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Original Article

Persian Mental Number Representation in Symbolic and non-Symbolic Tasks Iran

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Abstract

Objective: Association between number and space is called the spatial-numerical association response code (SNARC) effect. According to the SNARC, the smaller numbers are associated with the left space and larger numbers are associated with the right space in an imaginary mental line. This interaction could be a predictor for children's mathematical skills or learning deficit. Various studies have been investigated this effect in Iranian population, however the existence of the SNARC effect is under controversy in these studies. This study postulated that the SNARC effect is sensitive to different task presentation. Therefore, the mental representation of numbers were investigated by three types of tasks symbolic (Posner and parity judgment) and non-symbolic (Posner cuing) tasks. So, the aim of the present study was to investigate the SNARC and markedness response code (MARC) in Persian academic students by different tasks.

Materials and Methods: Twenty-seven right-handed medical students (age= 24±2 years) participated in the present study. We used two symbolic and non-symbolic Posner cueing tasks and another parity judgment task with eastern Arabic numbers: 1, 4, 6, and 9. We assumed that different patterns of SNARC would be revealed in different tasks.

Results: No main or interaction effects were seen in the non-symbolic Posner task (p>0.05). In the symbolic Posner cueing task, only the magnitude was significant with slower processing for large numbers (p>0.05). However, a partial SNARC effect and Markedness of Response Code (MARC) effect was revealed in the parity task.

Conclusion: This study showed task dependency of SNARC effect in Iranian people. In addition, MARC effect was observed in Iranian people.

Keywords: *Number, Representation, SNARC, MARC, Mental number line.*

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Introduction

A mental representation (MR) (or cognitive representation) is a hypothetical internal cognitive symbol that represents external reality. It enables us to think about things that have never been experienced as well as entities that do not exist [1, 2]. The ability of manipulating mental representations of quantity, space, and time are very important for math skills in children [3].

Many studies have investigated the nature of mental number representation. This representation is assumed to be as a mental number line (MNL) with the small numbers at the left and the big numbers at the right [4-6]. Dehaene, Bossini, and Giraux (1993), revealed an association between number and space for the first time in some French participants, and called it the spatial-numerical association response code (SNARC) [7]. Studies revealed that the mathematical capacity relies on brain cognitive abilities such as spatial processing of the numbers [8]. It also has been reported that the SNARC effect could be a reliable predictor for children's mathematical skills or learning deficiency [9].

Previous investigations have been studied the SNARC effect in various languages, blind, and deaf people [10-13] . The

SNARC effect was Observed in different tasks, including parity judgment and Posner cueing task, magnitude comparison, with one hand, bi-manual, saccadic, and vocal response production [7, 14, 15]. Goebel, Maier and Shaki (2015), showed a cultural rather than biological origin for SNARC effect [16]. However, Dehaene et al. (1993) reported unreliable or probably reverse SNARC effect in Iranian immigrants in France [7]. Recently Rashidi-Ranjbar et al. (2014), could not find number-space association in Iranian university students by performing the random number generation task. They asked participants to generate numbers randomly while their heads were rotated the left- and rightward position. They concluded no horizontal MNL in Iranians [6]. However, Shaki and Fisher (2014) with removing the situational spatial demand of the task showed a left-to-right SNARC effect in Hebrew readers which have a mixed writing system like Persian readers [17].

It is said that the SNARC effect is affected by the direction of writing in Persian language, which is right-to-left for sentences and left-to-right for numerical notations. This is a questionable factor in non-symbolic numerosity tasks, as non-symbolic representation may not be affected by the writing habits. Therefore, we postulated that the access to the magnitude is different in the symbolic and non-symbolic formats, with a more direct activation of magnitude in the non-symbolic task. This can reveal a clearer number-space association contrary to abovementioned conflict for Persian.

On the other hand, Haines et al. (1990), found slower reaction time for the odd numbers [18]. Nuerk, Iversen, and Willmes (2004) reported an interaction between the parity and response hand, which they named the Markedness of Response Code (MARC) [19]. They found a clear MARC effect in parity judgment of number-words, but a lesser effect (marginally significant) for the numbers. As known, there are no previous research done in Persian numbers and is interesting to see existence of MARC effect in Iranian people.

Therefore, in this study, symbolic (numbers) and equivalent non-symbolic (dot arrays) cues were used in the Posner tasks. Moreover, comparison was made between the Posner tasks and parity judgment to consider the SNARC effect in one-hand and bimanual response production tasks. Additionally, the MARC effect was investigated in Persian university students for the first time.

Materials and Methods

Subjects

Two Posner cueing tasks were completed by 27 right-handed psychology students (age= 24±2 years). The inclusion criteria was right handed subject, Persian language university students, with no history of psychology or neurological disorder or cognitive impairment. Exclusion criteria was bi-lingual volunteers and using medications affecting the central or the peripheral nervous system.

Experimental Design

Volunteers were asked to sit in front of a 17 inch TFT monitor. Each trial started with a cross at the center and two 3*4 cm squares on the left and right sides of the screen (blank frame). After 500ms the cross was replaced by one of the eastern Arabic numbers 1, 4, 6 and 9 (1, 4, 6, and 9 respectively) in the symbolic task, and a set of 1, 4, 6 or 9 dots in the non-symbolic task -as cues-lasting for 300ms. After 450ms (with 50ms jitter), the cue was followed by a target stimulus (star sign) inside the left or the right square lasting for 300ms. Finally, the blank frame was presented again for 1300ms awaiting response (Figure 1). Participants pressed the right Shift key on the keyboard as soon as they detected the target either in the right or left squares. They were asked not to press the key for the number 3 or a set with 3 dots (Figure 1). Size of the target dots was adjusted to keep constant the coverage area of the image [20]. Moreover, the arrangement of the dots was varied to avoid the possible symbolization or relying on spatial information. Each number or set was displayed 10 times followed by the right target and 10 times for the left target, making a total of 90 trials (ten as catch up trials) for each task. The order of trials was randomized.

Same students participated in the parity judgment (age=25±3 years). In a 3*4 cm square, eastern Arabic numbers 1, 4, 6 and 9 were presented for 500ms. Participants were instructed to press right (left) SHIFT key if the number was odd (even) in the first block and inversely in the second block. Each number was presented 10 times in each block. Participants were instructed to give a rapid and accurate response for all tasks.

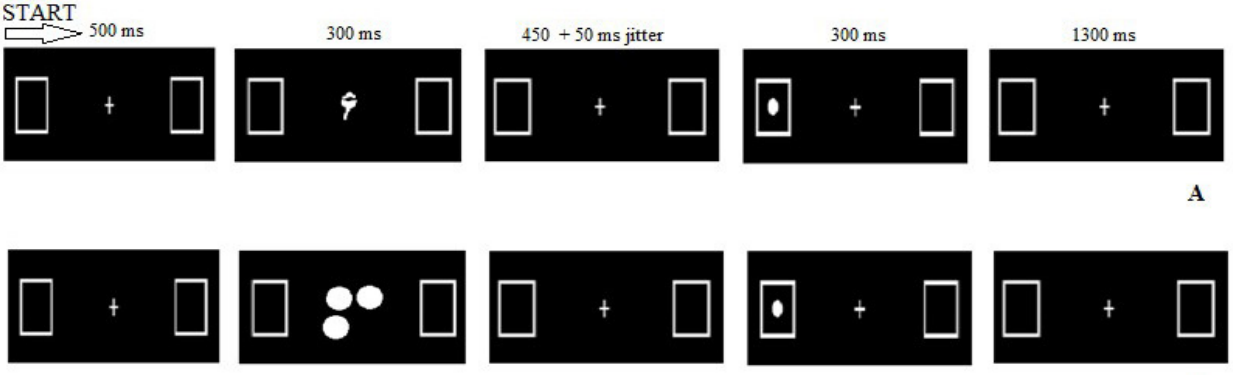

Figure 1. A) Numerical Posner's task, **B)** Non-Symbolic Posner's task.

Statistical Analysis

Statistical analysis was performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Variables were tested for normal distribution with the Shapiro-Wilk test. To compare reaction times in Posner cueing task, 2*2 repeated measure analysis of variance (two levels of presentation side (right/left); two levels of magnitude (small/big)) was used to determine main effects and interactions of these factors.

To compare reaction times in parity judgment task, 2*2 repeated measure analysis of variance (two levels of response hand (right/left); two levels of parity (odd/even) and two levels of response hand (right/left); two levels of magnitude (small/big)) was used. Statistical significance was set at P <0.05.

Results

In a non-symbolic Posner task, the main effects of presentation side (F=2.01, p=0.16), and the number of dots (F=1.80, p=0.15) were insignificant (Figure 2a). Moreover, the interaction of side×magnitude (F=1.31, p=0.27) was not significant.

Results of the symbolic Posner task showed a significant difference in the number magnitude (F=3.14, p=0.03) (Figure 2b). However, the side of presentation (F=0.11, p=0.74) and the interaction of side×magnitude (F=0.23, p=0.87) were not significant.

In the parity judgment task, the main effect of response hand was significant (F=4.73, p=0.04, eta=0.16), in favor of the right-hand responses (570ms) compared to the left-hand responses (588ms). In addition, the main effect of parity was significant (F=73.8, p<0.001, eta=0.75). The post hoc analysis showed that the numbers 1 and 9 were processed slower than the 4 and 6, with no difference between 1 and 9 (mean diff=2.35, MSE=9.6 p>0.05), and 4 and 6 (mean diff=7.75, MSE=7.16, p>0.05) (Figure 3). The main effect of magnitude was non-significant (F=0.75, p=0.40, eta=0.75). However, the interaction of response hand×magnitude was significant (F=16.7, p<0.001, eta=0.45) (Figure 4a). The post hoc analysis showed magnitude difference only in the big numbers (mean diff=35.9, MSE=8.31, t=4.32, p<0.001). In the right hand, the big numbers were responded faster than the small numbers. In addition, the interaction of response hand×parity was significant (F=19.7, p=0.000, eta=0.45) (Figure 4b). The post hoc analysis showed the parity difference only in the right hand (mean diff=-62.0, MSE=11.5, t=5.37, p<0.001).

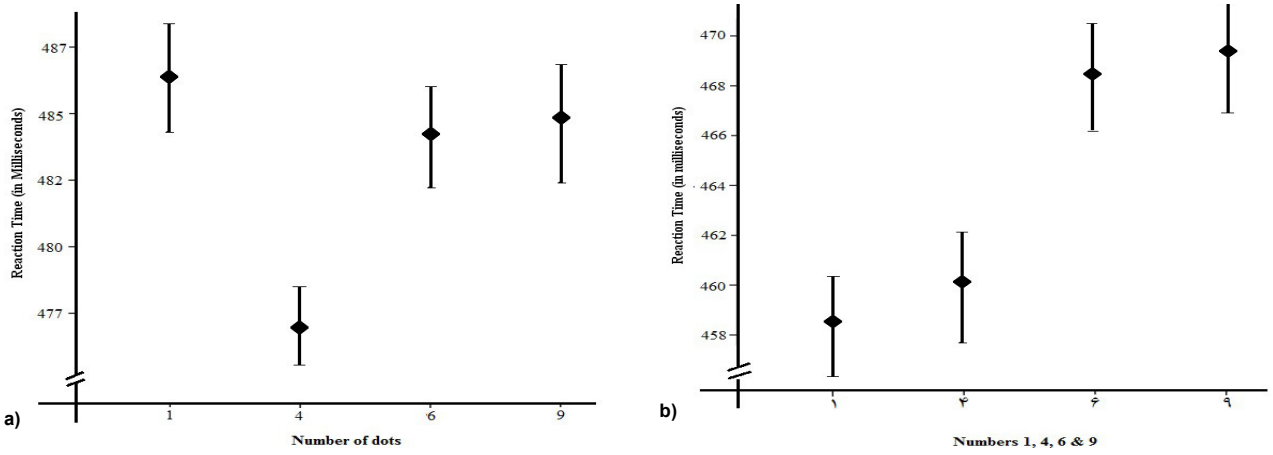

Figure 2. Reaction times for different **a)** number of dots (non-symbolic format), **b)** symbolic numbers.

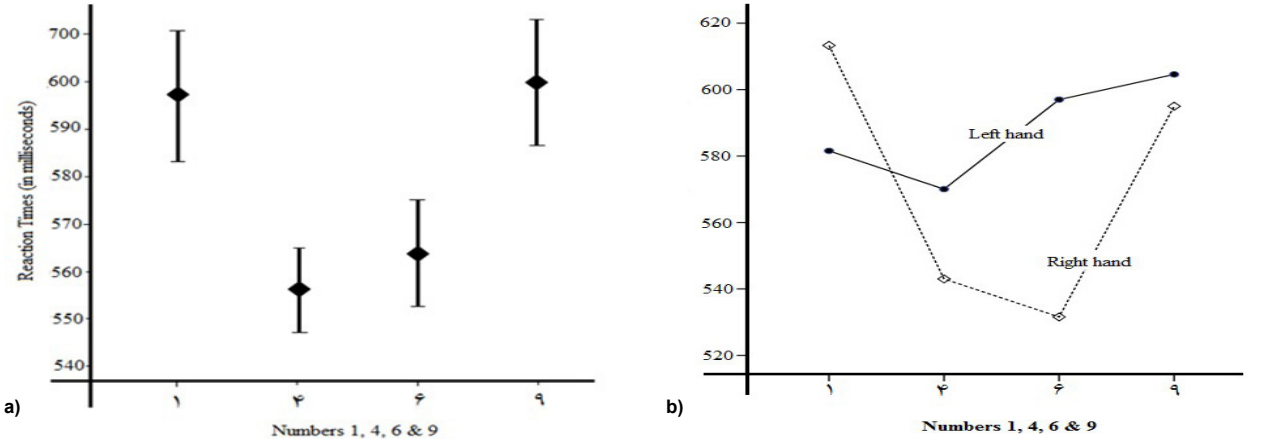

Figure 3. (a&b) Response production times for different numbers in parity judgment task.

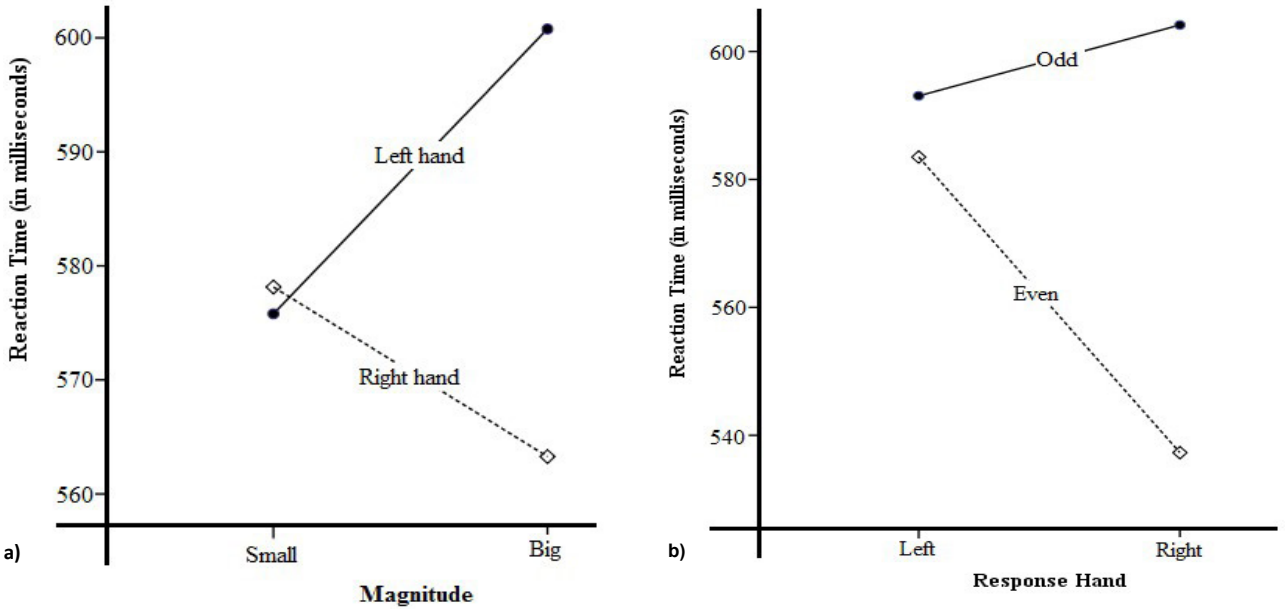

Figure 4. a) Interaction of magnitude and response hand. **b)** Interaction of parity and response hand in parity task.

Didcousion

This study investigated the processing of numbers in Iranian students by performing three different tasks. The non-symbolic task did not show any main or interaction effect, which is contrary to our hypothesis, as the non-symbolic notation engages direct and automatic access to the magnitude. A possible explanation could be the processing difference between the small (1 & 4 dots) and the big sets (6 & 9 dots). It is known that subitizing takes place in sets containing less than 4 items [21]. The subitizing in catch up trials with three dots could lead to a response strategy that bypasses the magnitude activation.

In the symbolic task, the bigger numbers led to slower target detection. However, the SNARC effect was not revealed in symbolic Posner task. In other words, the number magnitude did not modulate the attention shift as Salillas et al. (2008) have previously suggested [22]. Thus, it seems that the result does not support the perceptual origin of the SNARC effect [23].

In the parity task, the responses with right hand were made faster than left hand, and the odd numbers were processed slower than the even numbers. The interaction of response hand, and the number magnitude was significant, as an index of SNARC (Figure 4a). Despite the significant interaction, the pattern does not fully support the small-left/big-right SNARC, but only the right hand shows faster responses for the big numbers. As shown in Fig. 3, numbers 1 and 9 have longer reaction times (especially in right hand, Figure 3b). Dehaene et al. (1993) reported slow processing for numbers 1 and 9. They suggested that as 9 equals 32, it evokes twoness sense, which intervenes in parity judgment [7]. Numbers 2 and 8 are even extreme numbers which may influence the SNARC effect.

The results support partial SNARC effect in parity task with faster reaction times for the bigger numbers by the right hand. This is contrary to Dehaene et al. (1993), with a heterogeneous sample of Iranian immigrants with different immigration times [7] and Rashidi-Ranjbar et al. (2014) [6]. However, this study shows a partial SNARC effect in a more homogenous sample of Iranian people. Shaki and Fisher (2014) also found left-to-right SNARC effect in Hebrew which has a writing system similar to Persian [17].

In the Posner tasks, the response selection was limited to one choice (i.e. right hand only), while in parity judgment task, the selection of correct hand (right/left) is important for task accomplishment. Herein, the superiority of right hand and significant interaction of side by magnitude was only seen in parity judgment task.

Task demands seems to cause these conflicting results. For example, Fias (2001), found that the task demand is important in expression of SNARC. He found the SNARC effect in parity judgment but not in phoneme monitoring of number-words [24]. Therefore, in addition to number of response choices (especially involvement of hands), the cognitive demand of the task seems to be important in expression of the SNARC effect in Iranians.

In addition, our results showed a clear MARC effect in number parity judgment (Figure 4b). It is suggested that the origin of the MARC effect is the interaction of linguistic markedness congruency (even-right/odd-left as congruent condition and odd-right/even-left as incongruent). Adjectives “even” and “right” are non-marked in contrast to “odd” and “left” [19]. This demonstrates that the MARC effect is not influenced by mixed writing direction and linguistic factors, such as the markedness, plays an important role in the mental representation of numbers. The number range used in this study is limited, and both extreme values are the odd numbers, which complicates the interpretation of parity and magnitude main effects. The full range analysis may show different patterns. Having to ignore cultural influences such as different mathematical teaching tools (such as rulers), computers, cellphones, and other objects on which number representation are in the western Arabic digits was another limitation in this study. It should be noted that according to previous reports mathematicians show different patterns of

spatial-numerical association response code (SNARC), therefore the fact that subjects are academic students, probably with higher mathematical experience more than the general population, might have some degrees of importance to be considered in future studies.

Conclusion

In summary, this study showed different patterns of number-space interaction in parity and Posner tasks. The demand of the task seems very important in detecting the number-space association. The existence of MARC effect in Persian subjects was showed for the first time. This may denote that the MARC effect is not influenced by mixed writing direction.

Conflict of Interest

The authors have declared that no competing interests.

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