Neuroscience Letters 617 (2016) 1–5

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research paper

Numerical distance effect in patients with schizophrenia

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HIGHLIGHTS

- Patients with schizophrenia exhibited the standard distance effect.
- Access to the mental number line is preserved in patients with schizophrenia.
- Automatic numerical processing is intact in patients with schizophrenia.

ARTICLE INFO

Article history:
Received 19 July 2015
Accepted 28 January 2016
Available online 1 February 2016

Keywords:
Distance effect
Schizophrenia
Number comparison

ABSTRACT

There is growing evidence showing that mental representation of numbers is impaired in patients with schizophrenia. Yet, no study has examined the distance effect in the patients.

We assessed the distance effect using two number size comparison tasks, with different number references (5 and 7) in 23 patients and 28 healthy individuals. Response times and error rates significantly increased when the distances between the centered references and the targets decreased in both groups. However, patients responded significantly slower and had more error rates compared to controls. Our finding indicates distance effect in patients is similar to the controls, indicating an automatic numerical processing is preserved in patients with schizophrenia.

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1. Introduction

The mental representation of numbers is an essential ability of the mind. It is strongly influences performance in everyday human activities such as handling of objects, usage of money and measures of distance and time.

An important behavioural observation related to the numerical cognition research is the distance effect [1]. The effect is usually obtained in the number comparison task. In this task, individuals need to decide among two numbers which one is the largest or smallest. The distance effect in number comparison task reflects that discriminating two numbers that are numerically close is harder than discriminating numbers that are numerically far apart [1–4]. For example, comparison is faster for 2 and 7 than for 2 and 3.

One of the influential theories for distance effect suggests that it is the result of the placement of numbers on an analogue continuum. Indeed, studies have indicated that the semantic representation of numbers in brain is organized along a 'Mental Number Line (MNL)', with small numbers on the left and large ones on the right [5,6]. Numbers closer together (e.g., 2 and 3) have more distributional overlap than numbers that are further apart (e.g., 2 and 7), so it would be more difficult to distinguish the closer numbers.

Although distance effect has been replicated in several studies in healthy individuals, only two studies have explored this basic phenomenon in neuropsychiatric patients. Delazer and colleagues examined patients with unilateral intractable temporal lobe epilepsy, and Cappelletti & Butterworth examined patients with degenerative disorders [7,8]. Both studies reported standard distance effect in the patients. To our knowledge, no study has investigated distance effect in patients with schizophrenia, which is the aim of this study.

Schizophrenia is a severe mental disorder with cognitive deficits across several domains including verbal memory, working memory, attention, social cognition, and executive functions. Recently, number processing has attracted attention of a number of researchers studying cognition in schizophrenia. There is growing evidence suggesting that the mental representation of numbers is impaired in the patients with schizophrenia. For example, in mental

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http://dx.doi.org/10.1016/j.neulet.2016.01.065
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number bisection task (MBT) in which the individuals are required to judge the numerical centre of two orally presented numbers, Cavezian et al. found an exaggerated leftward bias in patients with schizophrenia relative to controls (report the smaller number of the true midpoint) [9]. However, two more studies have found no difference between the patients and controls on MBT [10,11]. A recent study used a combination of MNB and a visual oddball task, in which participants were asked to discriminate an infrequent ('one' or 'nine') from a frequent written number ('five'). In MBT task, the patients with schizophrenia did not show the normal leftward bias observed in healthy individuals. Moreover, the effect of number magnitude on the P3 latency was not observed in the patients [12].

Using tomographic imaging and scalp recording of event-related potentials, studies have shown that the intraparietal sulcus (IPS) activates when performing a number comparison task. In fact, IPS is more active when comparing the magnitude of two numbers than when simply reading them [13]. Parietal activation in number comparison is present in both hemispheres, although some evidence suggests that it may be asymmetric, and is larger in the right than left hemisphere [13,14]. Considering that imbalance in hemispheric lateralization and dysfunction of the parietal lobe are suggested as underlying mechanisms involved in schizophrenia [15,16], we hypothesized that distance effect might be impaired in patients with schizophrenia.

The present study, for the first time, we aimed to determine whether patients show standard distance effect similar to controls, using two number comparison tasks with different number References

2. Methods

2.1. Participants

A group of 23 patients with schizophrenia (17 male) was recruited from outpatients of a psychiatric hospital. All patients met DSM-IV criteria for a lifetime diagnosis of schizophrenia. All the patients were assessed using the Scale for Assessment of Negative Symptoms (SANS) and the Scale for Assessment of Positive Symptoms (SAPS) [17,18]. At the time of testing, patients were receiving antipsychotic medication ($n = 20$ atypical, $n = 9$ on both typical and atypical antipsychotics) and were clinically stable. The mean chlorpromazine equivalent was 341.4 mg (SD = 186.5) [19].

The control group comprised 28 healthy participants (21 male) screened for a personal or family history of psychotic illnesses. Exclusion criteria for all participants included head injury, neurological disorder, and substance abuse at the time of testing. All the participants were right-handed and had normal or corrected-to-normal vision. Written informed consent was obtained from all participants. The study was approved by the Ethics Committees of Kerman University of Medical Sciences

2.2. Assessment procedures

All participants were tested on the two number size comparison tasks, with different number references (5 and 7), using Vuilleumier and van-Dijck methods [20,21]. For both tasks, stimuli were single digits (~2.5° of visual angle) presented each in turn at the centre of a computer screen. For number comparison task with reference 5, digits ranging from 1 to 9 (with the exception of 5) had to be judged whether they were smaller or larger than 5. For number comparison task with reference **7**, digits ranging from 1 to 9 (with the exception of 7) had to be judged whether they were smaller or larger than 7. The beginning of each trial was a fixation cross presented for 300 ms, followed by presentation of the number for 500 ms, with interstimulus intervals of 1600–2600 ms. Each digit was presented 12 times, resulting in a total of 96 trials per blocks.

Participants were seated in a sound-attenuating room, in front of a computer screen. Sitting distance from the screen was approximately 60 cm. Responses were made by key-presses, with one key assigned to "smaller" and the other to "larger" judgments.

To minimize the role of a simple SNARC effect [22], participants were asked to response with two hands (left hand with a left-sided key for "smaller" responses and right hand with right-sided key for "larger" responses). The order of tasks was counterbalanced.

Before starting the experiment, it was examined whether the participants could easily pay attention to the digits on the screen. Each task was preceded by 12 exercise trials.

Dependent variables were response reaction time and error rate.

Table 1
Demographic and clinical characteristics of the study participants.

	Patients N = 23	Controls N = 28	P
Age	34.4 (6.1)	35.4(6.9)	NS
Education	9.9 (3.3)	9.7 (3.3)	NS
Sex- N (%males)	17 (74%)	21 (75%)	NS
Edinburgh	99.1 (2.9)	100 (0)	NS
Length of illness (year)	12.7 (7.6)	–	
Age onset of illness (year)	21.9 (5.8)	–	
Mean Chlorpromazine equivalent (mg)	318.5 (165.2)	–	
SANS	35.3 (14.5)	–	
SAPS	25.3 (15.9)	–	

2.3. Data analyses

The mean response times for correct answers and mean error rates to each digit (1–4 and 6–9 for reference 5, and 1–6 and 8–9 for reference 7) were calculated for each individual. To examine response time and accuracy of number comparison tasks between groups in different comparison distance, two repeated-measures ANOVA with group (patient, control) as between-subject and comparison distance as within-subject carried out. Follow-up analyses were conducted using independent-samples *t*-test. Chi-square and *t*-tests were applied to analyze the demographic and clinical data.

3. Results

Table 1 shows the demographic and clinical characteristics of all patients and healthy individuals. Groups were well matched for age, gender, and education.

3.1. Number comparison tasks

3.1.1. 5 as reference

On response time, the results of repeated-measures ANOVA showed a significant main effect of group [$F(1, 49) = 28.5$, $P < 0.001$, $\eta2 = 0.37$], indicating that patients responded significantly slower than controls (Table 1A). In addition, there was a significant comparison distance effect [F (4.7, 227.9) = 12.7, $P < 0.001$, $\eta2 = 0.21$], showing response time significantly increased when the distance between the centered reference and the target decreased. However the interaction effect between comparison distance and group was not significant [F (4.7, 227.9) = 0.87, $P = 0.5$, $\eta2 = 0.02$], indicating similar performances of the two groups for different comparison distance. Fig. 1 shows that response times for numbers close to centered reference 5 were increased (Fig. 1A).

On error rate, the results showed a significant main effects of group [$F(1, 49) = 25.6$, $P < 0.001$, $\eta2 = 0.34$], indicating that patients were significantly less accurate than controls (Table 1A). Moreover, there were significant comparison distance effect [F (3.06, 149.9) = 13.3, $P < 0.001$, $\eta2 = 0.21$], suggesting that error rates sig-

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