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The Role of Linguistics Habits and Proprioception Sense on Mental Number Line

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Abstract

The present study investigated the relationship between linguistic styles and numerical representation as evidenced by the Spatial Numerical Association of Response Codes effect, which smaller (larger) number is respond faster with left (right) hand. In Study 1, sixteen participants did numerical judgments by pressing left-or-right side keyboard button with digits presented randomly on three sides of the screen. SNARC effect was found to be significant whereas no significant main effect of number placement was found. In Study 2, fifteen participants reacted with moving the joystick to leftward or rightward with one hand only. No SNARC effect was found as well as the interaction effect. These results suggested the role of proprioception sense in the conceptualization of mental number line.

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Keywords: Mental Number Line; SNARC effect; Language; reading direction; writing direction.

1. Introduction

According to the Mental Number Line hypothesis, numbers are suggested to be spatially organized on an imaged line in which numbers run from left to right with low digits occupying left space and high digits occupying right space (Dehaene, Bossini & Giraux, 1993). Based on this hypothesis, various phenomena associated with numeric magnitude and corresponding spatial locations have been discovered and studied. The most important example is the Spatial Numerical Association of Response Codes Effect, also known as SNARC effect, discovered by the study of

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Dehanene and his colleges (1993), participants were asked to signal the parity (odd or even) of the number by pressing left-or-right sided key. It was found that the participants were responded faster to small number (such as digit 1 or 2) with left hand than right hand, and vice versa, they responded faster to large number (such as digit 8 or 9) with right hand than left hand. This finding might be attributable to the spatial orientation on the mental number line in which numbers run from left to right with the increasing magnitude. Similar conclusions have been drawn by other studies (e.g., Fias, 2001, Fischer, 2003; Fischer, Warlop, Hill & Fias, 2004). From the growing body of literature on the SNARC effect, it seems that such directional pattern (i.e. from small numbers to large numbers) is similar by our linguistic spatial habits. Readers of languages like English and French that are written from left to right represent numbers spatially with number positioned from left to right in an ascending order (Dehaene, Bossini & Giraux, 1993), whereas readers of languages like Farsi or Arabic that are written from right to left show the reverse directional pattern (Zebian, 2005). In addition, English and French readers have a faster reaction time to respond to small numbers using a left response key and faster to respond to large numbers using a right response key (Bachtold, Baumuller & Brugger, 1998; Dehaene et al., 1993); but such left-to-right directional pattern is weakened or reversed for Farsi-French bilinguals, depending on the amount of exposure to the French left-to-right writing system (Dehaene et al., 1993). According to Zebian (2005), monolinguals showed a right-to-left SNARC effect while Arabic-English bilinguals showed a however weakened right-to-left SNARC effect, and illiterate Arabic speakers showed no SNARC effect. As the review is shown, the SNARC effect is registered despite the facts that number magnitude is irrelevant to the task (Dehaene et al, 1993) and that without semantic processing of the numbers (Fias, Lauwereyns & Lammertyn, 2001). In sum, the above findings have led to the conclusion that people have the automatic tendency to access spatial represenatation when processing numbers, that potentially relate to the linguistic experiences, i.e., reading and writing (Fuhrman, & Boroditsky, 2010). A similar phenomenon of the SNARC was also found in reasoning process regarding another abstract notion, time. For example, the Spatial Temporal Association of Response Codes Effect, i.e. STARC effect, showed that English speakers were faster to make “earlier” judgments when the “earlier” response required to be made with the left response key than with the right response key (Fuhrman, & Boroditsky, 2007). In consistent to the SNARC effect, Hebrew speaker whom read from right to left showed exactly the reverse STARC pattern. Previous studies have also found that the direction of writing in language affects the way people lay out time in terms of graphic (Tversky, Kugelmass, & Winter, 1991) that English speakers who read from left to right mapped a sequence of events onto a horizontal line in a rightward direction, placing earlier events on the left and later events on the right. In contrast, Arabic and Hebrew speakers, whom read from right to left, showed the reverse pattern, placing earlier events on the right and later events on the left (Tversky, Kugelmass, & Winter, 1991; Fuhrman, & Boroditsky, 2010). The different directionalities across language systems have also been shown to affect other aspects of our mental representations (Nachshon, 1985; Nachshon, Argaman & Luria, 1999; Tversky, Kugelmass, & Winter, 1991). Maass and Russo (2003) required Arabic and Italian speakers to draw scenes described in simple sentences (e.g. “The girl pushes the boy.”). Italian speakers, who read from left to right, tended to position (i) the subject to the left of the object, and (ii) happening from left to right; whereas Arabic speakers showed a reverse pattern in both. Dobel, Diesendruckm and Bolte (2007) further investigated that German or Hebrew speaking preliterate kindergarteners did not show the spatial preferences found in literate adults in both languages; it can be concluded that such behavioral pattern is associated with our linguistic habits, including writing and reading experiences.

1.1 Aims of the present study

Given the theoretical positions taken for the study and the status of the field as briefly reviewed above, this current study intended to provide an answer to the following question: whether and how numerical representation is related to the linguistic habit in Chinese. In particular, this study would like to separately look into how it associated with (i) reading habit; and (ii) writing habit of Chinese. The aim of the present study is twofold. First, we investigated the hypothesis that the effect of directional preference in reading activity on the mental number line of Chinese speakers, whom read from left to right. We predicted that the different positions (left, middle, or right) of numbers would affect the performance of the SNARC effect in terms of accuracy and reaction time. Second, we explored how the writing direction of Chinese speakers, whom write from left to right horizontally, might influence the SNARC effect in terms of accuracy and reaction time, by requiring participants to react moving the joystick

either leftward or rightward with one hand, which is analogous to the writing movement.

2. Method

2. 1. Study 1

2. *1. 1. Participants*

Twenty-three undergraduates, age ranging from 19 to 23, from Hong Kong Shue Yan University were recruited in Study 1. All of them possessed normal vision or corrected-vision.

2. 1. 2. Stimuli

A list of digits ranging from 1-4 and 6-9 was included in this study. Each digit was presented randomly for five times in each of the positions of the screen (i.e., middle, 5 cm left and 5 cm right to the middle) in each experimental session, i.e., 120 trials in each session. The reason of excluding "5" was that it usually locates in the middle of a number line of single digits that might not pose a salient left or right preference in the mental representation of the number line. Moreover, participants might be confused the parity nature of the digit "zero" (Fias, 2001). In order to reduce the confusion about judgement, zero was therefore excluded in this study.

2. 1. 3. Procedure

Participants were asked to sit seventy-five cm in front of a seventeen-inches, four-by-three computer screen. There was a practice session before any experimental session. Each trial began with a fixation point appearing in the middle of the screen for a second. Afterward, a number was presented on the screen and participants were required to determine whether the shown digit was an odd or even number as quickly and as accurate as possible by pressing "A" or "L" on a computer keyboard. A new trial began after the keystroke response was received. Accuracy and reaction time were collected by the software Direct RT. A counter-balance of the response keys are made so that there were two experimental sessions. In one of the sessions, participants needed to use their left hand to press "A" as to indicate the shown digit was even and "L" with right hand to indicate the digit was odd number. In other session, the response keys were reversed so that "A" was pressed when there was an odd number shown and "L" was pressed when an even number was shown.

2. 1. 4. Results and Discussion

A two-way ANOVA was conducted in Study 1. Main effect of hand-number correspondence was found to be significant ($F=8.481$, $p<0.05$) whereas no significant main effect of the number placement was found ($F=0.820$, $p=0.441$). Interaction effect was found to be insignificant ($F=0.626$, $p=0.535$). In other words, SNARC effect was observed in Study 1 no matter the number was presented on any location, i.e., left, center or right, of the screen. Moreover findings in Study 1 illustrated that reading habit in Chinese in which readers usually start reading from left to right, did not facilitate the performance in the parity test when small (or big) numbers appeared on the left (right) hand side. It is consistent to the literatures that SNARC effect is mainly explained on the motor but not visual level (Dehaene, Bossini & Giraux, 1993).

2. 2. Experiment 2

2. 2. 1. Participants

Twenty undergraduates, age ranging from 19 to 23, from Hong Kong Shue Yan University were recruited in experiment 2. All of them possessed normal vision or corrected-vision.

2. 2. 2. Stimuli

Stimuli were identical to Study 1 except that the digits in Study 2 were randomly shown only in the middle of the screen, i.e., 40 trials in each session.

2. 2. 3. Procedure

The procedure was highly similar to the one in Study 1. Participants were required to determine whether the shown digit in each trial was an odd or even number. Each trial began with a fixation point shown in the middle of the screen and was terminated after receiving a response from the participants. There were also four experimental sessions. In one of the sessions, participants were asked to use their left hand to move the joystick leftward as quickly as possible if the shown digit was an odd number and vice versa. In another session, participants were asked similarly to use their left hand but move the joystick rightward as to respond to the even digit shown on the screen and vice versa. After using the left hand to control the joystick, participants were then asked to use their right hand to repeat the two experimental sessions again. The sequence of hand-using was counter balanced. Accuracy and reaction time were collected by the software Direct RT.

2. 2. 4. Results

A three-way ANOVA was conducted in Study 2. Main effects of movement direction, responded hand and number were found to be insignificant ($F=0.002$, $p=0.968$; $F=1.639$, $p=0.202$; $F=3.06$, $p=0.082$ respectively). There was no significant interaction effect found in Study 2. In other words, no SNARC effect was observed in Study 2.

3. General Discussion

The current research aimed at studying the relationship between both reading and writing directional preferences and the mental representation of mental number line. Consistent to the prediction of SNARC effect, small numbers were generally responded faster with left hand than right hand and the results were reversed in responding to large numbers. Moreover, the positions of the number presented in the parity test did not affect the performance in terms of accuracy and reaction time. In other words, reading direction in Chinese was independent to mental representation number line. On the other hand, no SNARC effect was observed in Study 2 in which participants react to the numbers presented by moving the joystick either leftward or rightward with one hand. It was analogous to the writing movement in which Chinese characters are usually written from left to right on a horizontal line. Separate analyses to hand movement and responded hand in Study 2 were conducted, neither result showed a significant contribution to SNARC effect.

3. 1. The hypothesis of linguistic relativity

Supportive evidence to the relationship between linguistic features and different cognitive behaviors has been reported in the last few decades (e.g., Fuhrman, & Boroditsky, 2007, 2010; Nachshon, 1985; Nachshon, Argaman, & Luria, 1999; Tversky, Kugelmass, & Winter, 1991). An effect of the reading/ writing direction to the conceptualization of number line has also been debated (Dehaene et al, 1993; Fias, Lauwereyns, & Lammertyn, 2001; Zebian, 2005). Considering that both reading and writing are directional and it is sensible to speculate a potential association between this linguistic feature and the mental representation of the number line. The current research separately investigated the effects of reading and writing and discovered that the directional preference in both linguistic activities were independent to the mental number line. The insignificant linguistic effect may possibly due to the variation of the reading and writing direction in Chinese. Unlike English, Chinese can be written and read vertically and horizontally. Chinese characters can be written (and read) horizontally in case the lines on the writing paper are horizontal. Yet Chinese characters written in newspapers, magazines, textbooks and other printed materials are commonly written vertically. Furthermore, even Chinese characters are written horizontally, the traditional writing sequence starts from the right to left, that is different from the modern writing sequence. People nowadays in Hong Kong are able to adapt both writing directions while reading a string of horizontally

written Chinese characters. The variability of the reading and writing directions in Chinese characters may therefore only leave a light trace to the mental representation of number line.

3. 2. Proprioceptive sense of left and right

The insignificant effect of the positions of the number presented in Study 1 confirmed that SNARC effect was better explained at the motor instead of visual level of processing (Dehaene, Bossini & Giraux, 1993). However, no SNARC effect was observed in Study 2 in which participants reacted to the numbers by moving the joystick leftward or rightward with either left or right hand. This suggested that reaction time in the parity test was determined by the participants' hands, but not the hand movement that the participants produced. This explanation could be supported by the differentiated bodily senses of left and right. Proprioceptors provides cues about the bodily position and movement. In terms of motor activity, moving an object leftward (or rightward) with a single hand as a response and using a left (or right) hand to response are two bodily sensations. Responding with both hands (in Study 1) and a single hand (in Study 2) could therefore generate different bodily experiences. Although participants were required to move the joystick leftward or rightward in the parity test, this movement triggered by a single hand might not be compatible to the bodily experiences (or representation) when using left and right hands in the same task. The sense of left and right in the former case related to movement whereas only the bodily structural sense of left and right was involved in the latter case. It is further speculated that if SNARC effect is mainly a result of the motor reaction bias, a difference in the neurological activations between using both hands and a single hand to respond in a parity test explained a diminishing effect of SNARC when only one hand was used to respond. In other words, the (structural) sense of left and right triggered by using both hands to respond in a parity test had a closer association to the mental representation of the number line than the motional sense of left and right.

4. Conclusion

Reading and writing directions in many language systems are similar to the mental representation of number line, i.e., starting from left to right. The present study investigated the relationship and discovered the presence of SNARC effect regardless to the positions of the number presented. Also no significant interaction effect was observed between the hand movement direction and the magnitude of the shown numbers. It is therefore confirmed an independent relationship between the linguistic habit in reading and writing in Chinese and the mental representation of number line. Moreover the present research demonstrated that a sense of leftward and rightward could be different when they are triggered by the hands (Study 1) or hand movements with a single hand (Study 2). SNARC effect was found only when both hands were engaged in the parity test. It is therefore speculated that SNARC effect can be explained not just by the motor level of processing but more precisely, it relates closely to the bodily structural sense of left and right instead of the motional sense of left and right.

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