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Rightward shift in temporal order judgements in the wake of the attentional blink

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The temporal order of two events, each presented in a different visual hemifield, is judged correctly by typical observers even when their onsets differ only slightly. The present study examined the influence of an endogenous process on TOJ, and shows that the perception of temporal order is also affected when available attentional resources are reduced via an attentional blink (AB) paradigm. Participants were presented with a first visual target stimulus (T1) at fixation and after a delay (either 280 or 1030 ms) a pair of lateralized stimulus occurred (T2). For the dual task and with the 280 delay between T1 and T2, accuracy in the TOJ deteriorated evincing an AB. However, instead of the left favoring asymmetry in normal attention conditions, a significant bias away from the left space emerged during the AB.

The lateralization of visual attention can be studied with the temporal order judgment (TOJ) task. In this task two stimuli are presented, one in each visual hemifield and with variable time lags between them. Then subjects have to judge which stimulus appears first (Shore & Spence, 2005). TOJ provides us with two fundamental measures of the possible effects of attention: (i) the time interval between stimuli for which the observer is able to differentiate their order, and (ii) the precision with which the task can be performed. Two summary statistics have typically been computed from data: (i) the point of subjective simultaneity (PSS) and (ii) the just noticeable difference (JND). PSS refers to the interval between two stimuli at which observers reports maximal uncertainty and JND provides a measure of how far in time must be presented for them to be ordered in time with a reliability of 75% accuracy level.

The temporal order of the two events is judged correctly by typical observers even when their onsets differ only slightly (Stelmach & Herdman, 1991). If attention is drawn to one side of the visual field by an exogenous

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cue, in typical subjects the TOJs are biased towards this cued side as compared with a baseline in which attention is equally distributed (Schneider & Bavelier, 2003; Shore, Spence, & Klein, 2001). This emphasizes underlining the sensitivity of the TOJ to attentional factors (Shore et al., 2001).

The TOJ is also very sensitive to attentional dysfunction subsequent to brain damage (Rorden, Mattingley, Karnath, & Driver, 1997). Brain lesions, most frequently in the right inferior parietal lobe and in the right temporal-parietal junction (Halligan, Fink, Marshall, & Vallar, 2003), often induce a strong attentional bias favoring the right side of the visual field, or the right side of objects. In visual neglect, awareness of information in the left visual hemifield is impaired (Danckert & Ferber, 2005; Driver & Vuilleumier, 2001; Driver et al., 2001). In visual extinction, a single stimulus on the left can be perceived, but it is not seen when presented simultaneously with a competing stimulus on the right (Baylis, Simon, Baylis, & Rorden, 2002; Vuilleumier & Rafal, 2000; Vuilleumier et al., 2000). In patients with extinction (Rorden et al., 1997) or neglect (Robertson, Mattingley, Rorden, & Driver, 1998; Sinnett, Juncadella, Rafal, Azanon, & Soto-Faraco, 2007), there is a strong tendency for the right stimulus to be perceived as appearing first in the TOJ, even when it lags behind the left stimulus by several hundred milliseconds.

In the present study we examine the relationship between spatially lateralized and non-spatially lateralized attentional mechanisms in healthy subjects. The motivation for the study comes basically from intriguing findings in patients suggesting that two types of attentional impairments (lateralized and non-lateralized deficits) could be functionally related (Husain, 2005; Battelli et al., 2001; Robertson et al., 1997; Husain & Rorden, 2003; Wojciulik, Husain, Clarke, & Driver, 2001; Bonneh, Pavlovskaya, Ring, & Soroker, 2004; Becchio & Bertone, 2006). The first observation supporting this functional relationship is that in many cases with neglect or extinction (and consequently with a striking bias of attention to one side) one can also find significant non-spatial attentional impairments. Cases with right-hemisphere lesions and neglect have impaired tonic alertness (Robertson et al., 1998). Further evidence comes from consideration of the "attentional blink" (AB). In the AB paradigm two sequentially presented target stimuli (T1 and T2), have to be identified. The AB is an impairment in the identification of T2 when presented within a few hundred milliseconds of T1 (Duncan, Ward, & Shapiro, 1994; Raymond, Shapiro, & Arnell, 1992; Raymond et al., 1992). The attentional nature of this effect is demonstrated by the reduction in the magnitude of the AB when T1 is ignored.

In patients with left-sided neglect the AB can be prolonged up to 1 sec (Husain, Shapiro, Martin, & Kennard, 1997), evincing sluggish temporal dynamics for attention.

A link between lateralized spatial bias and non-spatial attentional deficits has also been described in healthy adult population. It has been shown that reducing vigilance either by sleep deprivation (and possibly attentional resources) or by fatigue (related to time-on-task), produced a rightward shift on a line bisection task (Manly, Dobler, Dodds, & George, 2005). In the study of Manly et al (2005), the rightward shift in attention consisted in the reduction of the normal leftward spatial bias called pseudoneglect (Bowers & Heilman, 1980). This modest but very reliable leftward bias is best documented in the line bisection task (Bultitude & imola Davies, 2006; Jewell & McCourt, 2000; Porac, Searleman, & Karagiannakis, 2006) but could be found in a number of spatial attention tasks (Nicholls, Mattingley, & Bradshaw, 2005; Vingiano, 1991).

It has been also demonstrated that pseudoneglect was significantly reduced in participants from the normal population who performed poorly on a (non-spatial) sustained attention task (Bellgrove, Dockree, Aimola, & Robertson, 2004). Results of Bellgrove et al (2004) indicate that the leftwards spatial bias (assessed by a Greyscales Task) is attenuated in the case of poor performance in a dual-task version of the sustained attention to response task (SART). Others authors employed the dual task paradigm to measure spatial bias on a visual task while manipulating demands of a concurrent auditory task (Peers, Cusack, & Duncan, 2006). They demonstrated that dual task cause a global shift in visual attention to the right and suggested that may in some way be linked to arousal.

Perhaps the most direct evidence of a relationship between lateralized spatial bias and non-spatial attentional deficits was described in a study of phasic alerting in patients with neglect. In the traditional TOJ these patients showed a bias in favor of right sided stimuli. However, if the pair of upcoming TOJ stimuli was cued by a warning sound (which alerted only about the imminent onset of the stimuli but not about their temporal order) the bias in favor of the right visual side was abolished (Robertson et al., 1998). This suggests that mobilization of non-lateralized attentional resources can ameliorate the spatial bias for attention in neglect. In summary, lateralized attentional bias and non-spatial attentional deficits frequently co-exist in patients with brain damage, and non-lateralized attentional alerting can improve lateralized attentional bias.

Given the relationship between lateralized and non-lateralized attentional processes suggested by the patient and normal data, we wondered: Could a reduction of available non-lateralized attentional resources evince a spatial visual shift detectable with a TOJ task, in typical subjects? To address this question one possibility was to artificially produce this reduction by an AB. If in patients the mobilization of non-lateralized attention reduces lateralized bias, then perhaps depletion of non-lateralized attention could cause a lateralized bias in normal subjects. Note that this procedure differs from the lateralized exogenous cues that have been shown to sway temporal order judgments (TOJ) towards a spatial location (Schneider et al., 2003; McDonald, Teder-Salejarvi, Di Russo, & Hillyard, 2005).

To reduce the attentional resources available we used an AB paradigm coupled to a TOJ task. In a first experiment, the T1 was a small visual shape presented at fixation followed by bars that were presented respectively in each visual hemifield and served as stimuli for the TOJ task. When the subjects ignored T1, or the stimulus onset asynchrony (SOA) between T1 and T2 was large, then full attention could be devoted to the bars and accurate performance of the TOJ should be expected. Nevertheless when the subjects had to recognize the shape change of T1, then an AB for the two bars stimulus could be expected in a range described approximately up to 400 ms (Husain et al., 1997; Duncan et al., 1994; Raymond et al., 1992). If the depletion of attentional resources (due to the AB) can cause a lateralized attentional bias, then the perceived order of presentation should shift to the right visual field.

In an attempt to establish whether the spatial bias is strongly dependent of the nature of the task involved with T1 stimulus, we implemented a second experiment. The T1 task in Experiment 2 was a lexical decision. This task is primarily verbal and therefore recruits the left hemisphere (Hugdahl, 2000), as opposite to the detailed shape processing T1 task in Experiment 1, which involves the two brain hemispheres asymmetrically with right hemisphere more loaded (Corbetta, Miezin, Shulman, & Petersen, 1993). According to Kinsbourne's 'functional distance model' tasks which are processed by the same or anatomically close regions of the brain (such as speaking and the use of the right hand) are more difficult to perform simultaneously (Kinsbourne & Hicks, 1978). If we consider T1 task under AB conditions as a concurrent task, we may expect to see a bias to the left (weaker attention to the right) with a lexical decision task, whilst with a shape discrimination would be expected to shift the bias to the right (weaker attention to the left) in case that the effects depends on the exact content of the T1 task. If the bias exists and do not change direction with the nature of T1 task, we can discard that bias has been caused mainly because of the properties of the primary task.

EXPERIMENT 1

METHOD

Participants. Fourteen participants (3 females/11 males) with an age range of 22 to 45 years took part in the study. They were recruited as unpaid volunteers. All were right handed as assessed by self report with the Edinburgh Handedness Inventory (Oldfield, 1971), with scores above 85. All participants had normal or corrected-to-normal visual acuity, and had no history of neurological or psychiatric disorders.

Instruments. The experiment was conducted in a quiet room with natural illumination. Stimuli were presented on a 15” sVGA computer display with 800 x 600 pixels resolution and a black background, controlled by a 933 MHz Intel Pentium III Copermine computer, using a custom written program. The central stimulus, a white square of 0.8°, was present all the time. It contained a small diamond. Disappearance of one of the corners of this inner diamond was achieved by turning off 16 pixels. White 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 4.2° away from the fixation point. A two-alternative forced choice method was applied with no time pressure for the responses given via the keyboard. The experiment was preceded by a short training period of five to ten trials on each task to ensure that the participant had fully understood the instructions.

Procedure. Two different tasks were used, a local shape-change discrimination and a TOJ. For each trial, series of displays depicted in Figure 1 were presented on a computer monitor which was located approximately 50 cm in front of the subjects. The sequence was triggered by pressing a key. First a small white square was presented upon a black background. The centre of this white square was in the form of a black ‘diamond’, giving the appearance that the square had a ‘hole’. The diamond served as fixation point throughout the trial.

After a delay of 300 ms, the first target (T1) appeared, which consisted of the brief disappearance (30 ms) of one of the four corners of the diamond (see inset in Figure 1). This alteration had to be described by observers at the end of the trial, by a forced choice of the arrow key of the computer keyboard that indicated the corner that had disappeared (up, down, right and left).

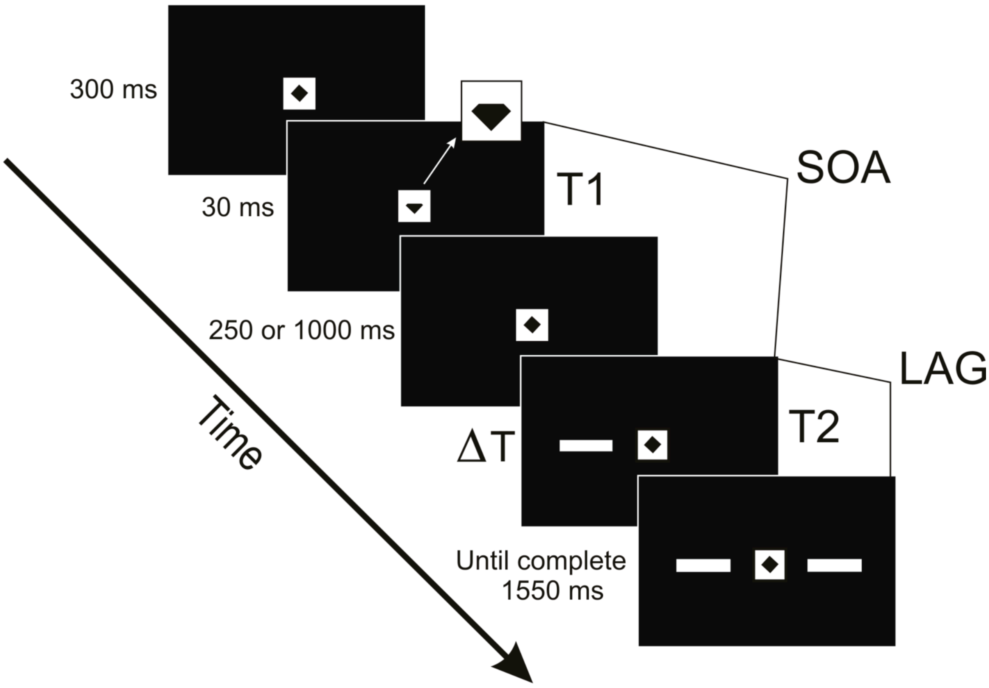

Figure 1: Temporal sequence of Experiment 1. After 300 ms screen presentation of a central square, one of the corners is erased for 30 ms (this is T1). After a variable SOA one of the bars appears. The other bar is added at different time lags (Δt=30, 60, 90 and 120 ms). The two bars are the T2 stimuli. Finally the two bars remain until 1550 ms have elapsed. Bar appearance order is randomized.

Appearance order is randomized. After the missing corner was restored, two stimulus onset asynchronies (SOA) were used: 280 and 1030 ms. Note that with short SOA of 280 ms an AB is expected and with a longer SOA of 1030 ms AB should be minimal or not present. Then T2 was presented, which consisted of the presentation of two bars, one on each side of the fixation point, with a variable time lag between the two. Nine different time lags were used, four in which the left bar preceded the right one (30, 60, 90, 120 ms lags), four in which the right bar preceded the left one (30, 60, 90, 120 ms lags) and a lag of zero (simultaneous presentation). After the two bars had been presented, the display was left on until trial completion (1550 ms). After the sequence of stimuli, the subjects were prompted to respond, indicating (forced-choice) if the left or the right bar had appeared first. Right or left arrow keys were used for responding. All responses were given with the right hand.

Two types of blocks were used, a divided-attention block and a focused attention block, the order of presentation of which was counterbalanced across participants. In the divided-attention block, responses to both T1 and T2 were required (T1 first and T2 second). In the focused-attention block, subjects were only required to perform the TOJ and asked to ignore T1. To facilitate this, on these blocks the local shape-change was the same on all trials, and consisted of the disappearance and re-appearance of the upper corner.

A total of 360 trials were presented in each block, which were uniformly distributed over the eighteen combinations of two SOA values and nine different time lags between the onset of the right and left bars. The order of presentation of different trial types was pseudo-random. 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, including only trials with correct response to T1.

The proportion of 'right first' responses was converted to its equivalent Z-score using probit analysis assuming a cumulative normal distribution (Finney, 1964). This transformation, commonly used in studies using the TOJ task (Zampini, Shore, & Spence, 2003; Sinnett et al., 2007), allows us to perform a linear regression with the transformed data and the intermediate nine LAGs. From the slope and intercept of the fitted line, derive the PSS and the JND, for each participant for each condition. The JND and PSS data were submitted to paired samples t-tests comparing the SOA 280 ms and the SOA 1030 ms in the Divided Attention and Focused Attention conditions.

The proportion of 'right first' responses were submitted to a repeated measures analysis of variance (ANOVA) the factors being SOA (SOA 280 ms vs. SOA 1030 ms) and Side (Left vs. Right). Zero LAG was not used. A Greenhouse-Geisser correction of probability was applied when appropriate.

RESULTS

T1 was discriminated accurately in all the blocks in which this was required, with hit rates above 91% for all conditions in all subjects. The order of presentation of blocks and all interactions involving order of presentation were not statistically significant. The results for the T2 (from the TOJ) are plotted in Figure 2, and are depicted as the percentage of trials in which the stimulus on the right was judged to be the first to appear (% right-first). Negative time-lags correspond to the left-bar appearing first, and positive time-lags to the right bar appearing first. Zero lag corresponds to simultaneous appearance. As expected the % right-first responses increased monotonically for all conditions as the timing for the onset for the two bars changed from left-first (negative LAG values) to simultaneity (LAG=0), and then to right-first (positive LAG values).

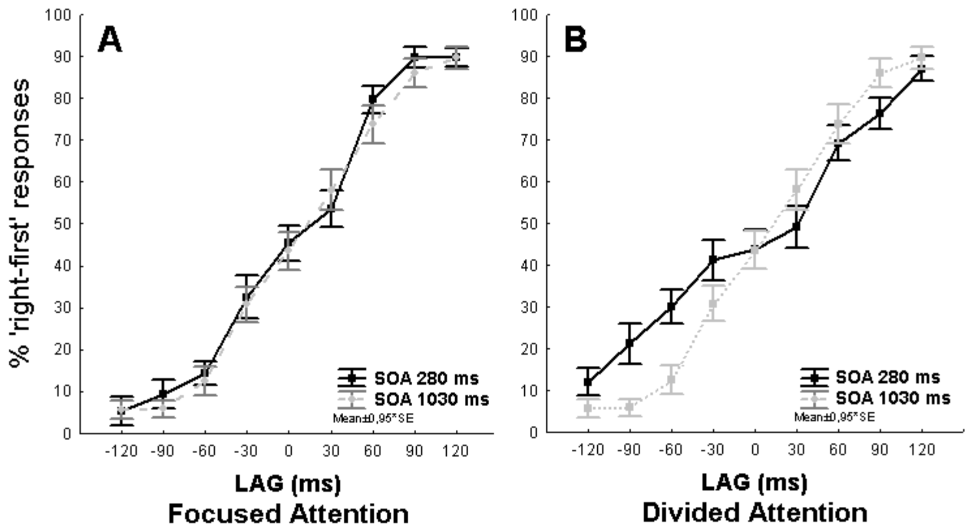

Figure 2: Experiment 1. Percent of right-first responses in TOJ as a function of the LAG between the two T2 stimuli. The first stimulus is a shape change detection. When the left bar appears first the LAGs is represented as negative values, and when the right bar appears first by positive values. Zero lag corresponds to simultaneous onset. A) Focused attention condition block in which T1 is ignored. B) Divided attention condition block. In the 280 ms SOA an AB appears.

The focused attention block, in which T1 was ignored and only the TOJ was performed were the conditions most similar to the TOJ used in other studies. The plots of the percentage of right-first responses as a function of LAG were very similar for the two SOAs in this block (figure 2-A). This was confirmed by a paired sample t-test comparing the performance measures of PSS and JND, in which no significant difference emerged between SOA 280 (PSS=16.3 ms, JND=36.6 ms) ms and SOA 1030 ms conditions (PSS=17.7 ms, JND=35.3 ms) (see table 1). The t-tests for single means revealed that the observed PSS positive values were significantly different from 0 ms in either the SOA 280 ms (t=2.7, p<0.02) and SOA 1030 ms conditions (t= 4.0, p<0.002). Positive PSS values are defined as the time in milliseconds that the bar on the right must be presented before the bar on the left for both events being perceived as simultaneous. Using de Z-scores for every LAG obtained from probit analysis, a t-test between SOA conditions was no significant in any LAG.

Table 1: Summary statistics from the PSS and JND of each participant from the TOJ task in divided attention and focused attention conditions. Mean, confidence intervals and standard deviation are showed.

	Experiment 1								Experiment 2			
	Divided Attention block				Focused Attention block				Divided Attention			
	SOA 280 ms		SOA 1030 ms		SOA 280 ms		SOA 1030 ms		SOA 280 ms		SOA 1030 ms	
	PSS	JND	PSS	JND	PSS	JND	PSS	JND	PSS	JND	PSS	JND
Mean	6.7	78.4	17.6	45.9	16.3	36.6	17.7	35.3	-2.3	50.2	5.4	31.9
Confidence -95%	-14.0	38.7	4.7	24.7	3.5	24.1	8.1	20.5	-27.4	30.8	-7.8	21.8
Confidence +95%	27.4	118.0	30.6	67.0	29.2	49.1	27.3	50.1	22.7	69.7	18.6	42.0
Std.Dev.	35.9	68.7	22.4	36.7	22.3	21.78	16.6	25.7	37.3	29.0	19.7	15.0

A repeated-measures ANOVA restricted to this block elucidated a non-significant SOA main effect. A Side effect (F(1,13)=8.94, p<0.02) emerged, with higher accuracy in the left-leading conditions (negative lags) than in the right-leading conditions (positive lags) (87% versus 79%). These data in addition to a PSS being significantly different from zero, confirms a leftward spatial bias consistent with the pseudoneglect phenomenon.

In the Divided Attention block (in which an AB was expected) the PSS and JND are not statistically different for SOA 280 ms and SOA 1030 ms in a paired t-test. For trials with the 1030 ms SOA where the AB should be minimal, observed PSS values were significantly different from 0 ms (t=2.93, p<0.02) in a t-test for single means. This is an indicator of pseudoneglect in this SOA condition, the most similar to the Focused Attention conditions. The same test confirmed no difference from 0 ms for trials with 280 ms SOA, it means no leftward spatial bias in this condition.

Repeated measures ANOVA was performed on the % right-first data just described. The main effect of SOA was significant ($F(1,13)=15.6$, $p<0.002$), the subjects perceived with more accuracy the order of bars for the long SOA than for the short SOA.

The comparison between the condition of divided attention with SOA 280 ms and condition of focused attention with SOA 1030 ms was expected to illustrate the maximal effects of the AB over TOJ. These are the conditions in which attentional resources available for T1 processing differ most. The PSS parameter was not different between these conditions. The JND parameter was significantly different ($t=2.4$, $p<0.04$) with longer times needed to identify accurately apparition order in the Divided attention SOA 280 ms.

Looking for possible effects due to fatigue, the trials in each block were divided in two successive halves (to gauge the effect of time-on-task). No effects due to time-on-task (i.e. fatigue) or its interactions with other variables were found either.

DISCUSSION

When attention was fully available for the TOJ task (at long T1-T2 SOAs or when ignoring T1), the temporal order of the T2 stimuli was more accurately perceived. Also with attention fully available, appeared a leftward spatial bias consistent with the pseudoneglect phenomenon (Bowers et al., 1980). However, when attention was clearly drawn away from the TOJ task (with active discrimination of T1 and with short T1-T2 SOAs), then the processing of T2 was impaired with a larger probability for left-first stimuli. This impairment consisted in defective information of the "arrival times" (Sternberg & Knoll, 1973). In trials with defective information the perceiving order is disturbed and the answers were given randomly. The result was an effect in which the percentages of the responses are closer to the 50% value. This effect is larger for the short LAG values.

One explanation to consider is that the described bias reflects a failure to see both T2 stimuli due to the AB produced by attending to T1. Guessing on a fraction of the trials would pull the curves towards chance behavior (50% right-first responses). But "T2 blindness" should have the same result for all the time-lags between T2 pairs, not the selective deficit of left-first trials observed here. Furthermore, the subjects reported on debriefing that they could clearly perceive the two T2 bar stimuli under the condition with a large AB.

Note that this bias only appeared under conditions when the AB is largest. This indicates that the effect is a consequence of attentional factors. Purely sensory effects due to T1 such as visual masking deficits would have also been present for the short SOA in the ignore-T1 condition. A systematic bias to select one response (i.e. right–first) would also have emerged in all the conditions, and thus can be discarded as an explanation.

Manly et al. (2005) suggest that a diminution in alertness may be sufficient to induce a rightward advantage in visual attention in the healthy brain. Peers et al. (2006) suggest a similar mechanism and argue that dual task is a high cognitive load condition in where, depleted resources are resulting in reduction of arousal (Smit, Eling, & Coenen, 2004a; Smit, Eling, & Coenen, 2004b). Perhaps effects reported by them, exert their effects through a reduction in attentional resources. Note however that fatigue is not an explanation for our data, since time-on-task did not affect our subjects' behavior on the TOJ.

EXPERIMENT 2

METHOD

Participants. Fourteen participants (10 females/4 males) with an age range of 27 to 34 years took part in the study. They were recruited as unpaid volunteers. All were right handed as assessed by self report with the Edinburgh Handedness Inventory (Oldfield, 1971), with scores above 85. All participants had normal or corrected-to-normal visual acuity, and had no history of neurological or psychiatric disorders.

Instruments. The Experiment 2 was conducted with the same equipment and conditions of Experiment 1. The central stimuli were written words in white color, with arial style and font size 26. A total of 640 words were employed, divided in two categories: nouns and verbal forms. All words had a high use frequency and all were selected from a cuban norm Frequency Dictionary (Havana, Neuronic S.A.) (Piñeiro, Reigosa, & Manzano, 1999). Every word would be completely occluded by a mask with 0.8° x 3.6° approximately size (see Figure 3).

White horizontal circles, with 0.7° of radio appeared at symmetrical locations in the left and the right visual fields and at the same height as the central word. The outer edges of the circles subtended 4.2° from the fixation. A two-alternative forced choice method was applied with no time pressure for the responses given via the keyboard. The experiment was preceded by a short training period of five to ten trials on each task to ensure that the participant had fully understood the instructions.

Procedure. The two different tasks used were a lexical decision and a TOJ. The successions of displays were presented on a computer monitor which was located approximately 50 cm in front of the subjects. During the trial the sequence of events (depicted in Figure 3) was as follows: first the mask with the two circles (one in each side) was presented upon a black background. Hitting a key initiated the trial. After a delay of 300 ms, mask is retired and a word (T1) appeared. Central word remains for 250 ms. Observers had to describe at the end of the trial by a forced choice with the arrow key of the computer keyboard if the word was a noun (up arrow key) or a verbal form (down arrow key).

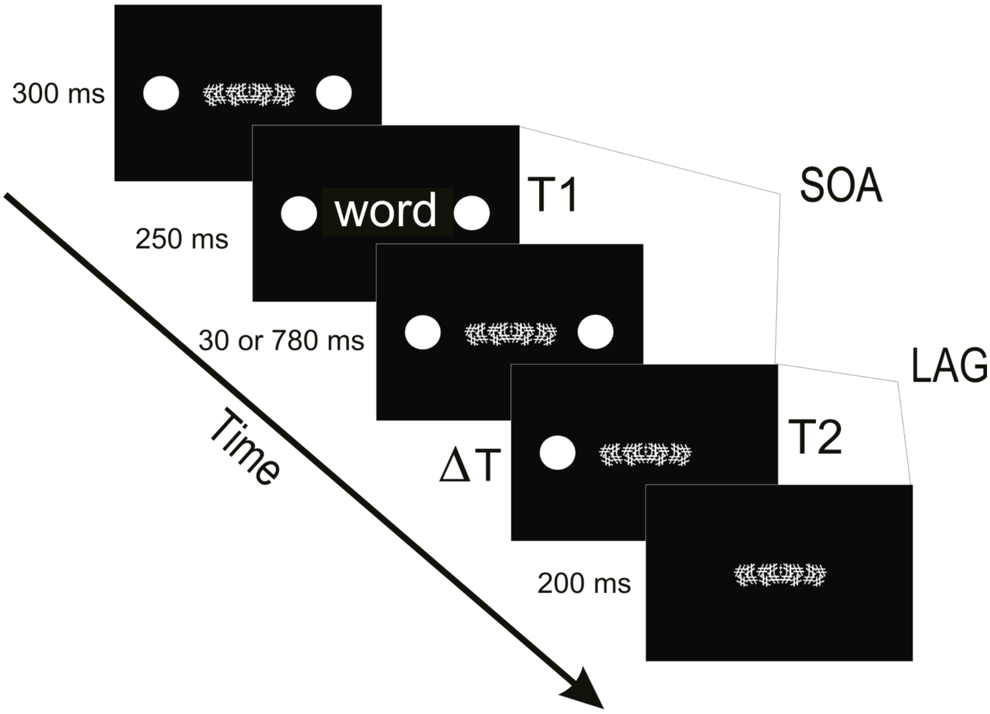

Figure 3: Temporal sequence of Experiment 2. Screen presentation of the two circles and a mask, a central word appeared for 250 ms (this is T1). After a variable SOA one of the circles disappears. The other circle is eliminated at different time lags (Δt=30, 60, 90 and 120 ms). Disappearance of the two circles is the T2 stimuli. Finally the mask remain 200 ms have elapsed. Circle disappearance order is randomized.

After the word was retired and the mask restored, two SOA were used: 280 and 1030 ms. TOJ task in this experiment (T2) consisted in the disappearance of the two circles, with a variable time lag between the two (offset mode). It has been proved that abrupt visual onsets receive prioritized selection for processing (Donk & Theeuwes, 2001; Yantis & Jonides, 1984), then TOJ in offset mode should be more attention demanding.

Same nine different time lags as in Experiment 1 were used. After the two circles disappeared, the display with the mask was left on 200 ms. After the sequence of stimuli, the subjects were prompted to respond, indicating (forced-choice) if the left or the right bar had disappeared first. Right and left arrow keys in the computer keyboard were used for responding according to the place the circle disappeared first. All responses were given with the right hand.

Only one block was used, the divided-attention block in which responses to both T1 and T2 were required (T1 first and T2 second). A total of 360 trials were presented, which were uniformly distributed over the eighteen combinations of two SOA values and nine different time lags in the TOJ. The order in which different trial types were presented was pseudo-random. The percent of responses on which the subject indicated that the right circle disappeared first (% right-first responses) was calculated for each condition in all subjects, including only trials with correct response to T1.

RESULTS

T1 was discriminated accurately with hit rates above 95% for all conditions in all subjects. The proportion of the 'right first' responses (see Figure 4) was converted to its equivalent Z-score with a probit analysis and the intermediate nine LAG were used to calculate a best-fitting straight line, just as in Experiment 1. The PSS an the JND data were submitted to paired samples t-test comparing SOA 280 ms vs. SOA 1030 ms condition.

One participant was excluded from the subsequent data analysis because she reported no left-first stimulus under AB conditions. A posterior MRI scan revealed an asymptomatic brain anomaly.

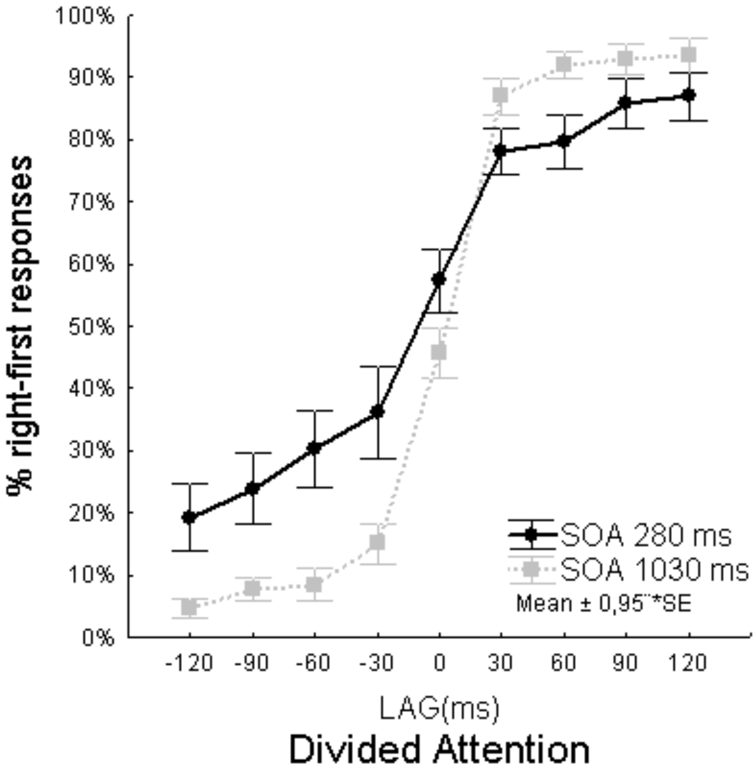

Figure 4: Experiment 2. Percent of right-first responses in TOJ as a function of the LAG between the two T2 stimuli. The first stimulus is a written word (lexical decision task). When the left bar appears first the LAGs is represented as negative values, and when the right bar appears first by positive values. Zero lag corresponds to simultaneous onset. Attention is divided between T1 and T2 stimuli. In the 280 ms SOA condition an AB is denote.

The PSS mean for the SOA 280 ms (-2.3 ms) reflected a shift towards the right (the left stimulus had to lead the right stimulus for subjective simultaneity to be achieved). For the SOA 1030 ms PSS mean (5.4 ms) reflected the opposite, a shift towards the left (the right stimulus had to lead the left stimulus to be perceived as simultaneous)(see Table 1). The t-test revealed that the observed PSS values were not significantly different between conditions but exist the tendency to a rightward shift under AB conditions. Neither each conditions was different from 0 ms. In the case of the JND data, a significant difference between conditions was found ($t=2.3$, $p<0.04$). The lower values in SOA 1030 ms (mean: 33 ms) than in SOA 280 ms condition (mean: 78.3 ms) indicated less accuracy in the TOJ performance under AB conditions. Even when the data is not conclusive, due to variation among individual performances, we interpret the results as a need of longer processing time for left-sided stimuli during AB conditions and therefore a rightward shift in visual attention.

DISCUSSION

For the AB condition there was less accuracy (larger JND) as well as a tendency of PSS to shift toward negative values. It could be considered as a replication of the main results, a rightward shift in visual attention. The nature of the task involved in T1 could not explain a bias when processing T2 within a short interval as a carry-over effect. In fact, if we don't consider T1 as a concurrent task an opposite pattern of results could be expected. That is because, according to the Kinsbourne's theory, the two cerebral hemispheres co-exist in a form of dynamic competition and relative increases in activation in one hemisphere (as it could be possible with T1) tend to bias attention towards contralateral space (Kinsbourne, 1970). For example, it has been suggested that the act of performing a spatial task is enough to shift attention leftwards (McCourt, Freeman, Tahmahkera-Stevens, & Chaussee, 2001). From this point of view, bias in Experiment 1 would be a leftward bias (opposite to results obtained) and bias for Experiment 2 should be a rightward bias. Within this view other factors such as the hand used to perform the task can exert an additional influence (Failla, Sheppard, & Bradshaw, 2003). Anyway, this alternative explanation only emphasized in the validity of the results obtained. In brief, the experiment helps to discard the bias obtained as a carry-over effect produced by the nature of T1 task.

GENERAL DISCUSSION

To our knowledge no previous work has examined the effect of endogenous-attentional factors on the symmetry of TOJ in typical subjects. Several studies have shown that exogenous cueing of one side of the visual field will bias the TOJ in favor of the cued side (Jaskowski, 1993; McDonald et al., 2005; Shore et al., 2001). But in our study the manipulation of attention was non-lateralized. Via the AB we provoked a diminution in the TOJ performance accuracy. However, a few studies have examined the relationship of endogenous-attentional and spatially-lateralized attention with other tasks in healthy subjects (Manly et al., 2005; Rhodes & Robertson, 2002; Peers et al., 2006).

The pseudoneglect found in the "base-line" can be related to the reading scanning habits (left to right). It has been described an effect of reading scanning habits on performance asymmetry in lateralized tasks. There are two mechanisms possibly involved in lateral preferences in recognition. One of them is the scan for the leftmost element (Heron, 1957). This mechanism biases reflexive attentional orienting towards the side at which reading usually begins (Eviatar, 1995), left side in English and Spanish language. Note that the possible influence of the ocular movements is discarded because the first stimulus is central, therefore does not move the sight to any side. Instead, maximal LAG time used (120 ms) is not enough time to make ocular movements (saccade latency is 180 ms approximately) (Husain et al., 2001), avoiding ocular movements until the occurrence of both stimulus. Another possibility for the pseudoneglect presence is about the fact that all observers are right handed.

The results reported here may be considered as a rightward shift in visual attention under AB conditions and could be explained by the Biased Competition model developed by Desimone and Duncan (1995). It postulates that objects in the visual field, acting as wholes, compete for limiting processing capacity and control of behavior. This competition is biased by bottom-up neural mechanisms (such as stimulus saliency), and top-down mechanisms (such as task relevance) that select an object significant to the current behavior. Biasing of competition produces a preferred attention in favor of some stimuli over others (Desimone & Duncan, 1995).

In both the TOJ and line bisection tasks, stimuli from two sides of the visual field can be considered to be competing for attention and therefore for the strength, priority and clarity of phenomenological representation. When attention can be fully devoted to the stimuli (when the subject is alert, not fatigued, and with focused attention), the strength of the representation of the competing stimuli can be unbalanced by top-down attentional mechanisms, as the overestimation of the left in pseudoneglect. If attentional resources are depleted (by drowsiness, fatigue, or by distracters) then the competition is played out without top-down guidance and spatially-lateralized biases can shift.

These preliminary results may have some implications for the study of disorders with attentional impairments and for understanding the pseudoneglect phenomenon. The left-sided deficits of visual processing that have been observed in dyslexic subjects (Stein & Walsh, 1997; Hari & Renvall, 2001; Hari, Renvall, & Tanskanen, 2001; Hari & Koivikko, 1999; Sireteanu, Goertz, Bachert, & Wandert, 2005) and in children with attention deficit hyperactivity disorder (ADHD) (George, Dobler, Nicholls, & Manly, 2005; Dobler et al., 2005; Manly, Cornish, Grant, Dobler, & Hollis, 2005), can be interpreted in part as a consequence of the lost in the normal preference for the left side, due to attentional impairment factors. Pre-existing biases in visuo-spatial processing have been invoked to explain why lesions to the two brain hemispheres are differentially prone to neglect and extinction (Duncan et al., 1999). If this is true then, it suggests that the strong lateral biases found after lesions of the right hemisphere are not exclusively due to the lateralized nature of the brain damage (Husain, 2005). Furthermore, the reason of the left overestimation in pseudoneglect may be due to an asymmetry in the previous active assignation of attention in competing stimuli. Further research should concentrate on using imaging methods (i.e. event-related potentials, functional magnetic resonance) to explore the biological basis of this bias away from the left side of the space.

RESUMEN

Cambio hacia la derecha en los juicios de orden temporal durante el parpadeo atencional. El orden temporal de dos eventos, cada uno de ellos presentado en un hemicampo visual diferente, puede ser juzgado correctamente por observadores típicos inclusive cuando la diferencia de tiempo entre las presentaciones sea muy pequeña. El presente trabajo analiza la influencia de un proceso endógeno sobre el juicio de orden temporal (JOT) y nos muestra que la percepción del orden temporal está también afectada cuando los recursos atencionales disponibles son reducidos mediante un paradigma de parpadeo atencional (PA). A los participantes se les presentaron los siguientes estímulos: un primer estímulo visual (T1) en el centro de fijación y luego de un intervalo de tiempo variable (280 ó 1030 ms), un par de estímulos lateralizados (T2). Para la tarea dual con el intervalo de tiempo de 280 ms entre T1 y T2, la precisión en el JOT se deterioró, evidenciando un PA. Sin embargo, durante el PA en lugar de la asimetría favorable al lado izquierdo, aparece un significativo sesgo en contra de ese lado.

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