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Research Article

From SNARC Effect to SELF-SNARC Effect: Evidence from Chinese Character Numbers and Arabic Numbers

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Abstract: The presence of the SNARC effect and the SELF-SNARC effect in the processing of various numeric types and how they evolved through representation guidance were investigated through two experiments. The study identified the typical SNARC effect in various numeric types and examined the reversal of the SELF-SNARC effect based on different numeric types and the hypnotic self representation mode. From the perspective of social cognitive semantic conflict and social cognitive reaction conflict, the findings provide a new interpretation of the SELF-SNARC effect.

Keywords: SELF-SNARC effect, SNARC effect, Social cognitive conflict

INTRODUCTION

The Spatial-Numerical Association of Response Codes (SNARC) effect has been demonstrated to depend only on relative number magnitude and to be weaker or absent with letters or in the absence of numerals. Direction did not vary with handedness or hemispheric dominance but was linked to the direction of writing, as it faced or even reversed in right-to-left writing Iranian Ss (Dehaene *et al*., 1993). The cognition of the numbers based on self belongs to a part of the social cognition, and it is different from the pure cognition of numbers. For example, a person's age may have a social meaning in addition to having a numerical significance. In the study, the general number materials would be expanded to numbers involving information about the self for further development. The study discussed the SNARC effect based on self from the conscious and subconscious level. So, based on Chinese Character Numbers and Arabic Numbers, an in-depth study of the SELF-SNARC effect was carried out by embedding the experimental materials of self information in the SNARC effect. From the perspective of social cognitive semantic conflict and social cognitive reaction conflict, our research makes a new interpretation of the SELF- SNARC effect.

The SNARC effect: The SNARC effect has been studied by several different groups. In the study of stimulation materials, Brysbaert and Tan studied the SNARC effect of Arabic two-digit numbers (Brysbaert, 1995; Tan and Dixon, 2011). The SNARC effect has also been studied on negative numbers (Fischer and Rottmann, 2005; Shaki and Petrusic, 2005). A recent study showed that the SNARC effect of negative numbers eliminate, but do not reverse (Dodd, 2011). The experimental task was very important for the SNARC effect to occur (Nuerk *et al*., 2001). In line with models of spatial stimulus–response congruency, the research modeled the SNARC effect as the result of parallel activation of preexisting links between magnitude and spatial representation and short-term links created on the basis of task instructions (Gevers *et al*., 2006). Müller and Schwarz (2007a, b) reported two experiments with vertically arranged buttons in which the nature of the SNARC effect depended on whether the task set was button or hand. Other experiments have shown the vertical SNARC effect in a parity judgment task (Ito and Hatta, 2004). A study on the SNARC effect in serial learning suggested that any ordered information, even when the order is not intrinsically relevant to it, is spontaneously mapped in the representational space. This spatial representation was likely to acquire a left-to-right orientation, at least in western cultures (Previtali *et al*., 2010).

The SNARC effect researches which adopted different experimental materials, experimental tools, experimental paradigms and responses increased gradually and permeated to various directions. Studies of the SNARC effect have also been done in cross-cultural contexts (Dehaene *et al*., 1993; Brysbaert, 1995; Fias *et al*., 1996; Ito and Hatta, 2004; Keus and Schwarz, 2005; Zebian, 2005; Shen *et al*., 2006; Shaki *et al*., 2009). The relevant cognitive neuroscience research of the SNARC effect has been increasing (Schwarz and Kens, 2004; Zhu, 2008). When accustomed to systematic changes in inter-element

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Table 1: Descriptive statistics of SNARC effect (experiment1)

	Response type	Mean	S.D.	N
Small- Chinese character numbers	Inconsistent	974.48	151.77	15
	Consistent	955.18	172.86	15
	Total	964.83	160.13	30
Big-Chinese character numbers	Inconsistent	1002.65	179.51	15
	Consistent	1119.37	260.78	15
	Total	1061.01	227.84	30
Small-Arabic numbers	Inconsistent	1013.98	180.93	15
	Consistent	761.90	95.09	15
	Total	887.94	191.32	30
Big-Arabic numbers	Inconsistent	998.93	228.36	15
	Consistent	976.73	90.07	15
	Total	987.83	170.93	30

distances during training or faced with similar spatial changes attest, chicks identify as correct both the target positions from left and right ends (Rugani *et al*., 2011).

SELF-SNARC effect: However, research based on self was rare. While many individual characteristics have important effects on numbers, and these related numbers influence their profession, communication (maybe social activities have a link with the space) and so on. The cognition of the numbers based on self belongs to a part of the social cognition, and it is different from the pure cognition of numbers. For example, a person's age may have a social meaning in addition to having a numerical significance. In our study, the general number materials would be expanded to numbers involving information about the self for further development. Studies on the SNARC effect on the subconscious are rare. We discuss the SNARC effect based on self from the conscious and subconscious level. In fact, many numbers related to the social life of individuals are not simply numbers in a mathematical sense but also relate to psychological aspects of the individual. If these Numbers are inked with self, the SNARC effect is called SELF-SNARC. This kind of research has important implications in social psychology and cognitive psychology. The main aspects of SELF-SNARC are embodied by the following three points:

- The influence of human behavior on decision-making
- The influence on personal self-cognition
- The efficiency and valence of individual behavior

The digital representation is playing a positive role in the SELF-SNARC effect. The research of digital representation can improve the accuracy of self Spatial-Numerical encoding and reduce the mental load of human factors (such as the relationship between spatial positioning and digital instrument in an airline pilot's cabin).

The current study: In this study, an in-depth study of the SELF-SNARC effect was carried out by embedding the experimental materials of self information in the SNARC effect. From the perspective of social cognitive semantic conflict and social cognitive reaction conflict, our research makes a new interpretation of the SELF-SNARC effect. Social cognitive semantic conflict refers to the conflict resulting from the understanding of words in a social cognitive phenomenon. On the other hand, social cognitive reaction conflict pertains to the conflict resulting from external behavior in a social cognitive phenomenon. Our research offers a good reference for the self experiment on SNARC. We conducted 2 experiments to assess the presence of the SNARC effect and the SELF-SNARC effect (Chinese character and Arabic numbers). We discuss each experiment in detail below.

We formulated the following hypotheses:

H1: According to different numeric types, SNARC effect existed.

H2: According to different hypnotic representation modes, SELF-SNARC effect existed.

MERHODOLOGY

Experiment 1: SNARC effect: The goal of experiment 1 was to assess whether the SNARC effect existed in different numeric types such as, Chinese character numbers and Arabic numbers.

Participants: 30 college students between 17 and 24 years of age (M = 19.4 years, 14 women and 16 men) from Anqing normal college participated in Experiment 1. An additional 2 participants were tested but excluded from the final analyses because he failed to meet the criteria (More than 10% error rate). All participants were fluent with Chinese and Arabic numerals. All participants had normal or corrected-to-normal vision and were right-handed (Table 1).

Materials: The Designable Psychology Experiment System (DPES, Mind Ark, Beijing, China) was adopted to carry out this experiment. The stimuli consisted of the Arabic numbers 1–9 and Chinese character numbers "壹" – "玖". The index of the scale on number information is 5 ("伍"). All digits were located in the

center of the computer screen. Visual angle is 0.97° for the material. Distance to the screen was 60 cm.

Design: A 2 (numeric types: Chinese character numbers vs. Arabic numbers)×2 (numeric size: big vs. small)×2 (response type: consistent vs. inconsistent) mixed design was adopted. The response type was the between-subject variable whiles the numeric type and the numeric size were within-subject variables. The dependent variable was Reaction Time (RT). Data with less than 90% accuracy rate were omitted from our analyses.

Procedure: All experimental materials were presented using the DPES system, which includes 2 subsystems with the same test frequency of 20. The subjects were seated 70 cm in front of a computer screen with a white background. The word "伍" represents 5 in the Chinese number system. The first group of subjects was instructed to press H with their left hand if the numbers presented were less than 5 ("伍"). If the numbers were greater than 5 ("伍"), they were instructed to press the H key with their right hand. If the number 5 ("伍") appeared, they were instructed to press the H key with both hands. In the second group, subjects were told to press the H key with their right hand if the numbers were less than 5 ("伍"), with their left hand if the numbers were greater than 5 ("伍") and with both hands if the number 5 ("伍") appeared. Speed and accuracy were required to respond correctly in both groups. Responses that took longer than 15 s after the stimulus was displayed were considered mistakes.

The results: The main effect of the numeric types was significant ($F(1, 28) = 7.78$, $p<0.01$, Partial$\eta^2 = 0.22$), and the main effect of the numeric size was also significant ($F(1, 28) = 9.09$, $p<0.01$, Partial$\eta^2 = 0.30$). Additionally, the interaction between numeric types and response type was also significant ($F(1, 28) = 11.93$, $p<0.01$, Partial$\eta^2 = 0.25$), as was the interaction between numeric size and response type ($F(1, 28)= 7.91$, $p<0.01$, Partial$\eta^2 = 0.22$). The simple effects showed that the response type was significant at the small level on numeric size ($p<0.001$). The response type was significant at Chinese character numbers level ($p<0.001$). The response type was significant at Arabic numbers level ($p<0.001$).

Experiment 2: SELF-SNARC effect: The goal of experiment 2 was to assess whether there was SELF-SNARC effect based on the different numeric types and the hypnotic self representation mode. All subjects in the experiment group had to participate in hypnotic practice. The hypnotic experiments were conducted by Dr. Flower's method, and the deepening of the hypnotic experiments was conducted by the gradual relaxation method, fly method and the rainbow method.

Participants: A total of 31 college students between 17 and 22 years of age (M = 18.4 years, 16 women and 15 men) from Anqing normal college participated in experiment 2. An additional 2 participants were tested but excluded from the final analyses because he failed to meet the criteria (More than 10% error rate). All participants were fluent with Chinese and Arabic numer als. All participants had normal or corrected-to-normal vision and were right-handed (Table 2).

Materials: The DPES experimental design system was adopted to conduct this experiment. The stimuli consisted of Arabic numbers on self information and Chinese character numbers on self information. Visual angle is 0.97° for the material. Distance to the screen was 60 cm. Before the experiment, all participants filled in own relevant information (such as age, weight).

Design: We used a 2 (numeric types: Chinese character numbers vs. Arabic numbers)×2 (numeric size: big vs. small)×2 (response type of self-information: consistent vs. inconsistent)×2 (hypnotic self psychological representation mode: the group of hypnotic representation practice vs. the group of non-hypnotic representation practice) mixed design to study whether there was the SNARC effect in different numeric types and different hypnotic self psychological representation modes. The response type of self information and hypnotic self psychological representation mode were between-subject variables, while the numeric types and the numeric size were within-subject variables. The dependent variable was RT.

Procedure: All experimental materials were presented using the DPES system, which includes the same test frequency of 20. The subjects were seated 70 cm in front of the computer screen, which had white background. In the first stage of the experiment, all subjects in the experimental group had to participate in hypnotic practice, while subjects in the control group did need not to do so. An introduction of hypnotic experiments was conducted by Dr. Flower's method, and deepening of the hypnotic experiments was conducted by the gradual relaxation method, fly method and the rainbow method. The self material of second experimental phase is used as suggestions. Hypnotic depth was kept at about level 3. In the second stage of the experiment, after a minute, the awakened participants participated in the study. The subjects responded as follows: in the first group, if the numbers were less than their own relevant information (such as age, weight), they were supposed to press the H key with their left hand, but with their right hand if the numbers were greater than their own relevant information. If the numbers were equal to their own relevant information, they were supposed to press the H keys with both hands. Patients took practice tests before participating in the actual experiments. In the second group, if the numbers were less than their own relevant information, the subjects had to press the H key with

Table 2: Descriptive statistics of the reversal SNARC effect based on self (experiment2)

	Response type	Hypnotic self psychological representation mode	Mean	S.D.	N
Small Chinese character numbers	Consistent	Non-hypnotic	1606.29	789.96	7
		Hypnotic	2945.91	1268.77	9
		Total	2359.83	1256.68	16
	Inconsistent	Non-hypnotic	1606.47	121.91	7
		Hypnotic	2741.69	586.24	8
		Total	2211.92	722.40	15
	Total	Non-hypnotic	1606.38	543.02	14
		Hypnotic	2849.80	983.00	17
		Total	2288.26	1019.22	31
Big Chinese character numbers	Consistent	Non-hypnotic	1605.72	839.32	7
		Hypnotic	3269.74	1588.12	9
		Total	2541.73	1534.20	16
	Inconsistent	Non-hypnotic	2472.67	493.27	7
		Hypnotic	2357.50	279.74	8
		Total	2411.24	383.33	15
	Total	Non-hypnotic	2039.19	799.87	14
		Hypnotic	2840.45	1231.09	17
		Total	2478.59	1117.97	31
Small Arabic numbers	Consistent	Non-hypnotic	1565.59	948.09	7
		Hypnotic	2884.35	1060.88	9
		Total	2307.39	1190.09	16
	Inconsistent	Non-hypnotic	1861.81	271.30	7
		Hypnotic	3503.02	1710.29	8
		Total	2737.13	1487.41	15
	Total	Non-hypnotic	1713.70	687.35	14
		Hypnotic	3175.49	1394.20	17
		Total	2515.33	1337.26	31
Big Arabic numbers	Consistent	Non-hypnotic	1514.86	752.27	7
		Hypnotic	2430.52	1059.45	9
		Total	2029.92	1022.30	16
	Inconsistent	Non-hypnotic	2452.42	849.17	7
		Hypnotic	1735.29	414.04	8
		Total	2069.95	729.31	15
	Total	Non-hypnotic	1983.64	911.41	14
		Hypnotic	2103.35	874.17	17
		Total	2049.29	878.17	31

their right hand and with their left hand if the numbers were greater than their own relevant information. If the numbers were equal to their own relevant information, they were supposed to press the H keys with both hands. Subjects took part in practice tests to familiarize themselves with the tests before taking part in the actual experiment. Responses not made within 15s were considered mistakes.

The results: The main effect of hypnotic self psychological representation mode was significant ($F(1, 27) = 10.45$, $p<0.01$, Partial$\eta^2 = 0.28$), while the interaction between numeric size and hypnotic self psychological representation mode had a significant effect ($F(1, 27) = 15.28$, $p\leq0.001$, Partial$\eta^2 = 0.36$. The interactions among numeric size, response type of self information and hypnotic self psychological representation mode were significant ($F(1, 27) = 14.00$, $p\leq0.001$, Partial$\eta^2 = 0.34$, while the interaction of numeric types and numeric size was significant ($F(1, 27) = 4.75$, $p<0.05$, Partial$\eta^2 = 0.15$). The simple effects and the simple simple effects showed that the hypnotic self psychological representation mode was significant at the big level on the numeric size ($p<0.001$). The hypnotic self psychological representation mode was significant at the small level on numeric size ($p<0.001$). The interaction between response types of self information and hypnotic self psychological representation mode was significant at the small level on numeric size ($p<0.01$). Additionally, the numeric type was significant at the small level ($p\leq0.05$).

DISCUSSION

The SNARC effect on different numeric types: The main effects of numeric types and numeric size were both significant and the interaction between numeric types and response type was significant, as was the interaction between numeric size and response type. The results indicate that the SNARC effect or a trend towards it was seen in the capital Arabic numbers, lowercase Arabic numbers and Chinese numbers conditions, while the capital Chinese number conditions do not exhibit the characteristics of the SNARC effect. A study on the spatial numerical association of response code's effect of Chinese character number processing in different attention referential cues showed that when the validity of referential cue was 80%, the SNARC effect appeared in the attended condition, but it did not appear in the unattended condition. In contrast, when

the validity of referential cue was 50%, the SNARC effect appeared both in the attended and unattended conditions (Pan *et al*., 2009). It is possible that there are certain differences between capital Chinese characters and capital Arabic numbers, or lowercase Chinese characters and lowercase Arabic numbers in terms of digital spatial cognition. The cognition of the capital Chinese characters is more involved in image processing ingredients (characters) and abstract processing ingredients (numbers). Capital Arabic numbers tend to produce faster responses to the right hand, but image processing tends to elicit respond with the left hand. The comprehension of cognitive semantic conflicts and cognitive reaction conflicts make the SNARC effect disappear. These concerns may lead to little difference in RT between left and right hands.

The reversal of SELF-SNARC effect in different numeric types and different hypnotic self psychological representation mode: The main effect of hypnotic self psychological representation mode was significant, and the interaction between numeric size and hypnotic self psychological representation mode had a significant effect on RT. The interaction of numeric size, response type of self information and hypnotic self psychological representation mode was also significant, as was the interaction of numeric types and numeric size. Some studies found the conflict adaptation effect under the SNARC effect, which is inconsistent with the classic conscious monitoring view (Zhu and Liu, 2008). Different hypnotic self psychological representations have the SNARC effect or the reversal of SNARC effect. Lowercase Arabic numbers based on self, whether hypnotic or not, did not have the SNARC effect. Capital Arabic numbers based on self had the SNARC effect without hypnosis, but not with hypnosis. Similarly, lowercase Chinese characters based on self had no SNARC effect with or without hypnosis, but capital Chinese characters based on self had the SNARC effect under non-hypnotic conditions but not with hypnosis. It can be said that, without hypnosis, Arabic numbers and capital Chinese characters based on self have a traditional SNARC effect. In hypnotic cases, only lowercase Arabic numbers based on self have a traditional SNARC effect, while both the capital Chinese characters and the capital Arabic numbers based on self showed reversal of the SNARC effect. We pointed out that hypnosis could lead to the self information of participants to be processed at a deeper level (closer to social cognitive semantics processing) . Moreover, self numbers and spatial relations in the research are closer to the social cognitive reaction processing (including social information processing and cognitive reaction processing). We margined that self information processing at a deep level occurs in the right brain. Interestingly, in lowercase Chinese character conditions based on self, there is no SNARC effect with or without hypnosis. The lowercase Chinese numbers involving self information will lead to increase in the social cognitive semantics processing. Consequently, the social cognitive semantic conflicts of hands offset part of the social cognitive reaction conflict. In conscious and unconscious conditions, the SNARC effect exist for lowercase Arabic numbers, whether they are pure cognitive numbers or the numbers relate to social information. These findings are consistent with previous results on cognitive number processing. Yang (2009) think that the SNARC effect is significant at non-proficient degree, when the subjects were asked to learn of the Greek alphabet from the hearing presenting, otherwise it cannot lead to the SNARC effect.

Research limitations and future studies: The unconscious SNARC based on audition is a weakness of this study. Because the orientation and deepening process during hypnosis primarily depends on audition, further research on the unconscious SNARC based on audition is necessary. In addition, research on SELF-SNARC effect of symbols may be an interesting area of future research, as most self information and symbols are closely linked (such as Chinese subject and head portrait of giant pandas).

CONCLUSION

This study identified typical SNARC effects in different numeric types. Furthermore, reversal of the SELF-SNARC effect based on different numeric types and the hypnotic self representation mode was investigated.

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