female. All of them were native Russian speakers with normal or corrected to normal vision. The age varied between 17 and 28 y.o. (M = 20,1). All participants were naive to the experimental hypothesis.

Stimuli

The target was either the 2nd or the 5th letter in a string of six Cyrillic letters. The string could be a word or a nonword. The words were 6-letter nouns from the Frequency Dictionary of Russian language[3], balanced across frequency. Nonwords were constructed from these words by letter transposition and could not be recognized as words. 288 words and 288 nonwords were used. All words and nonwords were presented in black against a gray background. All letters were presented in upper case. A target letter was presented 7,326 degrees to the right or to the left from the fixation (no matter if it was the second or the fifth letter in the string). The string size was 3,043 degrees of visual angle horizontally and 0,818 degree vertically.

Procedure

The experiment was performed using a computer tachistoscope TX 4.01 (https://psy-journal.hse.ru/en/2014-11-4/139186576.html). A PC with Mitsubishi CRT monitor and video card NVidia GeForce 4mx was used at a refresh rate of 120 Hz. A special console for recording

[3] The dictionary by Lyashevskaya & Sharov is available online at: http://dict.ruslang.ru/freq.php

RT data from lpt port was used. Participants were sitting in the dark room, a chin rest maintained a viewing distance of 70 cm. The experiment consisted of 576 trials, divided into four parts with short breaks between them. In 192 trials the target was not present (catch trials, not further analyzed in the data analysis), the other 384 trials were distributed between different conditions, 48 trials for each combination of three independent variables (visual hemifield, letter string type, target letter position). The order of presentation was randomized.

The experiment was run individually. Each trial began with a 2000 ms target letter presentation at the center of the screen. The target letter was set separately for each trial. After that, a fixation cross was presented for 1000 ms in the center of the screen, and a participant was instructed to focus on it. The fixation display was followed by presentation of two letter strings 6,92 degrees to the left and to the right from the center of the screen. These two letter strings were of the same type (both were either words or nonwords). Any one of the strings could contain the target letter. The participant's task was to find the target as fast as possible and to press a key on the console. In case the target letter was not present a participant had to press another key. Letter strings remained on the screen until response. Trial design is shown in *Figure 1*. A training session of 10 trials preceded the experiment.

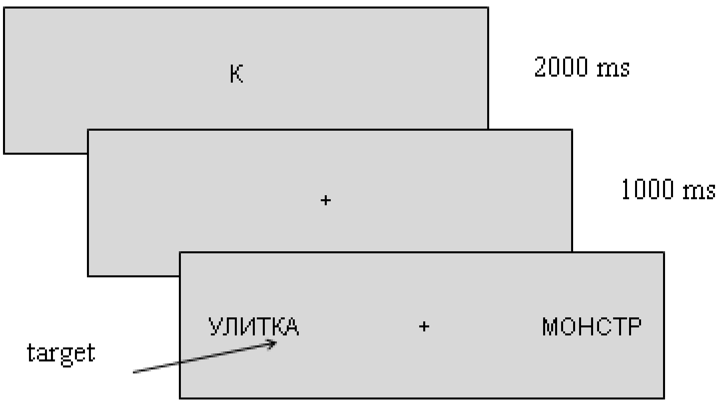

Figure 1. Trial design in Experiment 1 (target-present, words trial). "УЛИТКА" is a Russian word for "snail", "МОНСТР" is a Russian word for "monster".

Results

RTs and accuracy for different conditions were compared. RTs longer than three standard deviations above the mean were excluded from the analysis. There were no RTs shorter than three standard deviations below the mean. Trials with incorrect responses (7,54% of the overall data) were excluded from the RT analysis. Data analysis was performed using SPSS 17.0. Multivariate repeated measures analysis of variance (rmANOVA) was used. The first factor was visual hemifield (left or right), the second factor was letter string type (word or nonword) and the third factor was target position (second or fifth letter in the string). Pairwise comparisons for different target positions for each type of letter strings and each hemifield separately were also performed.

RTs

The mean RTs from target-present trials are presented in the *Figure 2*. The rmANOVA revealed a main effect of visual field, $F(1,21) = 21.94$, p =.001, a main effect of string type (lexicality), $F(1,21) = 54.64$, $p = .001$, and a main effect of target position, $F(1,21) = 24.83$, $p = .001$. The interaction between visual field and lexicality was not significant, $F(1,21) = 2.12$, $p = .160$, as well as the interaction between visual field and target position, $F(1,21) = .12$, $p = .734$, and the interaction between lexicality and target position, $F(1,21) = 1.46$, $p = .240$. The three-way interaction was significant, $F(1,21) = 12.71$, $p = .002$.

Pairwise comparisons revealed significant differences for target letters within words on the second position ($M = 806.53$, $SD = 148.78$) and on the fifth position ($M = 875.86$, $SD = 158.74$) in the LVF, $F(1,21) = 27.37$, $p = .000$, and also for target letters within nonwords on the second position ($M = 1087.41$, $SD = 242.42$) and on the fifth position ($M = 1179.34$, $SD = 280.11$) in the RVF, $F(1,21) = 21.44$, $p = .000$. No other significant effects were found.

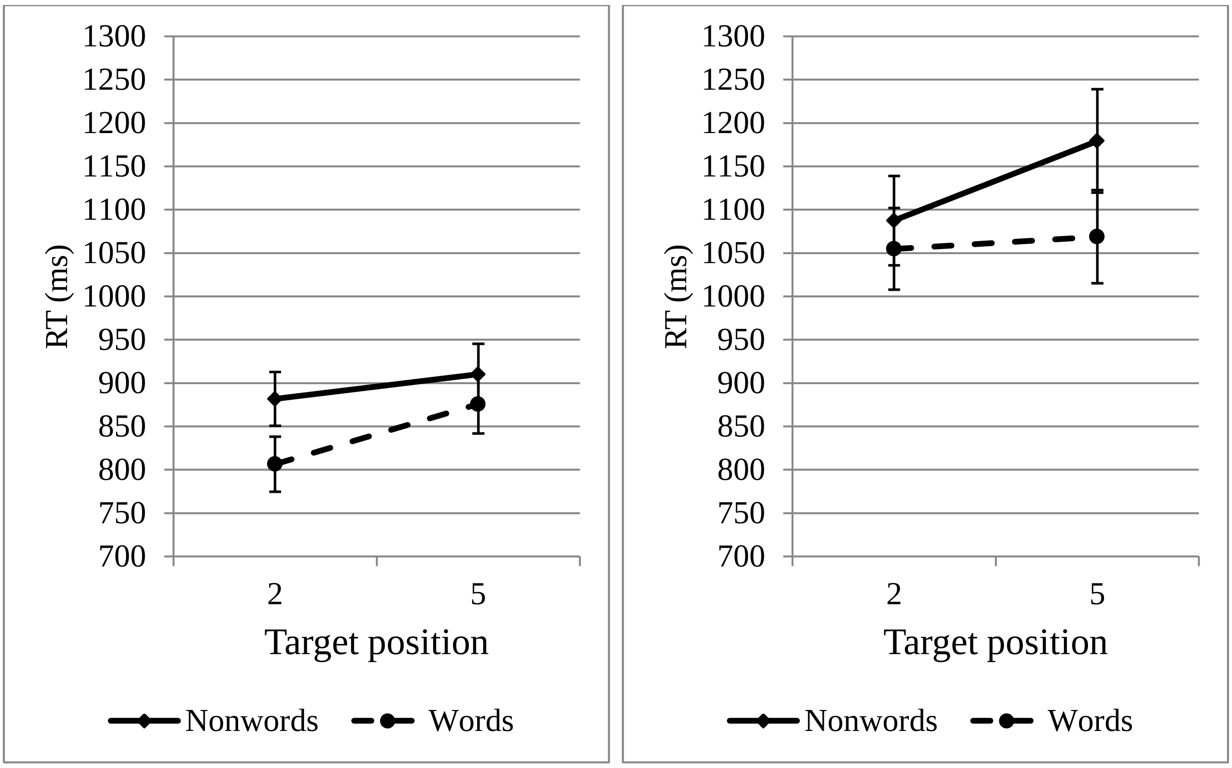

Figure 2. RT data for Experiment 1 for LVF (on the left) and for RVF (on the right). Error bars indicate standard errors of mean.

Accuracy

The accuracy data is presented in the *Figure 3*. The ANOVA revealed the main effect of visual field $F(1,21) = 4.81$, $p = .040$ and the main effect of string type $F(1,21) = 6.92$, $p = .016$. There was no main effect of target position $F(1,21) = 0.53$, $p = .477$. The interaction between visual hemifield and target position was significant $F(1,21) = 9.18$, $p = .006$. The interaction between visual hemifield and string type was not significant $F(1,21) = 0.02$, $p = .884$, as well as the interaction between string type and target position $F(1,21) = 0.02$, $p = .901$. The three-way interaction was significant $F(1,21) = 8.33$, $p = .009$.

Pairwise comparisons revealed significant differences for targets within nonwords on the second position ($M = 94.06$, $SD = 6.37$) and on the fifth position ($M = 91.36$, $SD = 6.26$) in the RVF, $F(1,21) = 6.23$, $p = .021$. No other significant effects were found. The results (including detailed pairwise comparisons) are presented in the *Tables 1-4*.

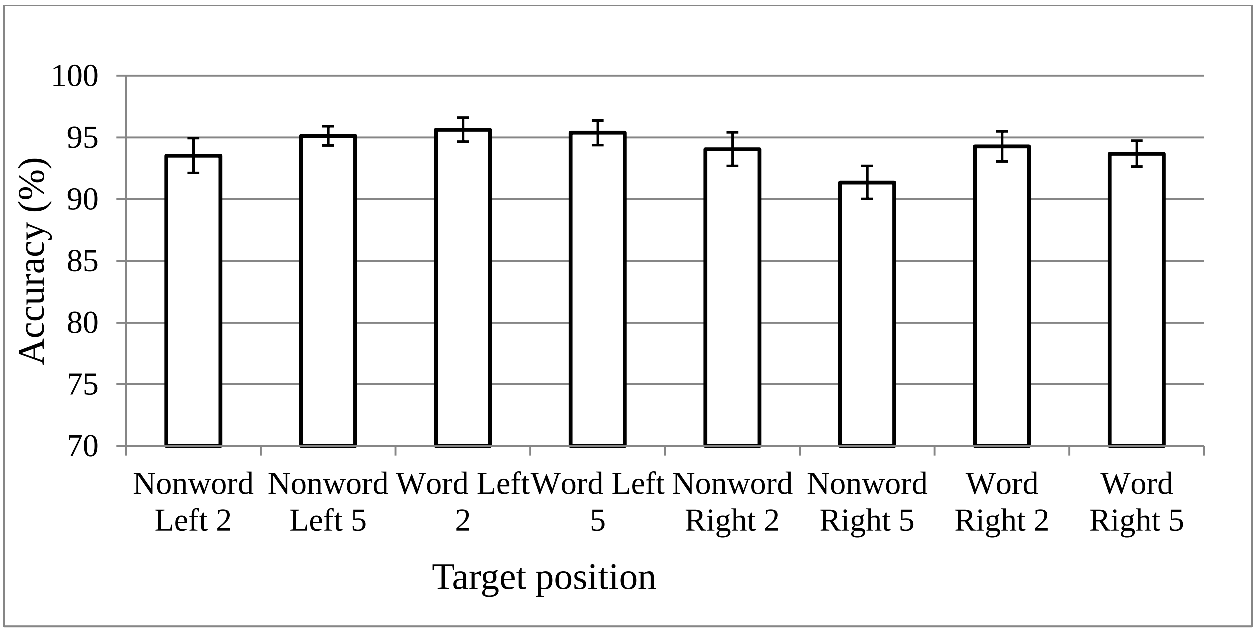

Figure 3. Accuracy data for Experiment 1. Error bars indicate standard errors of mean.

Discussion

The experiment revealed shorter RTs and better accuracy for words compared to nonwords thus providing support for the word superiority effect. This result is inconsistent with the results of an earlier study by Pantyushkov, Horowitz and Falikman (2008) who did not observe word superiority effect in visual search. This result can be attributed to the differences in the number and arrangement of stimuli used in that study: in each trial several (3, 7 or 10) letter string were presented at random locations on the display. In our current study only two letter strings were presented at the predictable locations. The recent study by Starrfelt, Petersen, & Vangkilde

(2013) did not reveal any word superiority when multiple stimuli were presented simultaneously. Thus the absence of the word superiority effect in the experiment by Pantyushkov et al., 2008 could be related to the reduction of visual working memory capacity for complex objects.

The mean RT for stimuli in the LVF was shorter as compared to the RVF. Accuracy was also higher for LVF as compared to RVF. This result might be related with left-to-right reading strategy due to which subjects started searching in the LVF and then proceeded to the RVF. The significant effect of target position for words in the LVF and for nonwords in the RVF suggests serial search. In contrast, no significant effect of target position for nonwords in the LVF and for words in the RVF suggests parallel search. These results might reveal differences between novel and familiar stimuli processing. For novel stimuli (nonwords), hemispheric information processing strategies (Bever, 1975) play the most important role. As holistic information processing is characteristic of the right hemisphere, the search within nonwords presented in the LVF is parallel. On the other hand, successive informational processing characteristic of the left hemisphere leads to serial visual search within nonwords in the RVF. In contrast, for familiar stimuli (words), top-down influences based on the observer's experience are more important than hemispheric information processing strategies. Processing units for the right hemisphere (LVF) are single letters as holistic configurations, which leads to serial search within words in LVF. The left hemisphere (RVF) is linked to lexical information processing and might process words as wholes, which leads to parallel search within words presented in RVF.

Our results are inconsistent with the results of Lavidor & Bailey (2005) who found positional effects for words in RVF in visual search task. However, this discrepancy in results might be attributed to the differences in perceptual load (Lavie, 1995, 2005). In Lavidor & Bailey's experiment one letter string was presented in one of the hemifields in each trial, whereas in our study two letter strings were presented one in each hemifield. Another possibility is that parallel search within words in RVF is partly due to presetting, i.e. an observer's readiness to process a particular type of stimuli (e.g. Osugi & Kawahara, 2013).

Experiment 2

In the second experiment we investigated the role of perceptual load in visual search for letters within words and nonwords in the right and the left visual hemifields. In each trial only one letter string was presented either in the RVF or in the LVF. From previous results by Lavidor & Bailey (2005) we expected serial search within both types of letter strings in both hemifields.

Method

Participants

20 right handed students and graduates of Lomonosov Moscow State University and other universities in Moscow participated in the study. None of them participated in Experiment 1. Results of 1 participant were excluded from the further analysis due to slow RTs (more than M + SD). The final data set included data from 19 participants, 8 male and 11 female. The age varied between 17 and 35 (M = 21,3). All participants were native Russian speakers, and had normal or corrected to normal vision. All were naive to the experimental hypothesis.

Stimuli

The stimuli were the same as in Experiment 1, except for that within each trial only one letter string was presented either in the LVF or in the RVF.

Procedure

The procedure was the same as that in Experiment 1. Trial design is shown in the *Figure 4.*

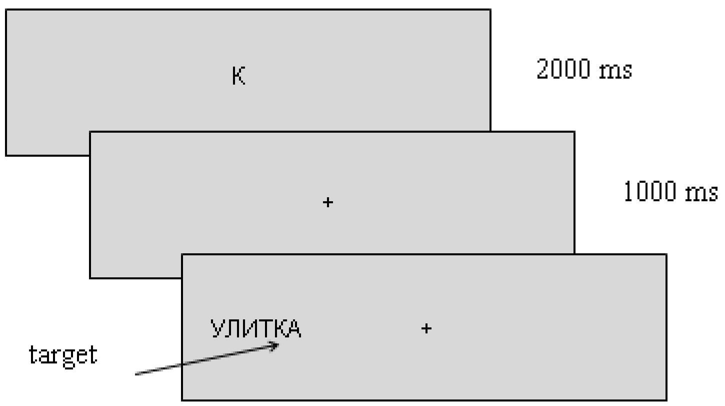

Figure 4. Trial design in Experiment 2 (target-present, words trial).

Results

RTs and accuracy for different conditions were compared. RTs longer than three standard deviations above the mean were excluded from the analysis. There were no RTs shorter than three standard deviations below the mean. Trials with incorrect responses (7,79% of the overall data) were excluded from the RT analysis. Data analysis was performed using SPSS 17.0. Multivariate repeated measures analyses of variance (rmANOVA) was used. The first factor was visual hemifield (left or right), the second factor was lexicality (word or nonword) and the third factor was target position (second or fifth letter in the string). Pairwise comparisons for two target positions for each type of letter strings and each hemifield separately were also performed.

RTs

The mean RTs from target-present trials are presented in *Figure 5*. The rmANOVA revealed a main effect of the letter string (lexicality), $F(1,18) = 44.33$, $p = .000$, and also a main effect of the target position, $F(1,18) = 39.03$, $p = .000$. The effect of visual field was not significant,

$F(1,18) = 0.06$, $p = .813$. The interaction between visual field and target position was significant, $F(1,18) = 14.76$, $p = .001$, as was the interaction between string lexicality and target letter position, $F(1,18) = 5.64$, $p = .029$. The interaction between visual field and lexicality was not significant, $F(1,18) = 3.03$, $p = .099$. The three-way interaction was also insignificant, $F(1,18) = 0.78$, $p = .389$.

Pairwise comparisons revealed significant differences for all compared conditions.

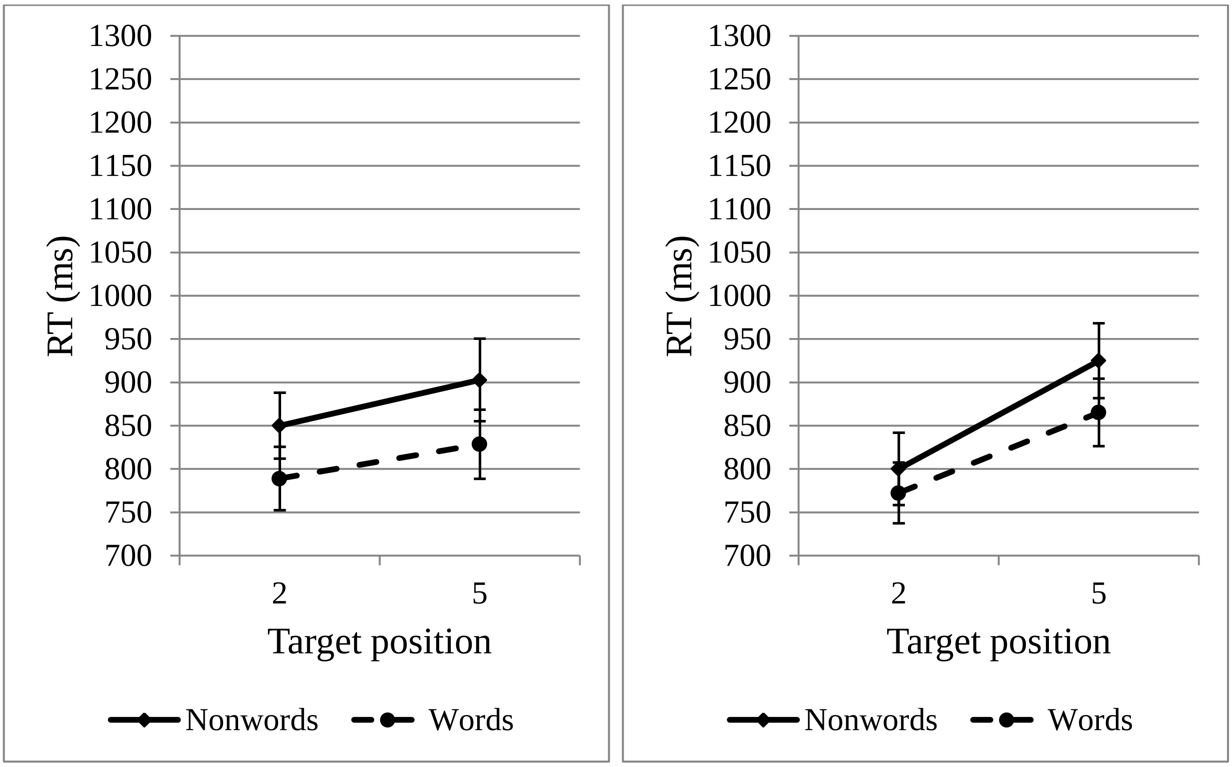

Figure 5. RT data for Experiment 2 for LVF (on the left) and for RVF (on the right). Error bars indicate standard errors of mean.

Accuracy

The accuracy data is presented in *Figure 6.* The rmANOVA revealed the main effect of visual field, $F(1,18) = 7.32$, $p = .014$. The effect of letter string (lexicality) was non-significant, $F(1,18) = 1.96$, $p = .179$, as was the effect of target position, $F(1,18) = 3.793$, $p = .067$. The interaction between visual field and target position was significant, $F(1,18) = 4.96$, $p = .039$. The interaction between visual field and lexicality was non-significant, $F(1,18) = 0.02$, $p = .903$, as was the interaction between lexicality and target position, $F(1,18) = 1.51$, $p = .235$. The three-way interaction was not significant, $F(1,18) = 1.77$, $p = .200$.

Pairwise comparisons revealed no significant effects of target position.

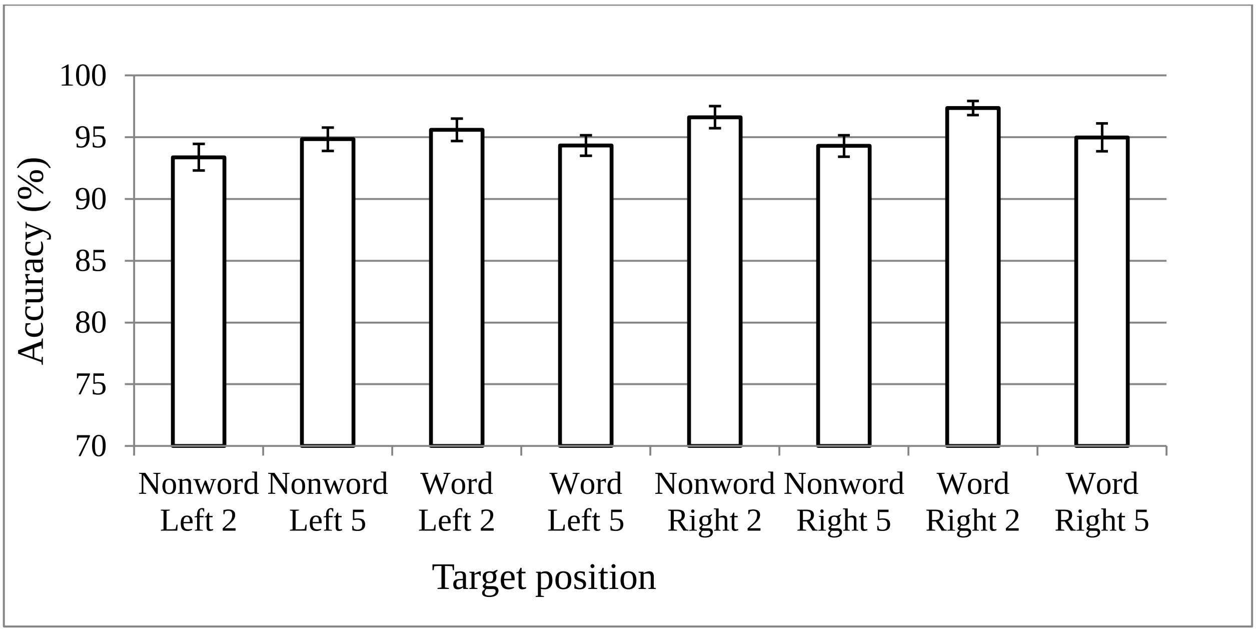

Figure 6. Accuracy data for Experiment 2. Error bars indicate standard errors of mean.

The results (including detailed pairwise comparisons) are presented in the *Tables 5-8*.

Discussion

The experiment once again revealed shorter RTs for words compared to nonwords, the result consistent with those obtained in Experiment 1. The effect of visual hemifield was not significant in this experiment due, which means that the contribution of the left-to-right reading strategy to the processing of letter strings was successfully equalized for both hemifields.

Significant interaction between the visual hemifield and the target position reflects less efficient search in RVF as compared to LVF regardless of the string type. This result is inconsistent with the data obtained in many experiments (Ellis et al., 1988; Madrid et al., 2010), where shorter RT were found for lexical stimuli in RVF as compared to LVF. Nevertheless, in our experiment RVF demonstrated better accuracy as compared to LVF (regardless of the string type), so this result may be due to the speed-accuracy trade-off (Fitts, 1954): improving the response accuracy leads to speed reduction.

Significant differences revealed by pairwise comparisons for different target positions regardless of the string type and the visual field suggest serial search in all four conditions: words in LVF, nonwords in LVF, words in RVF and nonwords in RVF. These position effects are consistent with the results of Lavidor & Bailey (2005) and support our hypothesis about the influence of perceptual load on the strategy of visual search for letters within words and nonwords in the right and the left visual hemifields. We suggest that the use of different search strategies (parallel or serial search for various string types and visual hemifields) depends of the number of stimuli in the visual field (perceptual load which was twice higher in Experiment 1 as compared to Experiment 2). Parallel search could be the result of the visual system overload. When the perceptual load is low (one letter string in either LVF or RVF, Experiment 2) serial search is a reasonable default option, but when the perceptual load is high (one letter string in each hemifield at the same time, Experiment 1) it would be more efficient to choose a search strategy depending on the string type and the hemisphere specialization.

Still, the question remains whether the parallel search within words in RVF in Experiment 1 was due to the letter string lexicality itself, or the visual system was to be preset or primed for words to take advantage of the more efficient mode of processing.

Experiment 3

In the third experiment we investigated the role of set for the processing of a particular type of a letter string in visual search for letters within words and nonwords in RVF. In experiment 1 we found parallel search for letters within words in RVF, which we believed to be due to top-down influences in word processing. In Experiment 3, we examined whether these influences could be at least partly related to presetting, i.e. readiness to process a letter string of a particular type (a word of an observer's native language). When starting to search for a target letter within the first letter string in LVF in Experiment 1, an observer might expects to find the same type of string in RVF and prepares to involve available processing mechanisms. We modified the procedure so that in each trial two letter strings were presented – one in the RVF and one in the LVF (as in Experiment 1), but unlike Experiment 1 these strings were of different type (one of them was a word and the other was a nonword).

Method

Participants

27 right handed students and graduates of Lomonosov Moscow State University and some other universities participated in the study. None of them participated in Experiment 2, one participated in Experiment 1 (the interval between the experiments was 13 months). Results of 4 participants were excluded due to slow RTs (more than M + SD). The final data set included results from 23 participants, 9 male and 14 female. Their age varied between 17 and 25 (M=20,3). All of them were naive to the experimental hypothesis, were native Russian speakers, and had normal or corrected to normal vision.

Stimuli

The stimuli were the same as in Experiment 1 except that two letter strings presented in each trial were of different type (one of them a was word and another one was a nonword).

Procedure

The procedure and the timeline were the same as in Experiment 1.

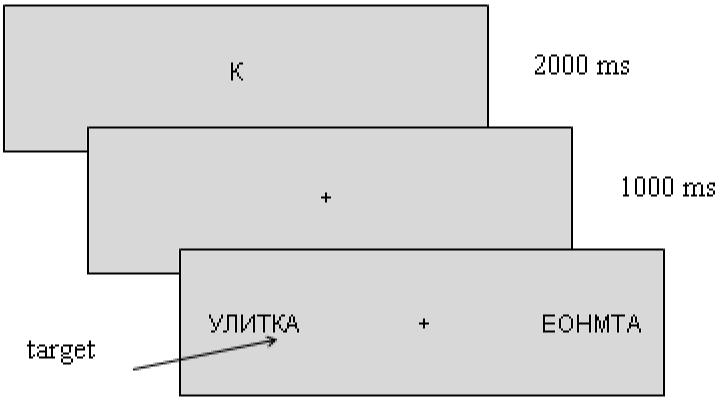

Figure 7. Trial design in Experiment 3 (target-present trial). "EOHMTA" is a nonword.

Results

RTs and accuracy in all conditions were compared. RTs longer than three standard deviations above the mean were excluded from the analysis. Again, there were no RTs shorter than three standard deviations below the mean. Trials with incorrect responses (7,26% of the overall data) were excluded from the RT analysis.. Data analysis was performed using SPSS 17.0. Multivariate repeated measures analyses of variance (ANOVA) was used. The first factor was visual hemifield (left or right), the second factor was lexicality (word or nonword) and the third factor was target position (second or fifth letter in the letter string). Pairwise comparisons for different target positions for each type of letter strings and each hemifield were also performed separately.

RTs

The mean RTs from target-present trials are presented in the *Figure 8*. The rmANOVA revealed a main effect of visual field $F(1,22) = 40.39$, $p = .000$, a main effect of string type (lexicality) $F(1,22) = 44.89$, $p = .000$, and a main effect of target position $F(1,22) = 61.78$, $p = .000$. The interaction between visual field and target position was significant $F(1,22) = 10.00$, $p = .005$. The interaction between visual field and lexicality was non-significant $F(1,22) = 3.42$, $p = .078$, as was the interaction between lexicality and target position $F(1,22) = 0.15$, $p = .701$. The three-way interaction was significant $F(1,22) = 4.86$, $p = .038$.

Pairwise comparisons revealed significant differences for target letters within words on the second position ($M = 796.74$, $SD = 151.82$) and on the fifth position ($M = 853.4$, $SD = 143.11$) in the LVF, $F(1,22) = 19.65$, $p = .000$, for target letters within nonwords on the second position ($M = 1080.83$, $SD = 206.12$) and on the fifth position ($M = 1186.92$, $SD = 255.28$) in the RVF, $F(1,22) = 28.28$, $p = .000$, and for word targets on the second position ($M = 1067.88$, $SD =$

227.52) and on the fifth position (*M* = 1143.55, *SD* = 234.68) in the RVF, *F*(1,22) = 33.33, *p* = .000. The difference for nonword targets on the second position (*M* = 874.92, *SD* = 156.76) and on the fifth position (*M* = 890.90, *SD* = 162.09) in the LVF was not significant, *F*(1,22) = 0.98, *p* = .333.

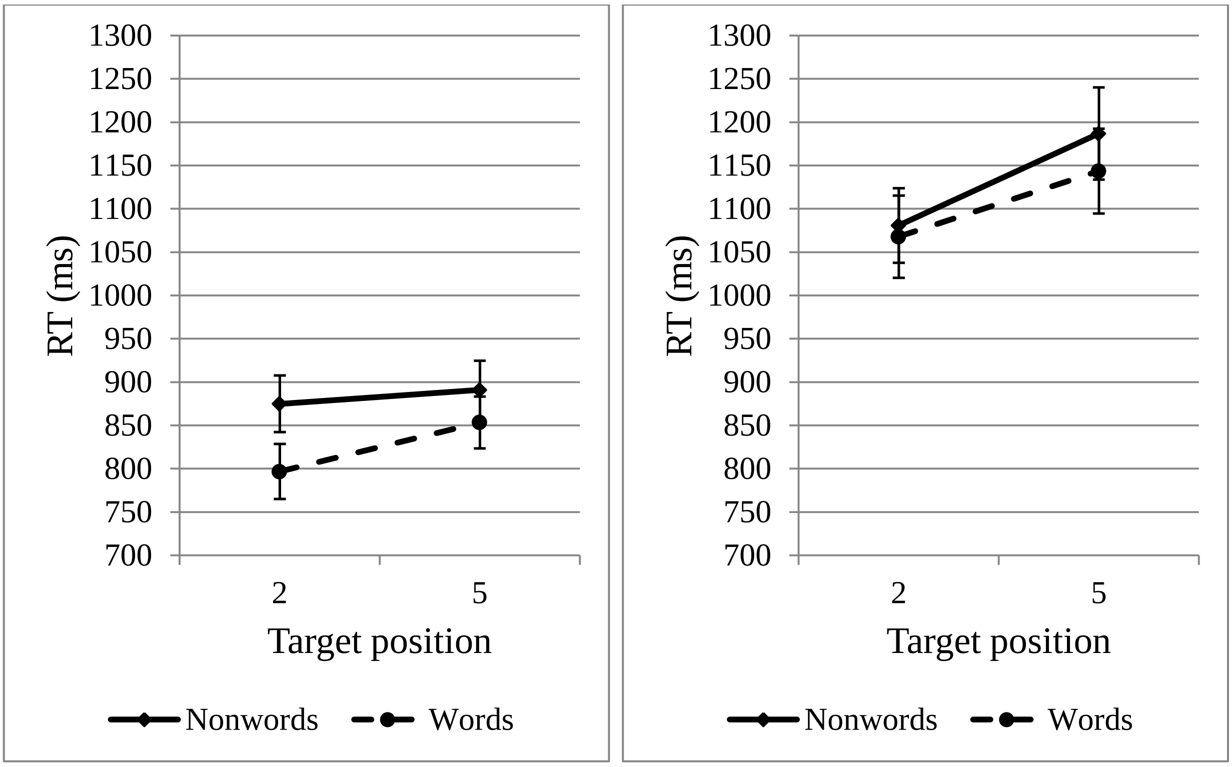

Figure 8. RT data for Experiment 3 for LVF (on the left) and for RVF (on the right). Error bars indicate standard errors of mean.

Accuracy

The accuracy data is presented in *Figure 9.* The rmANOVA revealed the main effect of string type (lexicality) *F*(1,22) = 8.62, *p* = .008. There was no main effect of visual field *F*(1,22) = 2.03, *p* = .168, and no main effect of target position *F*(1,22) = 1.14, *p* = .298. The interaction between visual field and lexicality was not significant *F*(1.22) = 0.29, *p* = .595, just as the interaction between visual field and target position *F*(1,22) = 3.04, *p* = .095, and the interaction between lexicality and target position *F*(1,22) = 0.42, *p* = .526. The three-way interaction was also non-significant *F*(1,22) = 0.001, *p* = .982.

Pairwise comparisons did not reveal any significant differences.

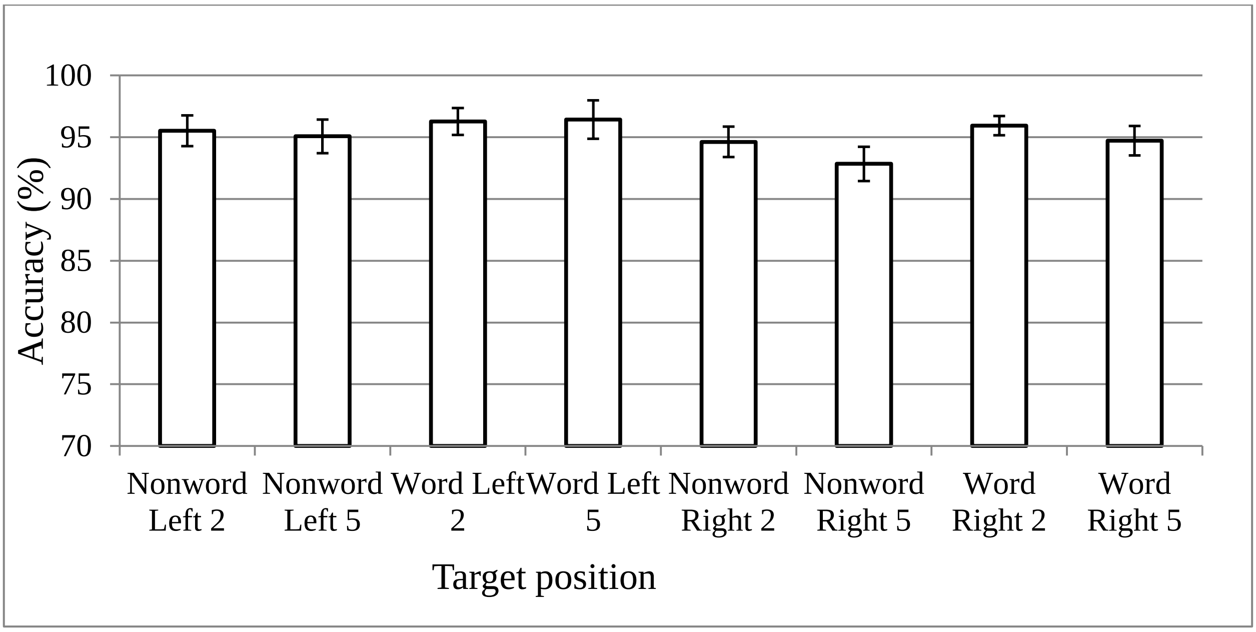

Figure 9. Accuracy data for Experiment 3. Error bars indicate standard errors of mean.

The results are presented in the *Tables 9-12*.

Discussion

The experiment again demonstrates shorter RTs and better accuracy for words compared to nonwords. This result is consistent with the results of both Experiment 1 and Experiment 2. The mean RT to targets in the LVF was shorter as compared to the RVF. This result is consistent with the result of Experiment 1, which we explained by the left-to-right reading strategy. The significant effect of target position for words in the LVF and for nonwords in the RVF suggests serial search in these conditions. No significant effect of target position for nonwords in the LVF suggests parallel search in this condition. These results are also consistent with the results of Experiment 1.

However, the significant effect of target position for words in the RVF, which diverges from the results of Experiment 1, but consistent with our hypothesis, provides evidence for serial search in this condition. We believe that this lack of parallel search within words in the RVF might be due to presetting. The overall pattern of results suggests that the search always begins in the LVF. In the trials containing a word in the RVF, the LVF contains a nonword. An observer starts searching in the LVF and then proceeds to the RVF, with his/her visual system being primed to process a letter string of the same type as was in the LVF. Then it might be assumed that the search strategy remains the same in spite of the string type change. Unlike Experiment 1, single letters become processing units in the search in RVF instead of words, which leads to the letter by letter analysis of lexical strings. At the same time, the search for letters within nonwords in

RVF remains serial. This search is not influenced by set. It seems to be impossible to apply a left-hemisphere search strategy fit for words to nonwords, opposite to our earlier rapid serial visual presentation studies, where we found a "word-reading" strategic effect upon random letter strings presented letter by letter at the same location (Falikman, 2011).

General discussion

The present study investigated visual search for letters embedded in letter strings presented in left and right visual hemifields. In Experiment 1, two letter strings were presented on both sides from the fixation and were of the same type (either Russian words or nonwords). The results provide evidence for serial search for a letter within a word in the LVF and within a nonword in the RVF and for parallel search for a letter within a nonword in the LVF and within a word in the RVF.

These results are inconsistent with the results of some previous studies, e.g. by Lavidor & Bailey (2005) who discovered position effects for words in RVF in letter search task. The plausible explanation for these discrepancies is perceptual load (Lavie, 1995; Lavie, 2005). Since 1995, when the perceptual load theory had been proposed by Lavie, a solid body of evidence has been accumulated demonstrating differences in perceptual processing when the load is low and high, both in normal subjects (e.g. Taya, Adams, Graph, & Lavie, 2009; Lavie et al., 2009) and in clinical populations, such as neglect patients (Lavie & Robertson, 2001). Word-letter processing proved to be sensitive to the perceptual load (Madrid et al., 2010).

One more factor contributing to the mode of processing employed by the visual system when two letter strings are simultaneously present in the visual field might have been an observer's readiness to process a letter string of a certain type (a word) in the RVF after processing a string in the LVF, i.e. a set (Osugi & Kawahara, 2013).

These assumptions were tested in the next two experiments. In Experiment 2, there was the only letter string presented right or left to the fixation (low perceptual load condition). The results of this experiment provide evidence for serial search in the low load condition regardless of the visual hemifield and string type, in agreement with the results of Lavidor and Bailey.

In Experiment 3, we tested the hypothesis that a letter string in the LVF could influence the processing of the other letter string in the LVF, providing for a sort of presetting. Two letter strings were presented on the both sides from the fixation, as in the Experiment 1, but now they were of different types (one word and one nonword). The results of Experiment 3 were mostly similar to those of Experiment 1, except for serial search within words in the RVF. These results provide evidence for presetting, i.e. employing a specific mode of processing to the letter string in the RVF influenced by the letter string in LVF. Interestingly, a nonword in the LVF prevents from parallel search within a word in the RVF. However, a word in the LVF does not induce parallel search within a nonword in the RVF. This result shows that to make search efficient, the left hemisphere specialization would contribute only to search within words (orthographically regular strings) and only when the visual system is primed to process words.

Taken together, the results of these experiments demonstrate the influence of the perceptual load on the observer’s choice of a search strategy when searching for a letter in different types of letter strings presented to in either visual field. When the perceptual load is low (Experiment 2, just one letter string), no special strategy is used. The search appears to be serial regardless of the string type and visual hemifield. When the perceptual load is high (Experiments 1 and 3, two letter strings left and right to the fixation), serial or parallel search strategies are applied depending on the visual hemifield and string type. We suppose that it makes sense to spend effort and / or time to apply a certain strategy only when the perceptual load is high. When the perceptual load is low, the strategy switch is not necessary, probably because it requires more effort and / or time than the default use of the less efficient serial search strategy. Thus, estimation of perceptual load seems to precede the search strategy choice in the visual search for a letter embedded in a letter string.

Our results provide a new explanation for the Lavidor & Bailey's (2005) results. The authors assume that letter-level processing (applied in the letter search task) is similar in both hemifields, but the whole-word processing is different in left and right hemispheres. Our results provide evidence for a variety of letter processing strategies. The parallel search mode emerges only when the perceptual load is high. We believe that using of different processing modes is associated not with the letter- or whole-word level of processing, but with the interaction of perceptual load and lexicality.

The results of Experiment 3 provide evidence for the role of set in letter search across the display. However, this factor is relevant only when the perceptual load is high, and only a word string can be subject to this set. This result echoes the finding of Theeuwes, Kramer and Belopolsky (2004) who revealed an interaction between perceptual load and attentional set in a visual search task.

In conclusion, we found that in letter search within words and nonwords visual search strategy depends on the visual hemifield in which the target letter is embedded, but this dependence is mediated by the perceptual load and the observer's readiness to process a word rather than a random letter string. These results suggest that there are at least three conditions of the efficient search for a letter within a word: its presentation to the right visual hemifield, high perceptual load and an observer's readiness to encounter a word rather than a random letter string there.

References

Alvarez, G. A., & Cavanagh, P. (2005). Independent resources for attentional tracking in the left and right visual hemifields. *Psychological Science*, 16(8), 637-643. doi:10.1111/j.1467-9280.2005.01587.x

Alvarez, G. A., Gill, J., & Cavanagh, P. (2012). Anatomical constraints on attentional selection: hemifield independence is a signature of multifocal spatial selection. *Journal of Vision*, 12(5), 1-20. doi:10.1167/12.5.9

Barber, H. A., Ben-Zvi, S., Bentin, S., & Kutas, M. (2011). Parafoveal perception during sentence reading?: An ERP paradigm using rapid serial visual presentation (RSVP) with flankers. *Psychophysiology*, 48(4), 523–531. doi:10.1111/j.1469-8986.2010.01082.x

Battelli, L., Alvarez, G. A., Carlson, T., & Pascual-Leone, A. (2009). The Role of the Parietal Lobe in Visual Extinction Studied with Transcranial Magnetic Stimulation. *Journal of Cognitive Neuroscience*, *21*(10), 1946–1955. doi:10.1162/jocn.2008.21149

Bever, T. G. (1975). Cerebral asymmetries in humans are due to the differentiation of two incompatible processes: holistic and analytic. *Annals of the New York Academy of Sciences*, 263, 251–262. doi:10.1111/j.1749-6632.1975.tb41589.x

Brand-D'Abrescia, M. & Lavie, N. (2007). Distractor effects during processing of words under load. *Psychonomic Bulletin & Review*, 14 (6), 1153–1157. doi:10.3758/BF03193105

Butcher, S. J., & Cavanagh, P. (2005). Within-field advantage for detecting matched motion paths. *Journal of Vision*, 5(8):964, 964a, http://journalofvision.org/5/8/964/, doi:10.1167/5.8.964.

Butcher, S. J., & Cavanagh, P. (2008). A unilateral field advantage for detecting repeated elements. *Perception & Psychophysics*, 70(4), 714–724.

Chakravarthi, R. & Cavanagh, P. (2009). Bilateral field advantage in visual crowding. *Vision research*, 49(13), 1638-1646. doi:10.1016/j.visres.2009.03.026

Corbetta M., Shulman G. L., Miezin F. M., Petersen S. E. (1995). Superior parietal cortex activation during spatial attention shifts and visual feature conjunction. *Science*, 270, 802–805. doi:10.1126/science.270.5237.802

Corbetta, M., Miezin, F. M., Shulman, G. L., & Petersen, S. E. (January 01, 1993). A PET study of visuospatial attention. *The Journal of Neuroscience: the Official Journal of the Society for Neuroscience*, 13, 3, 1202-26.

Devyatko, D. & Falikman, M. (2008) Would letters forming a word survive motion-induced blindness? *Journal of Vision*, 8(6), 1017

Ellis, A. W., Young, A. W., & Anderson, C. (1988). Modes of word recognition in the left and right cerebral hemispheres. *Brain and Language*, 35(2), 254-273. doi:10.1016/0093-934X(88)90111-3

Falikman, M. (2002). Word preference effect and the attentional blink: Who will have the upper hand? In Van der E. Meer, H. Hagendorf, R. Beyer, F. Krueger, A. Nuthmann, & S. Schultz (Hrsg.), 43.

Falikman, M. (2011). Word superiority effects across the varieties of attention. *Journal of Russian and East European Psychology*, 49(5), 45–61.

Fine, E. M. (2001). Does meaning matter? The impact of word knowledge on lateral masking. *Optometry and Vision Scienc*e, 78(11), 831–838. doi:10.1097/00006324-200111000-00013

Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology*, 47(6), 381-391. doi:10.1037/h0055392

Gorbunova, E. & Falikman, M. (2010). Word superiority within the attentional blink. *Journal of Vision*, 10, 203

Gorbunova, E., & Falikman, M. (2012). Visual search for letters within words and nonwords in the right and left visual hemifields. *Perception*, 41, Abstract Supplement, 143.

Grainger, J., Bouttevin, S., Truc, C., Bastien, M., & Ziegler J. Word superiority, pseudoword superiority, and learning to read: a comparison of dyslexic and normal readers. *Brain and Language*, 87(3), 432–440. doi:10.1016/S0093-934X(03)00145-7

Husain M., Shapiro K., Martin J., & Kennard C. (1997). Abnormal temporal dynamics of visual attention in spatial neglect patients. *Nature*, 385(6612), 154–156. doi:10.1038/385154a0

Johnson, N. F., & Carnot, M. J. (1990). On time differences in searching for letters in words and nonwords: Do they emerge during the initial encoding or the subsequent scan? *Memory & Cognition*, 18(1), 31–39. doi:10.3758/BF03202643

Johnston, J.C., & McClelland, J.L. (1974). Perception of letters in words: Seek not and ye shall find. *Science*, 184(4142), 1192-1194. doi:10.1126/science.184.4142.1192

Jordan, T.R., Patching, G.R., & Milner, A.D. (2000). Lateralized word recognition: Assessing the role of hemispheric specialization, modes of lexical access and perceptual asymmetry. *Journal of Experimental Psychology: Human Perception and Performance*, 26(3), 1192-1208. doi:10.1037//0096-152326.3.1192

Krueger, L. E., Keen, R. H., & Rublevich, B. (1974). Letter search through words and nonwords by adults and fourth-grade children. *Journal of Experimental Psychology*, 102(5), 845–849. doi:10.1037/h0036332

Lavidor, M, & Bailey, P. (2005). Dissociations between serial position and number of letters effects in lateralised visual word recognition. *Journal of Research in Reading*, 28(3), 258-273. doi:10.1111/j.1467-9817.2005.00269.x

Lavie, N. & Robertson I. (2001). The role of perceptual load in visual neglect: Rejection of ipsilesional distractors is facilitated with higher central load. *Journal of Cognitive Neuroscience*, 13 (7), 867-876. doi:10.1162/089892901753165791

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451– 468. doi:10.1037/0096-1523.21.3.451

Lavie, N. (2005) Distracted and confused?: selective attention under load. *Trends in Cognitive Sciences*, 9, 75-82. doi:10.1016/j.tics.2004.12.004

Lavie, N., Beck, D. M. & Konstantinou, N. (2014). Blinded by the load: attention, awareness and the role of perceptual load. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 369 (1641). doi:10.1098/rstb.2013.0205

Lavie, N., & Cox, S. (1997). On the efficiency of attentional selection: Efficient visual search results in inefficient rejection of distraction. *Psychological Science*, 8, 395–396. doi:10.1111/j.1467-9280.1997 .tb00432.x

Lavie, N., Lin, Z., Zokaei, N., & Thoma,V. (2009). The role of perceptual load in object recognition. *Journal of Experimental Psychology: Human Perception and Performance*, 21(1), 42-57. doi:10.1037/a0016454

Levine S. C., & Koch-Weser M. P. (1982). Right hemisphere superiority in the recognition of famous faces. *Brain and Cognition*, 1(1) doi:10–2210.1016/0278-2626(82)90003-3

Lindell, A.K. (2006). In Your Right Mind: Right Hemisphere Contributions to Language Processing and Production. *Neuropsychology Review*, 16(3), 131-148. doi: 10.1007/s11065-006-9011-9

Luck S.J., Hillyard S.A., Mangun G.R., Gazzaniga M.S. (1989). Independent hemispheric attentional systems mediate visual search in split-brain patients. *Nature*, 342(6249), 543-545. doi:10.1038/342543a0

Luiga, I., Bachmann, T. & Põder, E. (2002). Metacontrast masking of single letters in words and trigrams with varying loads on attention. *Perception*, 31 (ECVP Abstract Supplement), 79

Madrid, G.J., Lavie, N., & Lavidor M. (2010). Asymmetrical perceptual load in lateralised word processing. *European Journal of Cognitive Psychology*, 22(7), 1066-1077. doi:10.1080/09541440903264161

Michael, G. A., & Ojeda, N. (2005). Visualfield asymmetries in selective attention: Evidence from a modified search paradigm. *Neuroscience Letters*, 388, 65-70. doi:10.1016/j.neulet.2005.06.027

Osugi, T., Kawahara, J.I. (2013). Attentional set protects visual marking from visual transients. *Quarterly Journal of Experimental Psychology (Hove)*, 66(1), 69-90. doi:10.1080/17470218.2012.697177

Pantyushkov, A., Horowitz, T. S., & Falikman, M. V. (2008). Is there word superiority in visual search? In *Third International Conference on Cognitive Science: Book of abstracts* (Vol. 1, pp. 124–125). Moscow

Pechenkova, E. & Sinitsyna, M. (2009). Top-down modulations in perception of simultaneity. *Journal of Vision*, 9(8), 1083

Potter, M. C., Nieuwenstein, M., & Strohminger, N. (2008). Whole Report versus Partial Report in RSVP Sentences. *Journal of Memory and Language*, 58(4), 907–915. doi:10.1016/j.jml.2007.12.002

Reardon K.M., Kelly J.G., Matthews N. (2009). Bilateral attentional advantage on elementary visual tasks. *Vision Research*, 49(7), 691-701. doi:10.1016/j.visres.2009.01.005

Rees, G., Frith, C., & Lavie, N. (1997). Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science*, 278(5343), 1616 –1619. doi:10.1126/science.278.5343.1616

Reicher, G.M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology,* 81 (2), 275–280. doi:10.1037/h0027768

Salvemini, A.V., Stewart, A.L., Purcell, D.G., Pinkham, R.S. (1998). A word-superiority effect in the presence of foveal load. *Perceptual and Motor Skills*. 86(3, Pt 2): 1311-1319. doi: 10.2466/pms.1998.86.3c.1311

Scott, G.B., & Hellige, J.B. (1998). Hemispheric asymmetry for word naming: effects of frequency and regularity of pronunciation. *Laterality*, 3(4), 343-371. doi:10.1080/713754310

Starrfelt, R., Petersen, A., & Vangkilde, S. (2013). Don't words come easy? A psychophysical exploration of word superiority. *Frontiers in Human Neuroscience*, 7, 519. doTi:10.3389/fnhum.2013.00519

Stepanov, V. & Falikman, M. (2011). Temporal processing units relocate the attentional blink. *Vision Sciences Society 11th Annual Meeting. Abstracts.* Naples, FL

Tadros K., Dupuis-Roy N., Fiset D., Arguin M., Gosselin F. (2013). Reading laterally: the cerebral hemispheric use of spatial frequencies in visual word recognition. *Journal of Vision*, 13(4). doi:10.1167/13.1.4

Taya S., Adams W. J., Graph E. W., & Lavie N. (2009). The fate of task-irrelevant visual motion: Perceptual load versus feature-based attention. *Journal of Vision*, 9(12), 1–10. doi:10.1167/9.12.12

Theeuwes, J., Kramer, A.F., & Belopolsky, A. (2004). Attentional set interacts with perceptual load in visual search. *Psychonomic Bulletin & Review*, 11, 697-702. doi:10.3758/BF03196622

Turkovsky, A. A., Bespalov, B. I., Vartanov, A. V., & Kiselnikov, A.A. (2014). Evaluation of the Instrumental Error in a Chronometric Psychological Experiment Using Modern Equipment. *Psychology. Journal of Higher School of Economics*, 11(4), 166-176 (in Russian)

Wheeler, D.D. (1970).Processes in word recognition. *Cognitive Psychology*, 1(1), 59–85. doi:10.1016/0010-0285(70)90005-8

Whitney, C. & Lavidor, M. (2004). Why word length only matters in the left visual field. *Neuropsychologia*, 42(12), 1680-1688. doi:10.1016/j.neuropsychologia.2004.04.007

Wojciulik, E., & Kanwisher, N. (1999) The Generality of Parietal Involvement in Visual Attention. *Neuron*, 24(3), 747-764. doi:10.1016/S0896-6273(01)80033-7

Table 1. Mean RT's and standard deviations as a function of letter position, visual field, and lexicality in experiment 1.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 806.53, *SD* = 148.78	*M* = 875.86, *SD* = 158.74	*M* = 1054.85, *SD* = 220.87	*M* = 1068.88, *SD* = 252.4
Nonwords	*M* = 881.73, *SD* = 145.28	*M* = 910.15, *SD* = 164.81	*M* = 1087.41, *SD* = 242.42	*M* = 1179.34, *SD* = 280.11

Table 2. Mean correct response rates and standard deviations as a function of letter position, visual field, and lexicality in experiment 1.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 95.64, *SD* = 4.59)	*M* = 95.39, *SD* = 4.67	*M* = 94.28, *SD* = 5.73	*M* = 93.69, *SD* = 4.93
Nonwords	*M* = 93.54, *SD* = 6.60	*M* = 95.14, *SD* = 3.69	*M* = 94.06, *SD* = 6.37	*M* = 91.36, *SD* = 6.26

Table 3. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 1 (RT data).

	LVF		RVF	
	F	p-value	F	p-value
Words	27.37	.000*	0.74	.395
Nonwords	3.37	.081	21.44	.000*

* The mean difference is significant at alpha .05.

Table 4. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 1 (accuracy data).

	LVF		RVF	
	F	p-value	F	p-value
Words	0.13	.722	0.35	.559
Nonwords	1.98	.174	6.23	.021*

* The mean difference is significant at alpha .05.

Table 5. Mean RT's and standard deviations as a function of letter position, visual field, and lexicality in experiment 2.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 788.97, *SD* = 159.25	*M* = 828.72, *SD* = 173.82	*M* = 772.39, *SD* = 153.38	*M* = 865.31, *SD* = 170.05
Nonwords	*M* = 850.06, *SD* = 166.45	*M* = 902.77, *SD* = 207.64	*M* = 800.27, *SD* = 181.92	*M* = 925.03, *SD* = 187.85

Table 6. Mean correct response rates and standard deviations as a function of letter position, visual field, and lexicality in experiment 2.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 95.61, *SD* = 3.96	*M* = 94.32, *SD* = 3.62	*M* = 97.36, *SD* = 2.49	*M* = 94.99, *SD* = 4.93
Nonwords	*M* = 93.37, *SD* = 4.69	*M* = 94.84, *SD* = 4.17	*M* = 96.63, *SD* = 3.9	*M* = 94.3, *SD* = 3.75

Table 7. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 2 (RT data).

	LVF		RVF	
	F	p-value	F	p-value
Words	8.42	.010*	46.17	.000*
Nonwords	8.38	.010*	41.07	.000*

* The mean difference is significant at alpha .05.

Table 8. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 2 (accuracy data).

	LVF		RVF	
	F	p-value	F	p-value
Words	1.68	.212	3.90	.064
Nonwords	1.81	.195	4.29	.053

Table 9. Mean RT's and standard deviations as a function of letter position, visual field, and lexicality in experiment 3.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 796.74, *SD* = 151.82	*M* = 853.4, *SD* = 143.11	*M* = 1067.88, *SD* = 227.52	*M* = 1143.55, *SD* = 234.68
Nonwords	*M* = 874.92, *SD* = 156.76)	*M* = 890.90, *SD* = 162.09	*M* = 1080.83, *SD* = 206.12	*M* = 1186.92, *SD* = 255.28

Table 10. Mean correct response rates as a function of letter position, visual field, and lexicality in experiment 3.

	LVF		RVF	
	2 letter	5 letter	2 letter	5 letter
Words	*M* = 96.28, *SD* = 5.25	*M* = 96.44, *SD* = 7.49	*M* = 95.95, *SD* = 3.76	*M* = 94.73, *SD* = 5.73
Nonwords	*M* = 95.52, *SD* = 5.99	*M* = 95.07, *SD* = 6.55	*M* = 94.63, *SD* = 5.88	*M* = 92.84, *SD* = 6.66

Table 11. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 3 (RT data).

	LVF		RVF	
	F	p-value	F	p-value
Words	19.65	.000*	33.33	.000*
Nonwords	0.98	.333.	28.28	.000*

* The mean difference is significant at alpha .05.

Table 12. F and p-value in pairwise comparisons for different target positions for each type of letter strings and each hemifield in experiment 3 (accuracy data).

	LVF		RVF	
	F	p-value	F	p-value
Words	0.03	.858	2.24	.149
Nonwrods	0.41	. 530	1.23	.280

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