INSTRUCTION-DEPENDENT SNARC FOR COMPARISONS OF LINEARLY ORDERED SYMBOLIC STIMULI

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Abstract

In the present study, 45 participants first learned a linear ordering involving the names of six imaginary individuals assumed to differ in height. During both the learning and a subsequent test phase, pairs of horizontally aligned names were presented and participants pressed a response key on the same side as the name that they thought was either the shorter or the taller individual in the pair. Analyses of the comparison RT data for the pairs of individuals who were adjacent in the ordering revealed the presence of an interaction between the side of response and the relative position of the pair within the ordering that reversed across each form of the comparative instruction (i.e., instruction-dependent SNARC effects).

When participants are presented with numerical stimuli for classification, the magnitude information associated with them has been shown to prime up spatially designated response codes (Deheane, Bossini, & Giraux, 1993; Deheane, Dupoux, & Mehler, 1990; Fias, Lauwereyns, & Lammmertyn, 2001; Gevers, Caessens, & Fias, 2005; Gevers, Verguts, Reynvoet, Caessens, & Fias, 2006; Keus & Schwarz, 2005; Notebaert, Gevers, Verguts, & Fias, 2006; Shaki & Petrusic, 2005). Typically, it is the case that smaller numbers facilitate responses made on the left and larger numbers facilitate responses made on the right (i.e., the now well-known Spatial Numerical Association of Response Codes or SNARC effect), which has been deemed to provide evidence for the existence of a mental number line (Deheane et al., 1993). However, such facilitation has now clearly been shown to extend to vertically based, up-down responding (Gevers, Lammertyn, Notebaert, Verguts, & Fias, 2006; Ito & Hatta, 2004; Schwarz & Keus, 2004), indicating that spatial-numerical associations can actually have quite flexible priming effects.

Importantly, some recent work has demonstrated that stimuli from well-learned linear orderings such as the months of the year or days of the week can also show SNARC-like priming of left and right response codes (Gevers, Reynvoet, & Fias, 2003, 2004). Moreover, we have found that such effects also extend to comparisons of the remembered sizes of animals in semantic memory (Shaki, Petrusic, & Leth-Steensen, 2009). Such results clearly indicate that the priming of spatially based response codes does not depend on the use of numeric stimuli and, instead, is a property of the semantic representation of ordered magnitudes in general. Interestingly, though, the pattern of SNARC effects obtained by Shaki et al. (2009) was qualitatively different for comparisons of numerical magnitudes than for comparisons of the relative sizes of animals in that, for the latter case, the direction of the SNARC effect was reversed across each form of the comparative instruction (i.e., to choose to smaller or to choose to larger, respectively).

One reason hypothesized by Shaki et al. (2009) for the presence of instruction-dependent SNARC effects for remembered magnitudes is that the ordering of animal sizes is much less well-learned than is the ordering of number magnitudes, thus potentially rendering its use quite susceptible to the influence of contextual factors. If so, similar instruction-dependent SNARC effects should be obtained for comparisons of other types of symbolic magnitudes as long as their ordering is not over-learned. Hence, in the present study, we examine the pattern of SNARC effects obtained for size comparisons of symbolic items taken from an artificially induced, six-term linear ordering that has just been learned by the participants (Leth-Steensen & Marley, 2000).

Method

Participants. Forty-five Introductory Psychology students from the University of Illinois with normal or corrected-to-normal vision participated (individually) in a single 90-minute session for course credit.

Stimuli and Apparatus. The experiment was programmed and run using MEL v2.0 on a 486 computer. During each trial, the instruction for comparison (i.e., "Taller?" or "Shorter?") was first presented at the top of the screen, after which a pair of three-letter names was presented side by side in the centre of the computer screen (in MEL System48 font size). Responses were made by pressing either the "z" or "/" response keys on each side of the bottom row of the computer keyboard (marked in yellow).

Each name was a label that stood for an imaginary "person". Six “people” were used all of whom were assumed to differ in height. Four different orderings of these names were derived a priori. From tallest to shortest, the four orderings were (a) Pat, Bob, Ted, Dan, Jim, and Mel, (b) Dan, Ted, Jim, Pat, Mel, and Bob, (c) Ted, Dan, Mel, Bob, Pat, and Jim, and (d) Bob, Mel, Dan, Jim, Ted, and Pat. These orderings were assigned randomly to participants.

Procedure. The first part of the experiment was a learning phase, in which the participants were presented with each of the five comparison pairs consisting of the stimuli that were adjacent to each other in the relevant ordering (i.e., the Split 1 pairs). Each comparison trial began with a blank screen for 1000 ms. Before a pair of names appeared, the relevant comparative instruction ("Taller?" or "Shorter?") was displayed for 1000 ms just above a plus sign, which acted as a temporary fixation point for the location of the name stimuli. On each comparison trial, the participants were presented with two of the six names and had to choose which person (i.e., the name presented on the left or the name presented on the right) was either the shorter or, respectively, the taller of the pair. They were asked to use the index fingers on their left and right hands to make their responses.

The participants were not expected to know the relative heights of the stimuli at the very start of the experiment and, hence, would initially be guessing. After each response in the learning phase, though, feedback was immediately provided on the computer screen that indicated whether the response had been correct or incorrect and also showed the correct name for that comparison trial. This feedback helped the participants eventually learn which person was the taller and which was the shorter in each pair. They were able to examine this feedback for as long as they wanted and could initiate the next trial with a press of the space bar. Both the comparative instruction and the pair of names remained on the screen throughout the trial (including during the presentation of the feedback).

Learning trials were presented in blocks of 20 trials (i.e., five pairs with each of the two instructions in each of the two left-right spatial presentation of the pairs) with breaks after the first 2 learning blocks only. In the first 2 blocks, the pairs were presented in an ordered fashion and then presented randomly within the remaining blocks. The learning phase took anywhere from 15 to 35 minutes to perform and was completed when the participant had been correct for a full block of 20 learning trials. Two participants who did not reach this learning criterion within 10 blocks of learning trials were given a shorter version of the experiment by the experimental program, and their results were not included in the following analysis.

The second part of each experiment was the test phase and the procedure for it was essentially the same as that of the learning phase except for the fact that (a) all of the 15 possible pairs of names were now included in the stimulus set and (b) no feedback was provided. Each block of the test phase contained 120 randomized comparison trials (made up of the 15 pairs presented twice with each instruction in each left-right stimulus presentation order). The participants were given an optional rest period between each block and they were asked to be accurate with each decision without taking too much time to respond.

It must also be noted that the data used for this study actually came from three separate experiments. In each experiment, participants performed, in a counterbalanced fashion, two blocks of test phase trials in the standard fashion (i.e., exactly as just described) but also two other blocks that manipulated the presentation of the instruction (e.g., flashing it briefly or presenting it either after or simultaneously with the stimulus pair).

Results

Only the response time (RT) data for correct responses to the Split 1 pairs in the two blocks of test phase trials performed in the standard fashion were analyzed. Before running the analysis, any RTs for a participant that were more than 3 SDs above their mean for each Split 1 pair were removed (31 RTs in total). The independent variables in the ANOVA were instruction type (2 levels: shorter, taller), pair (5 levels), and response side (2 levels: left, right). All results significant at the .05 (Greenhouse-Geisser adjusted) level of significance are reported.

In the ANOVA results, the main effect of pair was significant, $F(4, 176) = 44.258$, $p < .001$, where the overall mean correct RTs for each of the increasing pairs (1, 2), (2, 3), (3, 4), (4, 5), and (5, 6) were 1494, 2131, 2157, 1836, and 1225 ms, respectively (with corresponding mean accuracies of .966, .949, .925, .951, .970, respectively). The interaction between instruction type and pair was also significant, $F(4, 176) = 16.2816$, $p < .001$, due to the presence of a robust semantic congruity effect in these data (i.e., faster RTs for shorter pairs when choosing the shorter individual and for taller pairs when choosing the taller individual; see Figure 1).

Finally, and most importantly, the linear trend of the three-way Instruction Type × Pair × Response Side interaction was significant, $F(1, 44) = 4.318$, $p < .044$. This interaction occurred due to the fact that when the instruction was to choose the shorter, there was a trend for correct left-hand responses to be faster than correct right-hand responses for relatively short pairs and correct right-hand responses to be faster than correct left-hand responses for relatively tall pairs (which is analogous to the standard SNARC effect found for number comparisons). On the other hand, when the instruction was to choose the taller, there was a trend for correct left-hand responses to be faster than correct right-hand responses for relatively tall pairs and correct right-hand responses to be faster than correct left-hand responses for relatively short pairs (i.e., a reversal of the SNARC effect). These effects are shown in Figure 2 (note that the values plotted there are mean right-hand minus mean left-hand RTs which are positive when left-hand responses are faster and negative when right-hand responses are faster).

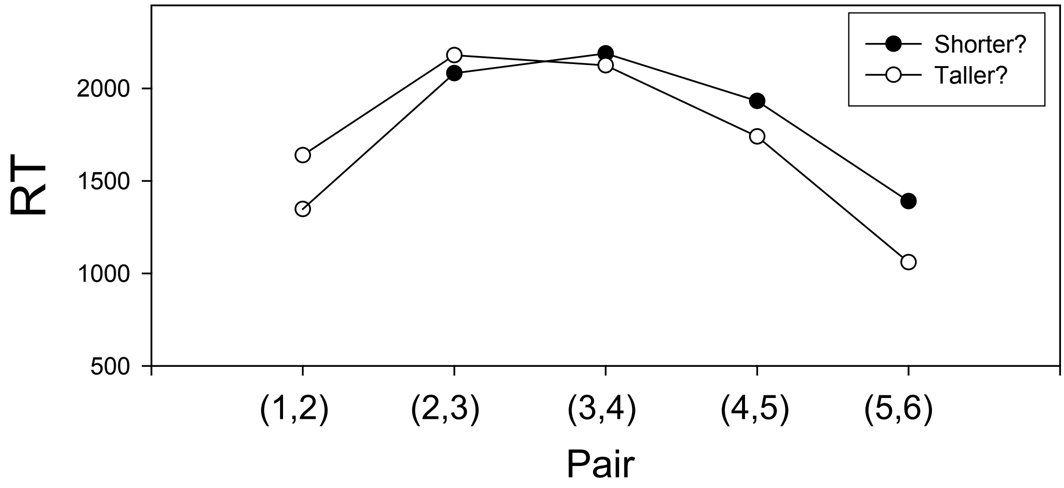

Figure 1. Mean correct comparison RTs for each of the Split 1 pairs (where the numbers refer to positions within the ordering with Position 1 being the shortest) under each form of the comparative instruction.

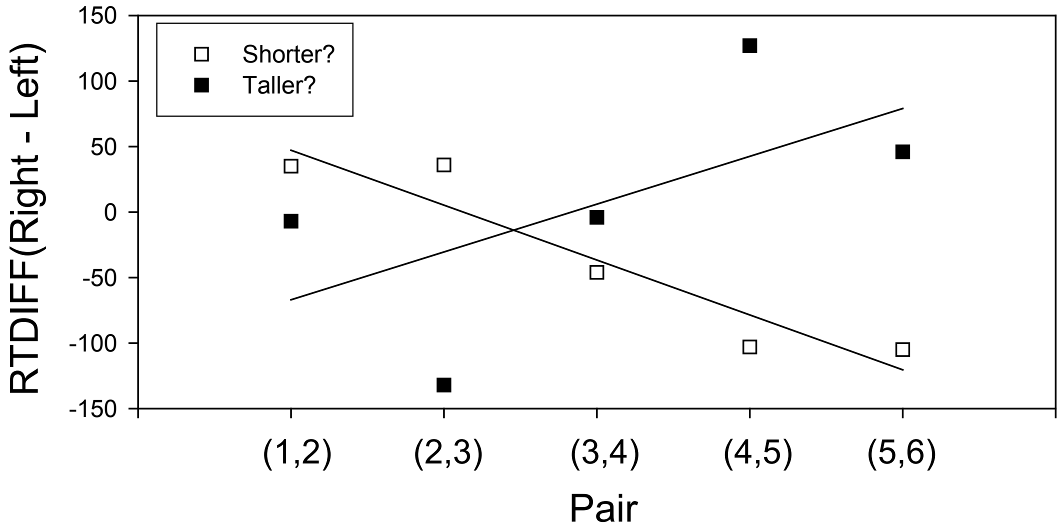

Figure 2. Right- minus left-hand mean correct RT differences for each of the Split 1 pairs (where the numbers refer to positions within the ordering with Position 1 being the shortest) under each form of the comparative instruction.

Discussion

The SNARC effects found here for comparisons involving a small set of very recently learned linearly ordered stimulus items, clearly represent a replication of the results obtained by Shaki et al. (2009) for comparisons of animal magnitudes. Hence, the present results provide some evidence that the semantic representation of linear order in shorter to intermediate-term memory also involves spatial components (as has been postulated by a few researchers such as Holyoak & Patterson, 1980, and Sternberg, 1990). The fact that instruction-dependent

SNARC effects were found here also provides support for the notion that one basis for the presence of such contextual–based SNARC effects is that the semantic ordering of the items not be over-learned.

In fact, it is important to note that left-to-right spatial elements (that reverse over instructions) became associated with the representation of this ordering of symbolic magnitudes even though the participants had never been exposed to the whole sequence of names ordered horizontally from side to side. Moreover, throughout the course of the experiment, the names of the individuals always appeared equally on the right and left sides. Hence, the present paradigm provides absolutely no external basis for the presence of an association between the names themselves and space. Moreover, the learning phase here did not involve any actual writing down of the information being learned suggesting spatial-motor processing during learning may not be a necessary component of the SNARC effect.

References

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

Dehaene, S., Dupoux, E., & Mehler, J. (1990). Is numerical comparison digital? Analogical and symbolic effects in two-digit comparison. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 626-641.

Fias, W., Lauwereyns, J., & Lammertyn, J. (2001). Irrelevant digits affect feature-based attention depending on the overlap of neural circuits. *Cognitive Brain Research*, 12, 415-423.

Gevers,W., Caessens, B., & Fias, W. (2005). Towards a common processing architecture underlying Simon and SNARC effects. *European Journal of Cognitive Psychology*, 17, 659-673.

Gevers, W., Lammertyn, J., Notebaert, W., Verguts, T., & Fias, W. (2006). Automatic response activation of implicit spatial information: Evidence from the SNARC effect. *Acta Psychologica*, 122, 221-233.

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. C*ognition*, 87, B87-B95.

Gevers, W., Reynvoet, B., & Fias, W. (2004). The mental representation of ordinal sequences is spatially organized: Evidence from the days of the week. *Cortex*, 40, 171-172.

Gevers,W., Verguts, T., Reynvoet, B., Caessens, B., & Fias, W. (2006). Numbers and space: A computational model of the SNARC effect. *Journal of Experimental Psychology: Human Perception and Performance*, 32, 32-44.

Holyoak, K. J., & Patterson, K. K. (1981). A positional discriminability model of linear-order judgements. *Journal of Experimental Psychology: Human Perception and Performance*, *7*, 1283-1302.

Ito, Y., & Hatta, T. (2004). Spatial structure of quantitative representation of numbers: Evidence from the SNARC effect. *Memory & Cognition*, 52, 662-673.

Keus, I. M., & Schwartz, W. (2005). Searching for the locus of the SNARC effect: Evidence for a response-related origin. *Memory & Cognition*, 33, 149-157.

Leth-Steensen, C., & Marley, A. A. J. (2000). A model of response time effects in symbolic comparison. *Psychological Review*, 107, 62-100.

Notebaert, W., Gevers, W., Verguts, T., & Fias, W. (2006). Shared spatial representations for numbers and space: The reversal of the SNARC and the Simon effects. *Journal of Experimental Psychology: Human Perception and Performance*, 32, 1197-1207.

Schwartz, W., & Keus, I. (2004). Moving the eyes along the mental number line: Comparing SNARC effects with manual and saccadic responses. *Perception & Psychophysics*, 66, 651-664.

Shaki, S., & Petrusic, W. M. (2005). On the mental representation of negative numbers: Context dependent SNARC effects with comparative judgments. *Psychonomic Bulletin & Review*, 12, 931-937.

Shaki, S., Petrusic, W. M., & Leth-Steensen, C. (2009). SNARC effects with numerical and symbolic comparative judgments: Instruction and language effects. Manuscript submitted to *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Sternberg, R. J. (1980). Representation and process in linear syllogistic reasoning. *Journal of Experimental Psychology: General*, *109*, 119-159.