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BRIEF REPORT

Cultural modulations of space–time compatibility effects

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Abstract The representation of elapsing time may require spatial attention. In certain circumstances, this spatial representation develops from left to right. This is suggested by a performance advantage in responding *short* with the left hand and *long* with the right hand (spatial–temporal association between response codes [STEARC]). The present study tests whether one possible determinant of the directionality of the STEARC effect is cultural. In particular, we investigated whether reading/writing habits can affect STEARC direction by administering a visual time judgment task to Italian participants, who were exposed to a left-to-right reading/writing system, and Israeli participants, who mainly used a right-to-left system. The Italian participants showed a left-to-right STEARC effect, while this effect was not present in the Israeli group. The study demonstrates that cultural habits can influence the way in which spatial attention supports the representation of time, similar to the pattern found in other nonspatial domains such as numbers.

Keywords STEARC effect · Time representation · Spatial processing · Writing system · Cultural differences

The representation of time is one of the most fascinating and challenging topics in cognitive psychology. Elapsing time is a special type of information for which there are no dedicated senses. Plenty of studies have recently tried to characterize how the cognitive system perceives and represents time (for recent reviews, see Bonato, Zorzi, & Umiltà, 2012; Grondin, 2010; Oliveri, Koch, & Caltagirone, 2009). One way in which time processing is implemented by the cognitive system is through spatial representations, as demonstrated by the multifaceted interactions found between the two domains, especially in terms of an influence of spatial attention over time processing (e.g., Santangelo & Spence, 2009; Santiago, Lupiáñez, Perez, & Funes, 2007; Torralbo, Santiago, & Lupiáñez, 2006; Vicario, Caltagirone, & Oliveri, 2007; Vicario, Rappo, Pepi, & Oliveri, 2009; Weger & Pratt, 2008).

Several studies have suggested that decisions about both past–future time and short–long durations are made through left-to-right representation of time in both the visual (Casasanto & Boroditsky, 2008; Santiago et al., 2007; Torralbo et al., 2006; Vallesi, Binns, & Shallice, 2008; Vallesi, McIntosh, & Stuss, 2011) and the auditory (Ishihara, Keller, Rossetti, & Prinz, 2008) domains. In the paradigm used by Vallesi and colleagues (Vallesi et al., 2008), participants had to decide whether the duration of a foveal visual stimulus was short (e.g., 1 s) or long (e.g., 3 s) by pressing the left- and right-hand keys, with the stimulus–response (S–R) mapping counterbalanced across different blocks within subjects. Response times (RTs) were shorter when participants responded *short* with the left hand and *long* with the right one, a phenomenon that has been labeled as a spatial-temporal association between response codes (STEARC) effect (Ishihara et al., 2008; Vallesi et al., 2008).

The classical explanation for this set of spatial compatibility phenomena in the temporal domain is borrowed by an analogous spatial compatibility effect found in the number domain—namely, the SNARC effect (Dehaene, Bossini, & Giraux, 1993). In this effect, smaller numbers are associated with the left side, and larger numbers with the right side of space (see Wood, Nuerk, Willmes, & Fischer, 2008, for a meta-analysis). This phenomenon has been interpreted culturally as

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a side effect of directional reading/writing habits. Since spatial attention during reading/writing moves from left to right in certain cultures, this directionality is also adopted when processing symbolic information like numbers. Supporting this explanation of the SNARC effect as a generalized habitual association, the spatial association for numbers is modulated by reading/writing long-term habits (Dehaene et al., 1993; Hung, Hung, Tzeng, & Wu, 2008; Shaki, Fischer, & Petrusic, 2009; Zebian, 2005; but see Ren, Nicholls, Ma, & Chen, 2011) and short-term experience (Fischer, Shaki, & Cruise, 2009; Herrera, Macizo, & Semenza, 2008; Shaki & Fischer, 2008). The fact, for example, that the SNARC effect may disappear under working memory load (Herrera et al., 2008) may suggest that availability of working memory resources is necessary for the spatial coding of numbers to occur. These factors may thus interact and, while the orientation of a default mental number line may be determined by long-term habits, in the retrieval phase the orientation may be redefined, which would explain short-term effects.

Orientation effects with SNARC suggest that number–space mapping develops through the acquisition of culture-specific skills and formal education. However, humans may be predisposed to process space and more abstract magnitude systems like the numerical one as intrinsically related.

In general, the spatial representation of time seems to also be influenced by cultural habits, probably through spatial attentional mechanisms. Zwaan (1965) found that Dutch people, who use a left-to-right reading/writing system, associate the idea of past with the left side of a page. In contrast, Israeli people, who use a right-to-left reading/writing system, relate this idea to the right side. Developmentally, when asked to produce a graphical representation of temporal relations, English-speaking children represented time from left to right, while the reverse was true for Arabic-speaking children, with Hebrew-speaking children in the middle (Tversky, Kugelmass, & Winter, 1991).

More specifically, it has been predicted that the same influence from the reading/writing system may also apply to the STEARC effect (e.g., Vallesi et al., 2011), but this has never been directly proven. The aim of the present study is to provide evidence in favor of a cultural modulation of the STEARC effect. In particular, we predict that, while left-to-right readers/writers will show a normal STEARC effect, as has already been demonstrated previously (e.g., Ishihara et al., 2008; Vallesi et al., 2008), this phenomenon will be attenuated or even reversed in people who read and write from right to left. To test this hypothesis, we administered a STEARC paradigm to two groups of participants: (1) Italians who had been exposed only to left-to-right reading/writing systems and (2) Israelis who were mostly exposed to Hebrew—a right-to-left reading/writing system. Previous studies have found null SNARC effects in digit classification tasks in Israelis (e.g., Shaki et al., 2009; see also Dehaene et al., 1993, for similar results with Iranians). The authors interpreted these null results as due to a conflict between reading/writing direction of numbers (left to right) and text (right to left). However, a right-to-left directionality effect could still be predicted for temporal classifications, by assuming that the number reading/writing habits are not relevant in the case of time.

Method

Participants

Twenty-four Italian (mean age, 24 ± 4.6 years; 17 females) and 28 Israeli (mean age, 23 ± 1.8 years; 23 females) university students voluntarily participated in the study. All participants reported being right-handed. For the Israeli participants, the exclusion criterion was exposure to any language with a left-to-right direction of reading/writing for more than once a week.

Apparatus and materials

Participants were tested individually in a quiet and normally illuminated room. The stimuli were presented on the screen of a personal computer at a distance of approximately 60 cm. The stimuli were exactly the same as in Vallesi and colleagues (Vallesi et al., 2008). A central cross formed by two yellow crossed bars served as the fixation stimulus whose duration on the screen had to be estimated. The imperative stimulus was a downward pointing white arrow (see Vallesi et al., 2008, for details).

Procedure and task

A trial started with the central cross, which remained on the screen for 1 or 3 s. These two durations were presented randomly for an equal number of trials. After this period elapsed, the imperative arrow was shown. The task consisted of pressing “Z” for a short cross duration (i.e., 1 s) and “M” for a long cross duration (i.e., 3 s). The stimulus-duration/response-key assignment was inverted after 160 trials. The order of presentation of the two possible S–R mappings was counterbalanced across participants. The imperative stimulus duration, which corresponded to the response deadline, was 1 s. The imperative stimulus was followed by a blank screen for 1 s. A practice block, which consisted of 20 trials, was administered before each experimental block with different S–R mappings (160 trials each). During the practice block, a visual feedback was displayed for 1 s soon after the response. The feedback provided during the initial practice phases consisted of the green string (either in Italian or in Hebrew, depending on the cultural group) “Good! Go on with the next trial!” for correct responses, the red string “Wrong response, be careful!" plus a sound (a 1500-Hz pure tone lasting 50 ms) for incorrect responses, and the red string "Too slow, try to be faster!" (plus the 1500-Hz sound) for slow (>1,500 ms) or null responses. The practice block was repeated until participants made two errors or less. All participants reached this criterion after one to two practice blocks.

Data analysis

Trials with anticipated responses (i.e., responses during the foreperiod) and with RTs outside the 100- to 1,500-ms range were discarded from further analyses. For the RT analysis, trials with errors were also discarded. For both mean RTs and accuracy analyses, a 2 × 2 × 2 mixed ANOVA was run with response side (left or right) and cross duration (1,000 or 3,000 ms) as the within-subjects variables and group (Italian, Israeli) as the between-subjects variable.

Results

Response times

Responses were faster for long durations than for short ones (duration main effect), $F(1, 50) = 151.8$, $p < .001$, $\eta^2_p = .76$. Moreover, there was a tendency for a response side × duration interaction, $F(1, 50) = 3.5$, $p = .067$. Importantly, the response side × duration × group interaction was significant, $F(1, 50) = 10.6$, $p = .002$, $\eta^2_p = .19$ (see Fig. 1). To better understand this three -way interaction, we ran an ANOVA with response side and duration as the within-subjects variables, separately for each group. This analysis showed a significant response side × duration interaction for the Italian group, $F(1, 23) = 8.4$, $p = .008$, $\eta^2_p = .27$. However, as has been found in other domains, the Israeli participants did not show any spatial response preference for either short or long duration, as demonstrated by a nonsignificant response side × duration interaction, $F(1, 27) = 1.7$, $p = .204$. Thus, the STEARC effect was present in the Italian group only.

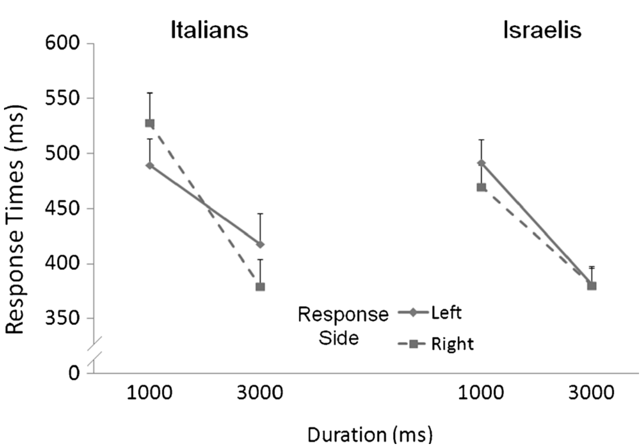

Fig. 1 Mean response times (and standard errors of the mean) as a function of cross duration (x-axis), responding hand (lines), and groups (panels)

Accuracy

The accuracy level was high and comparable between the two groups (for both, 94%). No significant effect was obtained in the ANOVA concerning accuracy data.

Discussion

The present study tested the importance of cultural habits in shaping the way in which we represent elapsing time. Previous studies showed that left-to-right Italian (Vallesi et al., 2008), German (Ishihara et al., 2008), and Canadian (Vallesi et al., 2011) readers/writers are faster in responding to short stimulus durations with the left effector and to long durations with the right effector, a phenomenon which has been called the STEARC effect.

By administering a visual STEARC task to two groups belonging to cultures with different reading/writing systems (i.e., Italian and Israeli), we were able to show that the STEARC effect was differentially modulated by the reading/writing habits. A normal STEARC effect emerged in the Italian group, whereas the Israeli group showed a null effect and, if anything, a nonsignificant tendency toward the opposite effect (at least for the short duration).

The null effect obtained for the Israeli group could be interpreted as due to a universal human tendency to represent time from left to right, possibly due to handedness, which may partially compensate conflicting culture-related directionality effects. Such an explanation, and especially the role of handedness in the universality of the left-to-right STEARC effect, can be discarded on the basis of the results by Vallesi et al. (2008), who found no correlation between this effect and handedness scores as assessed with the Edinburgh Handedness Inventory.

A more likely explanation of the null STEARC effect in our Israeli sample concerns their hybrid reading/writing habits for text and numbers, which is known to decrease the net SNARC effect (Shaki & Fischer, 2012; Shaki et al., 2009) and may also generalize to spatial representations of time. Moreover, the emergence of an opposite STEARC effect, which would have been compatible with the prevalent right-to-left reading/writing habit of our sample of Israeli individuals, may have also been prevented by the coexistence of conflicting cultural habits, such as left-to-right reading/writing systems for numbers and languages additionally known (mainly English).

A space-related representation is a perceptually more solid entity than more abstract representations like elapsing time or numerical sequences. The properties of such representations, like the (culturally influenced) default orientation and the modality of exploration, seem to be flexibly recruited whenever more abstract representations need to be manipulated. Where and how, exactly, in the cognitive processing stream both SNARC and STEARC effects arise and, more specifically, where and by which mechanisms cultural habits determine their directional bias remain to be determined. A previous ERP study (Vallesi et al., 2011) suggests that the spatial bias of temporal representations occurs well in advance with respect to the response execution—namely, during the response motor programming. However, a more complete picture still needs to be elucidated.

A limitation of the present study is that the critical independent variable—that is, direction of reading/writing habits—could not be manipulated directly by the experimenters but was already shaped by environmental constraints. This makes the present study a quasi-experiment, since other confounding variables, outside the experimental control, could be associated with reading/writing habits. Therefore, the conclusions drawn, although highly plausible, should be seen as a cautious explanation, which requires further investigation.

In summary, the present data confirm that temporal information, similar to what happens for numerical information, can be represented spatially in a way that, in specific situations, affects motor performance. The present study contributes to the literature by demonstrating that the spatial representation of time is modulated along with cultural biases, such as the direction of the reading/writing system mainly used by an individual. Future studies should try to test groups of individuals exclusively exposed to right-to-left reading/writing systems. The hypothesis that cultural habits are the critical factors biasing the spatial representation of time would be further confirmed if these individuals showed a STEARC effect that is significant and in the opposite direction with respect to that shown by individuals exclusively exposed to left-to-right systems.

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References

Bonato, M., Zorzi, M., & Umiltà, C. (2012). When time is space: Evidence for a mental time line. *Neuroscience and Biobehavioral Reviews, 36,* 2257–2273.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106,* 579–593.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122,* 371–396.

Fischer, M. H., Shaki, S., & Cruise, A. (2009). It takes just one word to quash a SNARC. *Experimental Psychology, 56,* 361–366.

Grondin, S. (2010). Timing and time perception: A review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics, 72,* 561–582.

Herrera, A., Macizo, P., & Semenza, C. (2008). The role of working memory in the association between number magnitude and space. *Acta Psychologica, 128,* 225–237.

Hung, Y. H., Hung, D. L., Tzeng, O. J., & Wu, D. H. (2008). Flexible spatial mapping of different notations of numbers in Chinese readers. *Cognition, 106,* 1441–1450.

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: evidence for the STEARC effect. *Cortex, 44,* 454–461.

Oliveri, M., Koch, G., & Caltagirone, C. (2009). Spatial-temporal interactions in the human brain. *Experimental Brain Research, 195,* 489–497.

Ren, P., Nicholls, M. E., Ma, Y. Y., & Chen, L. (2011). Size matters: Non-numerical magnitude affects the spatial coding of response. *PLoS One, 6,* e23553.

Santangelo, V., & Spence, C. (2009). Crossmodal exogenous orienting improves the accuracy of temporal order judgments. *Experimental Brain Research, 194,* 577–586.

Santiago, J., Lupiáñez, J., Perez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin and Review, 14,* 512–516.

Shaki, S., & Fischer, M. H. (2008). Reading space into numbers: a cross-linguistic comparison of the SNARC effect. *Cognition, 108,* 590–599.

Shaki, S., & Fischer, M. H. (2012). Multiple spatial mappings in numerical cognition. *Journal of Experimental Psychology: Human Perception and Performance, 38,* 804–809.

Shaki, S., Fischer, M. H., & Petrusic, W. M. (2009). Reading habits for both words and numbers contribute to the SNARC effect. *Psychonomic Bulletin and Review, 16,* 328–331.

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30,* 745–757.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology, 23,* 515–557.

Vallesi, A., Binns, M. A., & Shallice, T. (2008). An effect of spatial-temporal association of response codes: Understanding the cognitive representations of time. *Cognition, 107,* 501–527.

Vallesi, A., McIntosh, A. R., & Stuss, D. T. (2011). How time modulates spatial responses. *Cortex, 47,* 148–156.

Vicario, C. M., Caltagirone, C., & Oliveri, M. (2007). Optokinetic stimulation affects temporal estimation in healthy humans. *Brain and cognition, 64,* 68–73.

Vicario, C. M., Rappo, G., Pepi, A., & Oliveri, M. (2009). Timing flickers across sensory modalities. *Perception, 38,* 1144–51.

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin and Review, 15,* 426–430.

Wood, G., Nuerk, H. C., Willmes, K., & Fischer, M. H. (2008). On the cognitive link between space and number: A meta-analysis of the SNARC effect. *Psychology Science Quarterly, 50,* 489–525.

Zebian, S. (2005). Linkages between number concepts, spatial thinking, and directionality of writing: The SNARC effect and the REVERSE SNARC effect in English and Arabic monoliterates, biliterates, and illiterate Arabic speakers. *Journal of Cognition and Culture, 5,* 190.

Zwaan, E.W.J. Links en rechts in waarneming en beleving. [Left and right in visual perception as a function of the direction of writing]. Ph.D. dissertation, Rijksuniversiteit Utrecht, The Netherlands (quoted by Winn, 1994), 1965.