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Dissociation between visual line bisection and mental number line bisection in schizophrenia

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ABSTRACT

Many studies of hemispatial neglect patients have indicated that spatial attention processes operate similarly in visual space and number space. However, some studies have indicated a dissociation of processing between visual line bisection and mental number bisection. A number of investigations have suggested that schizophrenic patients show a mild right pseudo-neglect on visual line bisection tasks. The present study was designed to determine if a functional link exists between performance of visual line and number line bisection in schizophrenic patients. Groups of 40 schizophrenic patients and 40 controls performed each bisection task. In the visual line bisection task, schizophrenic patients showed a significant leftward bias relative to the healthy controls for 9 different line lengths. No significant difference in bias was found between the 2 groups on the mental line bisection task. These results indicated that schizophrenic patients may exhibit attention deficit with respect to visual space but not number space, suggestive of the dissociation of processing between visual line bisection and mental number line bisection. These results provide more insight into the correlation between the visual line and number bisection tasks in schizophrenic patients.

Schizophrenia is a common mental disorder that is frequently associated with an attention deficit in the right hemispace due to underlying left cerebral abnormalities [4,8,29]. Posner reported that schizophrenic patients' response to a target in the right visual field was slower than their response to a target in the left visual field, which implied attention asymmetry in schizophrenia. The performance of schizophrenic patients was similar to that of patients with unilateral lesions of the left hemisphere [24].

In recent years, attention asymmetry in schizophrenia has been demonstrated using visual line bisection tasks [4,20,21,26]. Visual line bisection is a common and sensitive test used to assess hemispatial neglect [2]. In the line bisection task, patients with left hemispatial neglect tend to place the subjective line's midpoint to the right of the objective mid-point [16]. It is generally agreed that this bias indicates the asymmetry of attention in the two hemispheres [23,30]. Conversely, numerous studies have found that schizophrenic patients tend to show a leftward bias, which represents a mild form of right pseudo-neglect, similar to right hemispatial neglect following left hemisphere brain damage [4,14,29].

Numerous studies have indicated that the semantic representation of numbers in the brain is organized along a mental number line, with small numbers on the left and large ones on the right [12,22]. Interestingly, patients with hemispatial neglect tend to misplace the midpoint of a numerical interval when asked to judge the numerical center of a pair of verbally presented numbers, and their deviation in this mental line bisection is similar to their deviation in a visual number line bisection. For example, when asked to bisect a mental number line, a patient with neglect might report that 5 is the midpoint between 2 and 6 [31]. These results provide direct evidence of the spatial nature of the mental number line and also indicate that orientation along the mental number line closely resembles orientation along a visual line [23,30,31].

Many studies of neglect patients have indicated that spatial attention processes operate similarly in visual space and in number space [5,18,23,25,31]. For example, Longo and Lourenco reported that hemispheric asymmetries in spatial attention operate similarly in visual and numerical space and that there is significant correlation in bias between the 2 bisection tasks [18]. However, increasing amounts of data have indicated a dissociation between the performance of visual line bisection and mental number bisection [1,9,17]. To clarify whether spatial attention processes operate sim-

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ilarly in visual and number space, researchers need to examine the correlation between performances on the 2 tasks in patients whose attention system is significantly compromised by localized brain damage or dysfunction. Previous works on schizophrenic patients reported separate evidence for bias in visual and number bisection but did not test the 2 tasks at the same time. Cavezian et al. found that in the number interval bisection task, schizophrenic patients show a small leftward bias [5]. Unfortunately, their study did not reported data on the eventual correlation between the visual line and number bisection tasks in schizophrenic patients. The present study was designed to determine whether a functional link might exist in the performance of these 2 tasks by schizophrenic patients. In light of the limitations of prior studies, we recruited a relatively large sample of patients and had them bisect both visual lines and mental number lines.

The patient group consisted of 40 hospitalized schizophrenic patients (21 males; mean age 35.67 ± 10.27 years). All patients were right-handed and met the DSM-IV [11] criteria for schizophrenia. Right-handedness was verified using a dominance questionnaire [28]. The Positive and Negative Syndrome Scale (PANSS) [16] was used to assess psychopathology. All patients were receiving antipsychotic medicine, and their symptoms had been under control for at least a month. The following inclusion criteria were met by all participants: (a) no demonstrable brain disease other than schizophrenia (i.e., no history of loss of consciousness and no history of neurological conditions such as epilepsy, Parkinson disease, or brain injury), (b) no history of mental retardation, and (c) no evidence of current substance abuse (including alcohol abuse).

The control group consisted of 40 neurologically normal participants (22 males; mean age 34.48 ± 10.17 years). They met the same inclusion criteria as the patient group and were matched in age and education level. All participants were right-handed and had normal or corrected-to-normal vision, and all of them showed intact numerical and arithmetic skills as evidenced by some simple mental calculations. The control and patient participants gave their informed consent prior to their inclusion in the study in accordance with the local ethics committee.

The visual line bisection test consisted of a series of 1-mm-thick black horizontal lines of 9 lengths (4, 6, 8, 10, 12, 14, 16, 18, and 20 cm). Each line was printed in the center of a white A4 paper.

The stimuli and procedure for the mental number bisection test followed the design in Zorzi's study [31]. The participants were presented with 2 spoken numbers in different numerical intervals. The interval sizes could be 3 (for example, 1–3), 5, 7, or 9. Each interval was presented using numbers below 10 (for example, 1–5), numbers between 11 and 19, and numbers between 21 and 29. Patients were given 48 trials using ascending intervals (for example, 1–9) and 48 trials with descending intervals (for example, 9–1), for a total of 96 trails in the test.

Participants sat comfortably in front of a table and were informed verbally about the procedure. They were required to perform the line bisection task as accurately as possible using their dominant hand to make a mark across the center of the line that would divide it exactly in half. The pen, arm, and hand were positioned so that no part of the line was hidden. Participants were randomly presented with 9 lines of different lengths in front of their body midline at a viewing distance of approximately 45 cm. There was no time limit.

For the mental number bisection task, 96 spoken number pairs were presented randomly to the participants. Following the oral presentation of each number interval, participants were asked to orally report the number lying halfway between the first number and the second number in the presented pair without making a calculation (e.g., "which number is the middle point between 1 and 9?"). Participants were required to respond as quickly as possible.

Table 1
Demographic and neuropsychological information.

	Control group (n = 40)	Schizophrenia group (n = 40)
Mean age (years ± SD)	34.48 ± 10.17	35.67 ± 10.27
Educational level (years ± SD)	11.35 ± 3.45	11.38 ± 3.05
Sex ratio (men/women)	22/18	21/19
Handedness (right/left)	40/0	40/0
Duration of illness (years ± SD)	–	6.56 ± 6.79
MMSE	28.48 ± 0.96	28.13 ± 0.85
PANSS positive score (mean ± SD)	–	11.90 ± 4.04
PANSS negative score (mean ± SD)	–	14.20 ± 5.80

SD, standard deviation; PANSS, Positive and Negative Syndrome Scale; MMSE, mini-mental state examination. All differences between the schizophrenia and control groups are not significant.

For the line bisection task, the distance between the participant's mark and the true midpoint was carefully measured in millimeters with calipers. This distance was the bias. Rightward bias (i.e., rightward error from the true center of the line) was given a positive value, and leftward bias (i.e., leftward error from the true center of the line) was given a negative value. For the mental number bisection task, the response was considered to have a leftward bias if the subject's answer was smaller than the true midpoint number. As previously described [13,30], these answers were scored negatively, whereas a rightward bias (which occurred when the subject's answer was higher than the true midpoint number) was scored positively. We also calculated the overall error rate (the number of error trials/96).

There were no significant differences between the 2 groups in terms of age, gender, education, handedness, or intelligence (Table 1).

To evaluate whether the control group presented significant pseudo-neglect in the line bisection, we compared the mean biases of the control group with the theoretical deviation of zero using analysis of variance (ANOVA, group × line length). There was no significant effect of group or line length ($F(1, 78) = 0.655$ and $F(8, 78) = 0.512$, respectively; $p > 0.05$). The interaction between group and line length was not significant ($F(8, 78) = 0.904$, $p > 0.05$). Thus, the control group exhibited no significant pseudo-neglect at any of the 9 line lengths (Fig. 1).

We then compared the biases of the patient and control groups in the line bisection task using an ANOVA (group × line

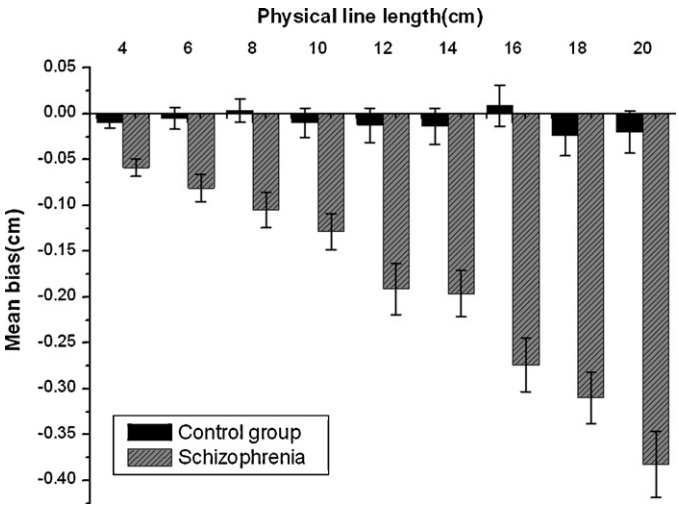

Fig. 1. Visual line bisection performance in schizophrenic patients and controls. Positive values indicate shifts to the right of the true midpoint. Negative values indicate shifts to the left of the true midpoint. The schizophrenia group showed a significant leftward bias relative to the controls for all 9 line lengths ($p < 0.05$).