Psychology
2011. Vol.2, No.2, 103-108

Scientific Research
DOI:10.4236/psych.2011.22017

# Influence of the Learnt Direction of Reading on Temporal Order Judgments

Alejandro Pérez[1,2], Lorna García[1], Mitchell Valdés-Sosa[3], Piotr Jaśkowski[4]
[1]Basque Center on Cognition Brain and Language, BCBL, Donostia-San Sebastian, Spain;
[2]Cognitive Neuroscience Laboratory, Faculty of Psychology, Universidad Diego Portales, Chile;
[3]Cognitive Neuroscience Department, Cuban Center for Neuroscience, Ciudad de La Habana, Cuba;
[4]Department of Cognitive Psychology, University of Finance and Management, Warszawa, Poland.
Email: a.perez@bcbl.eu
Received January 5th, 2011; revised February 18th, 2011; accepted February 22nd, 2011.

Our previous work has shown a leftward bias in the temporal order judgment task (Pérez, García, & Valdes-Sosa, 2008). This pseudoneglect was found in a sample of Spanish-speaking participants who read in a left-to-right manner. The goal of the current study was to examine if the reading related scanning habits modulate the bias observed in the TOJ task. To this aim, we replicated the study with Arabic participants who learned to read in a right-to-left direction. Results showed no lateralization suggesting that reading habit is probably a factor affecting the distribution of spatial attention. We suggested that our failure to obtain a reversed bias might be due to the fact that they experienced both types of reading habits. We also presented a possible explanation of why the finding of pseudoneglect in temporal order judgment tasks is rather unusual.

*Keywords*: TOJ, Pseudoneglect, Spatial, Bias, Attention

## Introduction

In the visual temporal order judgment task (TOJ) common experimental setting, two targets are presented right and left of a fixation point whilst the relative stimuli onset asynchrony (SOA) of the two events is manipulated, and participants are asked to report which of the targets appeared first (Shore, Spence, & Klein, 2001). In line with the law of prior entry that postulates: "the object of attention comes to consciousness more quickly than the objects we are not attending to" (Titchener, 1908), this task allows to make inferences about the distribution of visuospatial attention. Thus, TOJ had been commonly used, among other things, to study visuospatial attentional asymmtries (Sekuler, Tynan, & Levinson, 1973).

In TOJ, when the stimuli are presented simultaneously or with a very short SOA, the order is judged at chance (50%) and accuracy progressively rises by increasing the SOA (Bachmann, Poder, & Luiga, 2004; Jaśkowski & Verleger, 2000; Sternberg & Knoll, 1973). Two summary statistics can be extracted from the TOJ data: the 'point of subjective simultaneity' (PSS) indicating the SOA at which observers report maximal uncertainty, and the 'just noticeable difference' (JND), a measure of how far apart in time the stimuli must be presented for the subject to reliably order them in time in 75% of the cases (Shore & Spence, 2005). Theoretically, the maximal uncertainty of temporal order should occur when stimuli are presented simultaneously (i.e., with SOA = 0). Therefore subject's perceptual bias to one side manifests as a deviation of PSS from zero (Shore et al., 2001).

In patients with extinction and neglect syndromes consequent to brain damage who show strong attentional bias, favoring usually the right side (Halligan, Fink, Marshall, & Vallar, 2003), the TOJ task is characterized by a strong tendency to perceive the right stimulus as appearing first, even when it is presented hundreds of millisecond after the left stimulus (Robertson, Mattingley, Rorden, & Driver, 1998; Rorden, Mattingley, Karnath, & Driver, 1997). In patients with developmental dyslexia, a learning disorder with no apparent brain damage, researchers also detected small disadvantages for one-hemifield in the TOJ task (Hari, Renvall, & Tanskanen, 2001; Pérez, García, Lage, Leh, & Valdes-Sosa, 2008). Specifically, the work by Hari et al. (2001) showed that adult dyslexics processed stimuli in the left visual hemifield significantly more slowly than normal readers. They suggest that this abnormality could reflect right parietal lobe hypofunction, a consequence of a general magnocellular deficit. As the control of automatic attention is attributed commonly to the posterior right parietal lobe, the primary cause of left hemifield disadvantage rather could be sluggish attention shifting (Hari, Renvall, & Tanskanen, 2001). The TOJ task had been also used to study attention-deficit/hyperactivity disorder (ADHD), a child-onset disorder with negative adult outcomes (Bellgrove et al., 2006). Results in the study of Bellgrove et al. (2006), showed that the ADHD participants have an attentional bias toward the left hemifield that enhances the rate of perceptual processing for stimuli on that side. Subjects with ADHD could be impaired on those tasks requiring temporal attention due to ADHD has been associated with the A2 allele of a Taq I polymorphism of the Dopamine beta hydroxylase (DBH) gene, which catalyzes the conversion of dopamine to noradrenaline, and since catecholamines regulate visual attention, this could be the link. However, the explanation to the presence of an attentional asymmetry, remains unclear and may reflect the operation of a number of factors, including task demands (Bellgrove et al., 2006). In the case of normal observers, the TOJ is more commonly symmetrical (Hikosaka, Miyauchi, & Shimojo, 1993; Rorden et al., 1997; Shore et al., 2001). Only if attention is drawn to one side of the visual field by an exogenous cue (or in less extent, by an endogenous cue), the TOJs are biased towards the cued side as compared to a baseline in which attention is equally distributed (e.g. Schneider & Bavelier, 2003; Shore et al., 2001). This manipulation emphasizes the sensitivity of the TOJ to attentional factors (Shore et al., 2001). However, in a recent study using the TOJ task, a leftward bias was obtained (Pérez et al., 2008). This phenomenon is consistent with the so called pseudoneglect, a small but systematic leftward bias found in healthy subjects (Bowers & Heilman, 1980) with numerous spatial tasks (Luh, Rueckert, & Levy, 1991; Milner, Brechmann, & Pagliarini, 1992; Nicholls, Mattingley, & Bradshaw, 2005; Orr & Nicholls, 2005). The aforementioned study from Pérez et al. (2008), originally aimed at investigating the influence of an endogenous process on TOJ, via an attentional blink (AB) paradigm. To accomplish that, a first visual stimulus (S1) was displayed at the fixation point for 30 ms, followed (after either 250 or 1000 ms) by a pair of laterally located visual stimuli (S2) whose order had to be judged (the TOJ task). Subjects had to provide the TOJ responses in a forced choice manner. As in an AB paradigm, delay between S1 and S2 is manipulated to reduce the attentional resources. Also, a control block in which participants are asked to ignore S1 stimulus (i.e. no dual-task) is introduced, to discard purely sensory effects due to T1 such as visual masking deficits (this block resembles a classical TOJ task). Study shows that for the dual task and with the 280 delay between T1 and T2, accuracy in the TOJ deteriorated evincing an AB and supporting the conclusion that the perception of temporal order is also affected when available attentional resources are reduced. The study also expected that a rightward bias emerged during the AB (Manly, Dobler, Dodds, & George, 2005; Bellgrove, Dockree, Aimola, & Robertson, 2004). Interestingly; this rightward bias under AB conditions consisted in a significant bias away from the left favoring asymmetry in normal attention conditions. In other words, during normal attention condition (i.e. normal TOJ task, without AB effects), accuracy for the left-leading conditions was higher than for the right-leading conditions (87% versus 79%). These results, in addition to a positive PSS mean value being significantly different from zero, indicating that the right stimulus had to precede the left one to be judged as simultaneous, indicated a leftward spatial bias in the TOJ task used as control (for more details see Pérez et al., 2008).

To our knowledge, only Sekuler et al. (1973) reported a leftward advantage in a visual TOJ task similar to the one obtained serendipitously in the described experiment of Pérez et al. (2008). Sekuler et al. (1973) suggested that their TOJ-pseudoneglect effect was due to an internal mechanism that scans visual inputs in a left-to-right order, probably due to reading scanning habits (Heron, 1957). It had been suggested that pseudoneglect is related to reading scanning habits (Chokron & Imbert, 1993; Chokron & De Agostini, 1995; Chokron, Bernard, & Imbert, 1997), but results are not conclusive (Nicholls & Roberts, 2002). Therefore, we decided to test readers who learn to read in a right-to-left direction (right-to-left readers, RtLR) using the same TOJ task as in our previous study and to compare their results to those obtained with the exclusive left-to-right readers (LtRR) (Pérez et al., 2008). Here we examined the possible influence of the direction of reading on TOJ. If we find a TOJ pattern different to pseudoneglect in RtLR, this would suggest that the reading habits could affect the distribution of spatial attention.

## Methods

### Participants

Twelve subjects (1 female and 11 males) between 23 and 43 years of age volunteered to participate in the study. They gave informed consent in line with the Declaration of Helsinki. The inclusion/exclusion criteria were the same as in our previous study (Pérez et al., 2008): 1) they were in good health, had no past history of psychiatric or neurological illness, and had normal visual acuity, 2) had right handed-ness as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971) with all scores above 85 points and 3) had a high educational degree (university students or graduated).

All subjects were bilingual (Arabian and Spanish idioms) with the Arab as the primary language (RtLR). None of them used Spanish or any other language different from Arab before they were 17 years old, and all acquired writing and reading skills before they were nine years old, reading and writing fluid in their native language. Table 1 shows a description of the RtLR's participants. As the results of these subjects were compared to the LtRR subjects from our previous study, description of the latter was also given in Table 1.

### Instruments

Stimuli were presented on a 15" sVGA computer display with 800 × 600 pixels resolution and a refresh rate of 85Hz, controlled by a 933 MHz Intel Pentium III Copermine computer driven by a custom written software. All stimuli were displayed as white figures on a black background. The fixation square of 0.8˚ of visual angle was present all the time. It contained a small diamond shape. Disappearance of one of the corners of this inner diamond was achieved by turning off 16 pixels. Horizontal bars of 1.4˚ in width and 0.1˚ high appeared at symmetrical locations in the left and right visual fields, at the same height as the central square. The outer edges of the bars were subtending 4.2˚ from the fixation point warranting processing by the foveal area of the retina.

### Procedure

The procedures in this and the previous study were identical,

Table 1.
*Description of the RtLR group studied here and the LtRR group from the previous experiment.*

| Variables | Groups Comparison | |
|---|---|---|
| | *RtLR group* | *LtRR group* |
| Number of subjects | 12 | 14 |
| Sex distribution | 1 female/11 male | 3 female/11 male |
| Age range (years) | 22-45 (mean 27) | 23-43 (mean 32) |
| Handedness | Right (> 85) | Right (> 85) |
| Educational degree | University | University |
| Language | Arab and Spanish | Spanish |

the same equipment was used, conducted by the same experimenter, using the same program and close in time to previous study. All instructions were given in Spanish. In order to keep the same experimental design of the previous study, participants also performed a 'divided-attention block' (see Pérez et al., 2008 for more details), but data is not presented here. Blocks order was counterbalanced.

The experiment was conducted in a quiet room with natural illumination. Participants were seated in a chair at a distance of 50 cm from the screen. They were instructed to maintain fixation throughout the experiment on a diamond shape presented in the middle of the screen and to remain still.

For each trial, a series of displays were presented as shown in Figure 1. The sequence was triggered by pressing a key. After a delay of 300 ms, the upper corner of the central diamond disappeared (S1) for 30 ms (see inset in Figure 1). 250 or 1000 ms (ISI) after the missing corner was restored, the stimuli for the TOJ task were displayed. Note that the participants in this block had to ignore S1. But to keep the tasks as similar as possible, they also performed a 'divided-attention block' (not shown) in which one of the corners of the central diamond could disappear and they had to report it, dividing attention between S1 and the TOJ. TOJ stimuli consisted of two bars, one on each side of the fixation point. The stimulus onset asynchrony (SOA) of the two bars was varied from trial to trial. They were from –120, –90, –60 or –30 ms (the minus sign indicates that the left bar was presented before the right bar), 0 ms (both were displayed simultaneously), or 30, 60, 90 or 120 ms (positive numbers indicates that the right bar was presented before the left bar).

After the two bars had been presented, the display was left on until the trial complete of 1550 ms. After the sequence of stimuli, the subjects were prompted to respond. First, they pressed the up-arrow key in the computer keyboard (while keeping the tasks as similar as in the other block), and finally, they indicate with the right or left arrow if the right or the left bar had appeared first (forced-choice). All responses were given with the right hand.

The experiment was preceded by a short training period of ten trials to ensure that the participant had fully understood the instructions. A total of 360 trials were presented, uniformly distributed over the eighteen conditions (2 ISIs × 9 SOAs). The order of presentation of different trial types was pseudo-random (trials from a similar condition should not be presented more than seven consecutive times). The percent of responses in which the subject indicated that the right bar was presented first (% right-first responses) was calculated for each condition in all subjects.

## Results

Four-way ANOVAs with three within-subjects factors, ISI (250 ms vs. 1000 ms), Side ('right–first' vs. 'left–first') and SOA (excluding SOA = 0 ms or simultaneity for this analysis, because neither 'right–first' nor 'left–first' answer is a correct answer), and Group (RtLR group and LtRR group) as a between-subjects factor, were performed. A Greenhouse-Geisser correction of the degrees of freedom was ap-plied when appropriate.

As expected the number of correct responses increased with

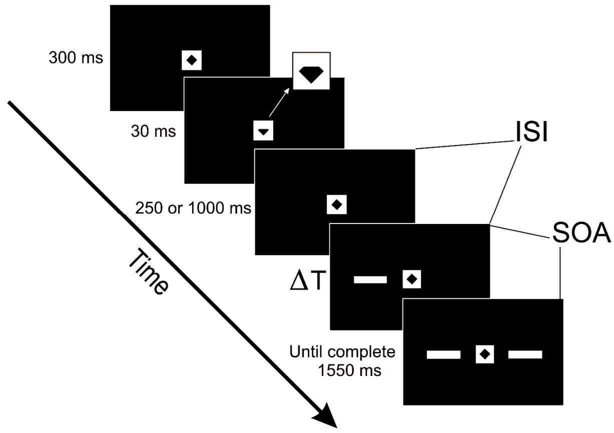


Figure 1.
*Experimental design. Sequence of events during each trial and time the stimuli were shown on the screen. ΔT represents the* 30, 60, 90 *or* 120 *ms necessary for SOAs* (*also represents de 0 ms of simultaneity*).

SOA, $F(3,72) = 148.2$, $MS = 1.4$, $p < .001$. Of some interest is that the performance depended on ISI being better at an ISI = 1000 (83%) than an at ISI = 250 ms (78%), $F(1,24) = 13.5$, $MS = 0.2$, $p < .01$. This reduction in performance for the short ISI could be explained by an attentional blink like effect. We will return to this suggestion in the Discussion. The main effect of Group was insignificant; however, the Group x Side, $F(1,24) = 8$, $MS = 0.88$, $p < .01$, and Group x SOA x Side, $F(3,72) = 3.79$, $MS = 0.04$, $p < .05$, interactions reached sig-nificance, thus indicating that the shape of psychometric functions depended on Side and Group. To explain these interactions, planned comparisons were performed for each Side showing that differences between groups are significant for left-first, $F(1,24) = 6.12$, MSE = 1.06, $p < .05$, with lower accuracy for the RtLR Group in the left-leading conditions (73% in the RtLR Group vs. 87% in LtRR Group) and vanished for the right-leading conditions (83% vs. 79%). In fact, the pattern showing a leftward bias in the LtRR Group (87% of accuracy for left-leading conditions vs. 79% for the right-leading conditions) is actually reversed in the RtLR Group (73% vs. 83%, respectively). This confirms that the pseudoneglect phenomenon was not present in RtLR Group. Planned comparisons were also performed for Side in each group, showing differences between right-leading and left-leading conditions only in the RtRR Group ($F(1,24) = 4.59$, MSE = 0.05, $p < .01$), indicating more accuracy in the right-leading conditions compared with the left-leading conditions in this group, an opposite pattern to the one shown by the LtRR Group. Finally, being more detailed, planned comparisons were performed for each SOA in each Side. For left-first condition, differences between groups, due to a larger accuracy for the LtRR Group in all SOA values, are significant in all of it (all $p < .05$) except for the 30 ms SOA in which it is marginally significant ($p = .057$). On other hand, for the right-leading condition the accuracy percentage is similar for both groups in the larger SOAs and only differ in the 30 ms SOA ($F(1,24) = 9.04$, MSE = 0.33, $p < .01$), being more accurate the RtLR Group (72% vs. 56%).

In addition, we performed probit analysis to estimate the basic parameters of psychometric functions (Finney, 1964). To this aim the proportion of 'right-first' responses was converted to its equivalent Z-score using a probit regression, assuming a cumulative normal distribution of the data. Transformed Z-scores are obtained by applying the inverse of the standard normal distribution function to the raw proportion scores (Sinnett, Juncadella, Rafal, Azanon, & Soto-Faraco, 2007). This transformation allows us to perform a linear regression with the transformed data and the nine SOAs. From the slope and intercept of the fitted line, we derive the PSS (corresponding to the intercept of the function) and the JND (corresponding to 0.675 point of the function). These two performance measures were calculated separately for each participant.

One participant of the LtRR group was excluded from the analysis because the estimated PSS value was greater than 120 ms, which was beyond the SOA range tested (see Spence et al. 2001, for similar criteria of exclusion). As no significant difference between ISIs emerged, we collapsed the data, considering both ISIs as independent observations; consequently number of observations doubled. Figure 2 shows the collapsed data of the responses obtained here (RtLR participants) jointed with LtRR participant's data from the previous experiment. Table 2 show the summary statistics from the PSS and JND in the two ISIs conditions.

In the LtRR group the PSS values were statistically different from 0 ms (mean = 17.0 ms, conf. limits –95% = 9.5 and + 95% = 24.5, $t(27) = 4.7$, $p < .001$), indicating that the bar on the right must be presented before the bar on the left for both events to be perceived as simultaneous. This indicates a leftward advantage consistent with the pseudoneglect phenomenon. In the RtLR group a trend to the left side was observed (PSS mean = –14.4 ms), but it couldn't be statistically validate. However, further between-group comparison revealed a difference between the PSS parameters ($t(48) = –3.5$, $p < .01$). Moving on to the JND measure, a mean SOA of 46.5 ms between the two stimuli was required for a correct discrimination order in the RtLR group which was not statistically different from the 36.0 ms required for the LtRR group, according to a t-test for independent groups. Even when RtLR group is not as accurate as the LtRR group, this result indicated equivalent precision in the performance of the task.

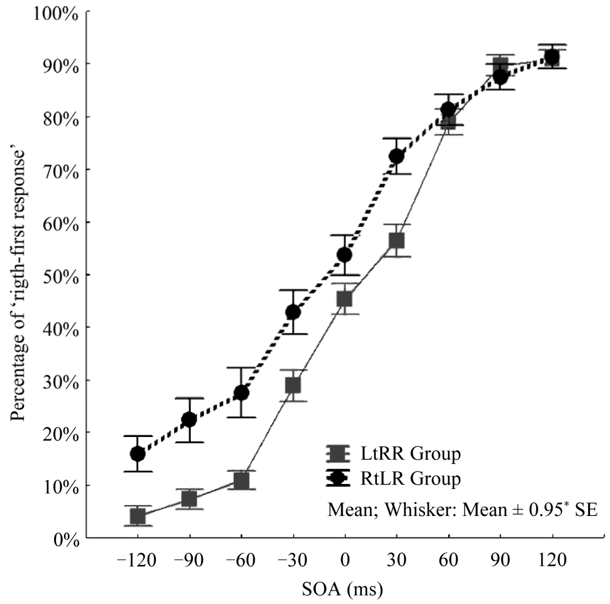


Figure 2.
*Mean probability of right-first responses as a function of SOA and group in the TOJ task* (*data from different ISIs were collapsed*). *Negative SOAs indicate that the left bar was presented first and positive ones that the right bar was presented first*; *zero SOA corresponds to simultaneous onset. Larger probabilities of* '*right-first*' *responses were obtained in the group of RtLR compared to the LtRR when the left stimulus preceded the right.*

Table 2.
*Summary statistics from the PSS and JND of each participant from the TOJ task in ISI* 250 *ms and ISI* 1000 *ms conditions. Mean, confidence intervals and standard deviation are showed.*

| | **RtLR Group** | | | | **LtRR Group** | | | |
|---|---|---|---|---|---|---|---|---|
| | *ISI* 250 *ms* | | *ISI* 1000 *ms* | | *ISI* 250 *ms* | | *ISI* 1000 *ms* | |
| | *PSS* | *JND* | *PSS* | *JND* | *PSS* | *JND* | *PSS* | *JND* |
| Mean | –14.2 | 51.9 | –14.5 | 40.9 | 16.3 | 36.6 | 17.7 | 35.3 |
| Std.Dev. | 48.6 | 25.1 | 38.5 | 16. | 22.3 | 21.7 | 16.6 | 25.7 |
| Confidence –95% | –46.8 | 35.1 | –40.4 | 29.9 | 3.5 | 24.1 | 8.1 | 20.5 |
| Confidence +95% | 18.4 | 68.8 | 11.4 | 52.0 | 29.2 | 49.1 | 27.3 | 50.1 |

## Discussion

In our previous TOJ experiment with LtRR it was obtained a leftward bias consistent with pseudoneglect, which is in line with Sekuler et al.'s (1973) finding. Here, we showed that with RtLR readers this effect disappeared. Differences could not be attributed to differences in sex or age and although participants' IQ was not tested, the participants in both groups had a comparable educational level.

An interesting finding is the reduction in performance when the intervals between the warning signal and the TOJ were short. We argue that this phenomenon could be an attentional blink (AB) like effect. In the AB paradigm two sequentially presented target stimuli (t1 and t2) have to be identified (dual-task). Recognition of the second target (t2) is impaired, the 'attentional blink', when it is presented within a few hundred milliseconds of t1, but only when the latter must be actively recognized (Duncan, Ward, & Shapiro, 1994; Raymond, Shapiro, & Arnell, 1992). Even when our paradigm is not a dual-task because the first stimulus has not to be attended, subjects performed an extra block (Divided-Attention block, data not shown) and in this block a first stimulus do had to be attended and responded, therefore a kind of task interference could be expected when we ask to press automatically a key before the response, something with a "meaning" in the other block. Maybe these factors resulted in an "overinvestment" of attentional allocation over S1 stimulus, provoking S1 to be a spuriously active distractor which effect is likely to be highest when it is closer to the stimuli which order was to be judged (Olivers & Nieuwenhuis, 2006). This could be possible if we consider that a 'meta-contrast' masking (which involves closely adjacent but non-overlapping contours) is present. Then, an integration mask (i.e. target and mask are perceived as part of the same pattern) could happen for the shorter ISI as a consequence of imprecise temporal resolution by the visual system (Enns & Di Lollo, 2000). Sekuler et al. (1973) suggested that a leftward bias in the TOJ task was due to reading scanning habits, related to the idea that attention is preferentially allocated to the side where the reading starts, affecting distribution of attention (Eviatar, 1997). In line with this hypothesis, the effect of reading direction on performing of some spatial tasks was found: on the ability to ignore irrelevant stimuli (Eviatar, 1995), the direction of stroke movement in free-hand figure drawing (Vaid, Singh, Sakhuja, & Gupta, 2002), the aesthetic preference in a mirror-image (Chokron & De Agostini, 2000) and the left-to-right bias in inhibition of return (Spalek & Hammad, 2005).

However, the leftward bias of the LtRR group was not reversed in the RtLR group. One may further argue that failure to find the rightward bias in RtLRs was due to the fact that the participants experienced both types of reading scanning habits. Although their native language requires right-to-left reading, they read from left-to-right from the moment they started their Spanish education. So, they didn't represent a pure sample of right-to-left readers. It is, therefore, plausible that their potential rightward bias was diminished due to the new reading conditions. In fact for the RtLR group we find a different TOJ pattern, a trend to a rightward bias. In addition, the power of the present experiment might be too low to detect a small or medium rightward bias. We plan to increase the sample of the RtLR-Group in a future study. However, the TOJ pattern is different to the pseudoneglect found in the LtRR-Group, suggesting an interaction between reading habits and distribution of spatial attention.

We think that even when the results suggest that reading habits affected TOJ, there are further important reasons to argue for an alternative explanation of a pre-existing leftward bias preventing the bias revert to right. As we have mentioned, some times a leftward bias has been reported irrespective of reading habits (Nicholls et al., 2002) and has been proved to exist in a wide range of perception aspects like: length, size, brightness and quantity (Orr et al., 2005). In addition, there is evidence for pseudoneglect in non-human species (Diekamp, Regolin, Gunturkun, & Vallortigara, 2005; Vallortigara, Rogers, Bisazza, Lippolis, & Robins, 1998) suggesting some evolutionary role for this bias. Other evidence suggesting a leftward bias, is the revealed superior activation of a visuospatial attention-related network for the left hemifield (Siman-Tov et al., 2007), giving a neural substrate to the pseudoneglect phenomenon.

It remains to explain why our results are at odds with the results of some previous studies where TOJs were found to be symmetrically distributed (Jaskowski & Rusiak, 2008; Shore et al., 2001). One reason for this could be the first stimulus changes that occurred in our experiment (i.e. S1). The spatial nature of this change, even when we asked to ignore it, could evoke a carry-over effect. The bias produced by the spatial nature of S1 could affect symmetry of TOJ. Indeed, it has been suggested that the act of performing a spatial task is enough to shift attention leftwards (McCourt, Freeman, Tahmahkera-Stevens, & Chaussee, 2001) because spatial tasks can preactivate the right hemisphere due to its supposed dominance for spatial events (Weintraub & Mesulam, 1987).

These ideas are based in Kinsbourne's functional distance model which postulates that two cerebral hemispheres interactively compete, in such a way that relative increases in activation in one hemisphere will tend to bias attention towards the contralateral hemi-space (Kinsbourne, 1970). In line with this reasoning, pseudoneglect commonly appears in visuospatial tasks. For example, the advantage of the left over right hemifield was found in the line bisection task (to bisect a line at its centre) (Milner et al., 1992), the Grey-scales task (forced-choice luminance discriminations between two mirror-reversed luminance gradients) (Nicholls et al., 2005; Orr et al., 2005) and the free-vision chimeric tasks (judging in an image composed by two different halves, for example, conjoined smiling and neutral half-faces) (Luh et al., 1991), all with a strong spatial component.

In case of the TOJ task, it has been widely used to study visual field asymmetries, because of the fact that one stimulus is presented in the opposite hemi field than the other, therefore assuming a spatial component. However, the principal component by definition is the temporal lag of stimulus onset, hence a temporal component, not a spatial one is the principal. Some research support a left hemisphere advantage for temporal resolution (Nicholls, 1996). In TOJ, such a temporal rightward bias could cancel the natural spatial leftward bias. This could be a reason for the TOJ task to be often reported as symmetric rather than asymmetric with a leftward bias.

Summarizing, reading habit is probably one of many factors affecting the attentional distribution. It implies that we have to be cautious in any study about visual lateralization taking into account a wide range of factors that should be controlled. A modulating effect of reading direction on spatial processing would have a number of important implications for deciphering the mechanisms for attention lateralization and may lead to improved diagnosis and treatment of attention deficits in disorders as neglect and developmental dyslexia.

## References


Bachmann, T., Poder, E., & Luiga, I. (2004). Illusory reversal of temporal order: The bias to report a dimmer stimulus as the first. *Vision Research, 44*, 241-246. doi:10.1016/j.visres.2003.10.012

Bellgrove, M. A., Dockree, P. M., Aimola, L., & Robertson, I. H. (2004). Attenuation of spatial attentional asymmetries with poor sustained attention. *Neuroreport, 15*, 1065-1069. doi:10.1097/00001756-200404290-00027

Bellgrove, M. A., Mattingley, J. B., Hawi, Z., Mullins, C., Kirley, A., Gill, M. et al. (2006). Impaired temporal resolution of visual attention and dopamine beta hydroxylase genotype in attention-deficit/hyperactivity disorder. *Biological Psychiatry, 60*, 1039-1045. doi:10.1016/j.biopsych.2006.03.062

Bowers, D. & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia, 18*, 491-498. doi:10.1016/0028-3932(80)90151-7

Chokron, S. & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research, 10*, 45-49. doi:10.1016/S0926-6410(00)00021-5

Chokron, S., Bernard, J. M., & Imbert, M. (1997). Length representation in normal and neglect subjects with opposite reading habits studied through a line extension task. *Cortex, 33*, 47-64.

Chokron, S. & De Agostini, M. (1995). Reading habits and line bisection: A developmental approach. *Cognitive Brain Research, 3*, 51-58. doi:10.1016/0926-6410(95)00018-6

Chokron, S. & Imbert, M. (1993). Influence of reading habits on line bisection. *Cognitive Brain Research, 1*, 219-222. doi:10.1016/0926-6410(93)90005-P

Diekamp, B., Regolin, L., Güntürkün, O., & Vallortigara, G. (2005). A left-sided visuospatial bias in birds. *Current Biology, 15*, R372-R373. doi:10.1016/j.cub.2005.05.017

Duncan, J., Ward, R., & Shapiro, K. (1994). Direct measurement of attentional dwell time in human vision. *Nature, 369*, 313-315. doi:10.1038/369313a0

Enns, J. T. & Di Lollo, V. (2000). What's new in visual masking? *Trends in Cognitive Sciences, 4,* 345-352. doi:10.1016/S1364-6613(00)01520-5

Eviatar, Z. (1995). Reading direction and attention: Effects on lateralized ignoring. *Brain and Cognition, 29*, 137-150. doi:10.1006/brcg.1995.1273

Eviatar, Z. (1997). Language experience and right hemisphere tasks: The effects of scanning habits and multilingualism. *Brain and Language, 58*, 157-173. doi:10.1006/brln.1997.1863

Finney, D. J. (1964). *Probit analysis: Statistical treatment of the sigmoid curve*. London: Cambridge University Press.

Halligan, P. W., Fink, G. R., Marshall, J. C., & Vallar, G. (2003). Spatial cognition: Evidence from visual neglect. *Trends in Cognitive Sciences, 7*, 125-133. doi:10.1016/S1364-6613(03)00032-9

Hari, R., Renvall, H., & Tanskanen, T. (2001). Left minineglect in dyslexic adults. *Brain*, *124*, 1373-1380. doi:10.1093/brain/124.7.1373

Heron , W. (1957). Perception as a function of retinal locus and attention. *The American Journal of Psychology*, *70*, 38-48. doi:10.2307/1419227

Hikosaka, O., Miyauchi, S., & Shimojo, S. (1993). Focal visual attention produces illusory temporal order and motion sensation. *Vision Research*, *33*, 1219-1240. doi:10.1016/0042-6989(93)90210-N

Jaśkowski, P. & Rusiak, P. (2008). Temporal order judgment in dyslexia. *Psychological Research, 72*, 65-73.

Jaśkowski, P. & Verleger, R. (2000). Attentional bias toward low-intensity stimuli: an explanation for the intensity dissociation between reaction time and temporal order judgment? *Consciousness and Cognition*, *9*, 435-456. doi:10.1006/ccog.2000.0461

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica, 33*, 193-201. doi:10.1016/0001-6918(70)90132-0

Luh, K. E., Rueckert, L. M., & Levy, J. (1991). Perceptual Asymmetries for Free Viewing of Several Types of Chimeric Stimuli. *Brain and Cognition, 16*, 83-103. doi:10.1016/0278-2626(91)90087-O

Manly, T., Dobler, V. B., Dodds, C. M., & George, M. A. (2005). Rightward shift in spatial awareness with declining alertness. *Neuropsychologia, 43*, 1721-1728. doi:10.1016/j.neuropsychologia.2005.02.009

McCourt, M. E., Freeman, P., Tahmahkera-Stevens, C., & Chaussee, M. (2001). The influence of unimanual response on pseudoneglect magnitude. *Brain and Cognition, 45*, 52-63. doi:10.1006/brcg.2000.1255

Milner, A. D., Brechmann, M., & Pagliarini, L. (1992). To halve and to halve not: an analysis of line bisection judgements in normal subjects. *Neuropsychologia, 30*, 515-526.

Nicholls, M. E., Mattingley, J. B., & Bradshaw, J. L. (2005). The effect of strategy on pseudoneglect for luminance judgements. *Brain Research. Cognitive Brain Research, 25*, 71-77. doi:10.1016/0028-3932(92)90055-Q

Nicholls, M. E. & Roberts, G. R. (2002). Can free-viewing perceptual asymmetries be explained by scanning, pre-motor or attentional biases? *Cortex, 38*, 113-136. doi:10.1016/S0010-9452(08)70645-2

Nicholls, M. E. (1996). Temporal processing asymmetries between the cerebral hemispheres: Evidence and implications. *Laterality, 1*, 97-137.

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia, 9*, 97-113. doi:10.1016/0028-3932(71)90067-4

Olivers, C. N. & Nieuwenhuis, S. (2006). The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 364-379. doi:10.1037/0096-1523.32.2.364

Orr, C. A. & Nicholls, M. E. (2005). The nature and contribution of space- and object-based attentional biases to free-viewing perceptual asymmetries. *Experimental Brain Research, 162*, 384-393. doi:10.1007/s00221-004-2196-3

Pérez, A., García, L., Lage, A., Leh, S. E., & Valdes-Sosa, M. (2008). Right impairment of temporal order judgements in dyslexic children. *Laterality: Asymmetries of Body, Brain and Cognition, 13*, 545-560.

Pérez, A., García, L., & Valdes-Sosa, M. (2008). Rightward shift in temporal order judgements in the wake of the attentional blink. Psicológica. *International Journal of Methodology and Experimental Psychology, 29*, 35-55.

Pérez, A., Peers, P.V., Valdes-Sosa, M., Galan, L., García, L., & Martínez-Montes, E. (2009). Hemispheric modulations of alpha-band power reflect the rightward shift in attention induced by enhanced attentional load. *Neuropsychologia, 47*, 41-49. doi:10.1016/j.neuropsychologia.2008.08.017

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849-860. doi:10.1037/0096-1523.18.3.849

Robertson, I. H., Mattingley, J. B., Rorden, C., & Driver, J. (1998). Phasic alerting of neglect patients overcomes their spatial deficit in visual awareness. *Nature, 395*, 169-172. doi:10.1038/25993

Rorden, C., Mattingley, J. B., Karnath, H. O., & Driver, J. (1997). Visual extinction and prior entry: impaired perception of temporal order with intact motion perception after unilateral parietal damage. *Neuropsychologia, 35*, 421-433. doi:10.1016/S0028-3932(96)00093-0

Sekuler, R., Tynan, P., & Levinson, E. (1973). Visual Temporal Order: A New Illusion. *Science*, *180*, 210-212. doi:10.1126/science.180.4082.210

Schneider, K. A. & Bavelier, D. (2003). Components of visual prior entry. *Cognitive Psychology, 47*, 333-366. doi:10.1016/S0010-0285(03)00035-5

Shore, D. I. & Spence, C. (2005). Prior Entry. In L.Itti, G. Rees, & J. Tsotsos (Eds.), *Neurobiology of Attention* (pp. 89-95). New York: Elsevier Academic Press. doi:10.1016/B978-012375731-9/50019-7

Shore, D. I., Spence, C., & Klein, R. M. (2001). Visual prior entry. *Psychological Science, 12*, 205-212. doi:10.1111/1467-9280.00337

Siman-Tov, T., Mendelsohn, A., Schonberg, T., Avidan, G., Podlipsky, I., Pessoa, L. et al. (2007). Bihemispheric leftward bias in a Visuospatial attention-related network. *Journal of Neuroscience, 27*, 11271-11278. doi:10.1523/JNEUROSCI.0599-07.2007

Sinnett, S., Juncadella, M., Rafal, R., Azanon, E., & Soto-Faraco, S. (2007). A dissociation between visual and auditory hemi-inattention: Evidence from temporal order judgements. *Neuropsychologia, 45*, 552-560. doi:10.1016/j.neuropsychologia.2006.03.006

Spalek, T. M. & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science, 16*, 15-18. doi:10.1111/j.0956-7976.2005.00774.x

Sternberg, S. & Knoll, R. L. (1973). The perception of temporal order: Fundamental issues and a general model. In S. Kornblum (Eds.), *Attention and Performance IV* (pp. 625-685). New York: Academic Press.

Titchener, E. B. (1908). *Lectures on the Elementary Psychology of Feeling and Attention*. New York: Macmillan. doi:10.1037/10867-000

Vaid, J., Singh, M., Sakhuja, T., & Gupta, G.C. (2002). Stroke direction asymmetry in figure drawing: influence of handedness and reading/writing habits. *Brain and Cognition, 48*, 597-602.

Vallortigara, G., Rogers, L. J., Bisazza, A., Lippolis, G., & Robins, A. (1998). Complementary right and left hemifield use for predatory and agonistic behaviour in toads. *Neuroreport, 9*, 3341-3344. doi:10.1097/00001756-199810050-00035

Weintraub, S. & Mesulam, M. M. (1987). Right cerebral dominance in spatial attention: Further evidence based on ipsilateral neglect. *Archives of Neurology, 44*, 621-625.