RESEARCH REPORT

CROSSED HANDS AND THE SNARC EFFECT: A FAILURE TO REPLICATE DEHAENE, BOSSINI AND GIRAUX (1993)

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Abstract

Dehaene et al. (1993, Experiment 6) presented evidence that the mental number line is left-to-right oriented with respect to representational associations and not with respect to left and right hands. Here we tried to replicate the study of Dehaene et al. (1993) in a larger sample (n = 32) using four different stimulus notations (Arabic numbers, number words, auditory number words, and dice patterns). As in the study by Dehaene et al. (1993), the spatial numerical association of response codes (SNARC) effect was examined with an incongruent hand assignment to left/right response keys (crossed hands). In contrast to Dehaene et al. (1993), we did not observe a SNARC effect in any condition. Power analyses revealed that n = 32 should have been large enough to detect SNARC effects of usual size. Furthermore, time-course analyses revealed no SNARC slope in faster and slower responses, so that the null effect could not be due to relatively slow responses with crossed hands. Joint analyses with previous data (Nuerk et al., 2005b) revealed significantly steeper SNARC slopes with congruent hand assignment, and no interaction between hand assignment and notation. Altogether, these findings suggest that the results of Dehaene et al. (1993) only hold under specific conditions. Differences between studies are discussed. We suggest that spatial context has an influence on the SNARC effect and that hand-based associations (and not only representational associations) are relevant for the SNARC effect.

Key words: SNARC effect, crossed hands, spatial frames of reference, post-hoc power estimation

Introduction

The spatial numerical association of response codes (SNARC) effect denotes the association of number magnitude with left-right responses, namely that the left hand responds faster to smaller numbers while the right hand responds faster to larger numbers (Dehaene et al., 1993). The SNARC effect has been found consistently over a wide range of experimental manipulations and participant groups (e.g., Dehaene et al., 1993; Fias et al., 1996, 2001; Fias, 2001; Gevers et al., 2003a, 2003b; Fischer 2003; Fischer and Hill, 2004; Fischer and Rotmann, 2005; Fischer et al., 2004; Ito and Hatta, 2004; Iversen et al., 2004; Mapelli et al., 2003; Nuerk et al., 2004, 2005a, 2005b; Schwarz and Keus, 2004; Keus and Schwarz, 2005). Recently a double route cognitive framework for the SNARC effect was proposed (Gevers et al., 2005, 2006).

Experiment 6 by Dehaene et al. (1993) examined whether the association of response codes remains unchanged when hand assignment is incongruent (i.e., when participants responded with crossed hands). Two associations of number magnitude and response codes could be postulated: (i) Hand-based spatial code: if the SNARC effect was encoded according to hands, the right hand should respond faster to larger numbers and the left hand to smaller numbers; (ii) Abstract spatial code: if the SNARC effect was encoded according to the abstract mental location, the left hand should respond faster to larger numbers and the right hand to smaller numbers when hands are crossed. The results of Dehaene et al. (1993) corroborated the second alternative: the SNARC effect was independent of hands. When hands were crossed, the left hand responded faster to larger numbers and the right hand to smaller numbers. The authors concluded that the SNARC effect does not depend on the spatial position of the response hands but rather on the position of the response in "[…] *a more abstract representation of the left-right axis*" (Dehaene et al., 1993, p. 384).

Fischer and Hill (2004) have presented data complementing those reported by Dehaene et al. (1993). In the study by Fischer and Hill (2004), numbers were presented auditorily. In Experiment 1, visual control over hands was allowed. For both congruent and incongruent (crossed) hand assignments, the SNARC effect was significant. However when visual control over hands was precluded, results were slightly different. When the hand assignment was incongruent, the SNARC effect was significant, in accordance with Dehaene et al. (1993, Experiment 6), but when the hand assignment was congruent, the SNARC effect disappeared. The authors attributed the non-significant SNARC effect to the stronger tactile and proprioceptive stimulation induced by hand-

crossing, which may partially substitute for the lack of visual perception and help to build up a spatial reference frame for responses. In the study by Fischer and Hill (2004), participants' forearms were permanently in contact when the hand assignment was incongruent. According to the interpretation of Fischer and Hill (2004), tactile and proprioceptive stimulation should not lead to an inversion of the SNARC effect, but reinforce the activation of the mental number line in representational coordinates.

However, the null effect obtained by Fischer and Hill (2004) for the congruent hand assignment in Experiment 2 may have been due to a lack of statistical power when testing for the SNARC effect. Fischer and Hill (2004) only examined 12 participants in Experiment 1 and 8 participants in Experiment 2. Therefore, the non-significant difference between congruent and incongruent hand assignment in Experiment 1 and the lack of a significant SNARC effect for the congruent assignment in Experiment 2 may be a consequence of examining small samples.

Negative SNARC slopes are – as reported for instance by Fias et al. (2001) and by Nuerk et al. (2004) – typically present in only a fraction of the samples studied. In the study by Fias et al. (2001), 70% of participants in Experiment 1 and 78% in Experiment 4 showed a negative SNARC slope. In the study by Nuerk et al. (2004), whose experimental setup (parity decision task with Arabic numbers and number words) was more similar to the present study, the proportion of participants showing a negative SNARC slope was 61% for Arabic numbers and 70% for number words. Therefore, in small samples the probability of obtaining a non-significant SNARC effect is substantial.

In the present study we tried to replicate the results of Dehaene et al. (1993; n = 8) with a much larger sample size. We extended the study of Dehaene et al. (1993) including different stimulus notations, which have not been tested before (i.e., number words, spoken number words and dice patterns). Therein we investigated the generality of a possible interaction between SNARC effect and hand assignment congruity over different numerical notations/modalities. For instance, Arabic numerals have been found to produce SNARC effects in non-semantic tasks while this was not true for other notations, such as number words (Fias et al., 1996; Fias, 2001). Thus, it has been claimed that the access of Arabic numerals to the mental number line is more automatic than for other notations. As laid out above, visual feedback of the response assignment may be important for the direction of the SNARC effect when hand assignment is incongruent.

According to Fischer and Hill (2004), somatosensory information may contribute to the activation of the SNARC association when participants were blindfolded. However, these authors only examined the SNARC effect in the auditory modality. As pointed out by Graziano (1999), the sense of limb position depends heavily on vision; therefore, the SNARC slope for auditorily presented number words may differ from the slopes obtained for the visual modality when hands are crossed.

Finally, symbolic and non-symbolic numbers have been claimed to activate the same magnitude representation (Buckley and Gillman, 1974). Therefore, the SNARC slopes obtained for dice patterns should be comparable with the SNARC slopes obtained for symbolic number notations.

In a previous study (Nuerk et al., 2005b), we have shown that in a parity judgement task, notation/modality of the stimuli does not influence the SNARC effect significantly for congruent hand assignment. In analogy with the task by notation interaction reported by Fias (2001), a notation/hand assignment congruity may occur, if the association of the mental number line with hand-based and representational associations is notation specific. Therefore, it is still an open question whether modality/notation influences the SNARC effect with crossed hands.

In summary, for incongruent hand assignment three hypotheses about the occurrence of the SNARC effect may be distinguished:

1. If (for a given notation/modality) the *representational association* determines the orientation of the mental number line exclusively, the SNARC effect should remain the same regardless of the congruity of hand assignment to response keys.

2. If, contrary to the claim of Dehaene et al. (1993), a *hand-based association* is the only determinant of the SNARC effect when hand assignment is incongruent, the SNARC effect should be inverted.

3. If representational and hand-based associations are recruited in a *context-specific way*, SNARC slopes are a weighted sum of the activation of both coordinate systems. As pointed out by Cho and Proctor (2003), the mapping of stimulus-response compatibility depends on which frames of reference are activated in each experimental set. Carlson-Radvansky and Irwin (1993) have shown how frames of reference may interact and to which extent the activation of a frame of reference depends on its saliency (Experiments 2a-2d). When hands are crossed, there is a conflict between representational and hand-based coordinates. If the saliency of both coordinates is approximately equal, we should observe a null SNARC effect, since hand-based and representational associations are complementary when the hand-to-response-key assignment is incongruent. If the weights of both coordinates are unequal, we should observe weaker SNARC effects than with parallel hands in the