On the mental representation of negative numbers: Context-dependent SNARC effects with comparative judgments

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In one condition, positive and negative number pairs were compared in separate blocks of trials. In another condition, the positive and the negative number pairs were intermixed. In the intermixed condition, comparisons involving negative numbers were faster with the left hand than with the right, and comparisons were faster with the right hand than with the left hand with the positive numbers; that is, a spatial numerical association of response codes (SNARC) effect was obtained, in which the mental number line was extended leftward with the negative numbers. On the other hand, in the blocked condition, a reverse SNARC effect was obtained with the negative numbers; that is, negative number pairs have the same underlying spatial representation as the positive numbers in this context. Nongraded semantic congruity effects, obtained in both the blocked and the intermixed conditions, are consistent with the idea that magnitude information is extracted prior to the generation of discrete semantic codes.

At the outset, in the teaching of number concepts to elementary school children, numbers are depicted in spatial terms. For example, Del Grande, Jones, Lowe, and Morrow (1974), in their text for the sixth grade, introduce integers in terms of walks. As such, integers represent both length and direction. They write the following:

Here is Larry on a sidewalk. The sidewalk is marked off at regular intervals. If Larry walks 3 spaces to the right, we call it a +3 walk (positive 3). If he walks 4 spaces to the left, we call it a -4 walk (negative 4). (p. 60)

Although the concept of integers as points on the number line is the basis for their mathematical representation, is there evidence for a mental representation of integers in terms of length and direction—that is, a *mental number line*?

Indeed, two lines of evidence, taken together, suggest that the mental representation of numbers is in terms of extents. First, following on Moyer and Landauer's (1967) seminal work, a *split*, or *distance*, effect is now a hallmark

of comparative judgments with numbers (and symbolic comparison generally): The larger the difference between the numbers compared, the shorter the response time (RT). Second, depending on the range of numbers used, a *magnitude* effect can be obtained: With split held constant at, say, one, as the numbers compared become larger, RTs increase, reflecting a Weber-law-like property. The distance effect and the magnitude effect, taken together, have led researchers (e.g., Dehaene, 1992) to postulate a compressive analogue mental representation for numbers; that is, numbers are represented in terms of length.

The most striking and influential demonstration of a *spatial* basis for the mental representation of a number line, with numbers arranged from left to right, was obtained by Dehaene, Bossini, and Giraux (1993). Dehaene et al. required their participants to classify the digits from zero to nine as odd or even (i.e., to make parity judgments). They found that parity judgments with the relatively small numbers in the set were faster with the left hand than with the right hand. However, when the numbers were relatively large, the participants responded more quickly with their right hand. The authors argued that since large numbers are represented to the right on the number line, they preferentially elicit a rightward response. Similarly, since small numbers are represented to the left on the number line, they become more readily associated with the left hand than with the right hand. Capturing the association between the spatial component of the mental representation of numbers and the hand of the response, Dehaene et al. labeled their finding as the *spatial numerical association of response codes* (SNARC) effect.

A clear extension of the SNARC effect (and the teaching of arithmetic) suggests that the number line extends left-

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ward to include the negative numbers (see Fischer, 2003a). On the other hand, it is possible that negative numbers do not have a psychological reality. Rather, they have a *two-dimensional* representation, in which the first and more dominant dimension is *magnitude* and the other is *polarity* (positive or negative), which is accessed only when the task requires it. The magnitude–polarity hypothesis arises from the view that negative numbers do not have a basis in terms of numerosity and, consequently, as Fischer (2003a) points out, “may not become associated with space in the same way that positive numbers are” (p. 278). The primary purpose of the present experiment was to distinguish between the number line and the two-dimensional, *magnitude–polarity*, representation hypotheses.

Although a number of studies have replicated and extended the SNARC effect with parity decisions (e.g., Berch, Foley, Hill, & Ryan, 1999; Fias, 2001; Fischer, 2003b; Ito & Hatta, 2004; Schwarz & Keus, 2004), in almost every case, only positive integers have been used. Recently, though, Ismail (2003), Fischer and Rottmann (2005, Experiment 1), and Nuerk, Iversen, and Willmes (2004) found that parity decisions with negative numbers yielded SNARC effects resembling those obtained with positive numbers. This should not be surprising, since parity can be determined without interrogating polarity. Nevertheless, these studies do show that the representation of negative numbers on the number line is not inexorably activated. In the present experiment, we used a numerical magnitude comparison task to distinguish between the number line and the magnitude–polarity hypotheses.

Fischer (2003a) employed a comparative judgment task and examined RTs with the left and the right hands as a function of the magnitude of the digits, to determine whether the mental representation of negative numbers was in terms of the number line extended leftward from zero. On each trial, he presented a pair of digits horizontally, one on each side of a central fixation point, and the participants selected the smaller number in the pair on half of the trials, and the larger on the other half. The main experimental manipulation was in terms of whether the numbers were displayed in a form that was spatially congruent (e.g., -9 , -4) or spatially incongruent (e.g., -4 , -9) with the number line representation. As was predicted on the number line hypothesis, with negative number pairs RTs were shorter with spatially congruent pairs than with spatially incongruent pairs. As well, and converging nicely with the spatial congruity result, when the digit pairs were spatially congruent, RTs were shorter for the negative digit pairs with the left hand than with the right hand; conversely, for the positive pairs, RTs were shorter with the right hand. Fischer (2003a) concluded that his findings supported the extension of the number line leftward from zero to include the negative numbers. However, there are aspects of his findings that are clearly not in support of his hypothesis. First, in contrast to the negative numbers, RTs were longer with the spatially congruent positive numbers (e.g., 4, 9) than with the incongruent pairs (e.g., 9, 4). As well, when the digits were not

spatially congruent, he obtained a reverse SNARC effect, which was not easily, if at all, interpretable. Moreover, and especially troubling, his findings remain equivocal because he confounded instruction with the hand of the response, and his SNARC-like effects may have, in effect, reflected a semantic congruity effect (SCE).

SCEs in numerical magnitude comparisons (e.g., Banks, Fujii, & Kayra-Stuart, 1976) are evident with the faster selection of the larger of two relatively large digits (e.g., 8 and 9) than of the smaller. Conversely, selection of the smaller of two relatively small digits (e.g., 1 and 2) is faster than the selection of the larger. In Fischer’s (2003a) data, with spatially congruent pairs (such as 4, 9), when the instruction was *smaller*, the left-hand response was correct but semantically incongruent with the relatively large number 9, thereby increasing the left-hand RT. On the other hand, with the instruction *larger* with this pair (4, 9), the right-hand response was semantically congruent, thereby accruing an advantage for the right-hand response, precisely as would be expected from SNARC-like evidence. Furthermore, the apparent SNARC-like extension of the number line to the negative numbers with the spatially congruent pairs (e.g., -9 , -4) would also arise as an artifact of the SCE. With the instruction to select the smaller digit, the leftward response to the digit -9 is semantically congruent with the instruction, but the rightward response to the digit -4 with the instruction to select the larger digit is slowed, since the digit -9 is incongruent with the instruction *larger*. Moreover, as the digit pairs become less extreme (e.g., 1, 6), the SCEs would be smaller than those with more extreme pairs, since SCEs are typically graded. As well, RTs with the between-polarity pairs (e.g., -3 , 2) would likely be the same with both instructions and with both hands, resulting in a SNARC index near zero. Consequently, in support of the extended number line hypothesis, when the SNARC index is plotted over the range from -9 to 9, it will show the required negative slope and will pass through zero, albeit artifactually.

When the numbers are not spatially congruent (e.g., 9, 4), the left-hand response is semantically congruent with the instruction to select the larger, but the right-hand response, which is entailed by the instruction *smaller*, is semantically incongruent; consequently, precisely as was found by Fischer (2003a), a reverse SNARC effect will ensue. Moreover, precisely as with the positive digit pairs, when the negative digit pairs are presented in a spatially incongruent order, the SCE effects obtained will appear as reverse SNARC effects, precisely as was reported by Fischer (2003a).

Thus, these concerns with Fischer’s (2003a) experiment force a reconsideration of the evidence provided in support of the number line hypothesis. In the present experiment, we also employed a comparative judgment task in order to test the number line hypothesis by examining the patterns of SNARC effects obtained with positive and with negative numbers. Our tests of the bases for the representation of positive and negative numbers

were based on the mean RTs for the left and the right hands as a function of the numerical magnitude of the digits compared, after balancing for presentation order and instruction, thus avoiding the confounds evident in the Fischer (2003a) experiment. As well, in order to determine whether the context in which negative numbers are encountered might influence the spatial representation activated, in one condition positive and negative number pairs were compared on separate blocks of trials, and in another they were intermixed.

On a strict form of the number line hypothesis, in both the blocked and the mixed conditions, the following pattern of SNARC effects will be obtained. RTs with the left hand will be shorter than those with the right hand for the negative numbers and RTs with the right hand will be shorter than those with the left hand for the positive numbers. In each case, as the digit pairs approach zero, the difference between the RTs with the two hands should approach zero. On the other hand, on the magnitude–polarity hypothesis, magnitude information has precedence over polarity, and the underlying mental representation of negative numbers is like that of positive numbers. Consequently, in both the blocked and the mixed conditions, as the negative numbers become larger in absolute value, RTs will be shorter with the right hand than with the left hand, paralleling the pattern obtained with positive numbers.

In addition, the particular form of SCE obtained with positive and negative number comparisons can be examined to distinguish between the number line and the two-dimensional, magnitude–polarity hypotheses. On the number line hypothesis, a full SCE effect should be obtained in discrimination of numerical magnitude with positive and negative numbers. Generally, selection of the smaller of two negative numbers will be faster than the selection of the larger, and for positive numbers, RTs will be shorter with the instruction to choose the larger number than with the instruction to choose the smaller number. Moreover, the full and orderly representation of numerical magnitudes with zero as the category boundary between the sets of negative and positive numbers will be evident with the occurrence of a *fully graded* SCE. In particular, the SCE should be the largest with the most extreme numbers in the sets of negative numbers and positive numbers, and then the SCE should monotonically decrease as the number pairs approach zero.

A strikingly different pattern of SCEs should be evident on the two-dimensional, magnitude–polarity hypothesis. First, since positive numbers activate the number line, a full SCE will be obtained within the positive numbers; RTs will be shorter with the instruction to choose the larger of two relatively large positive numbers, but RTs will be shorter in choosing the smaller of two relatively small positive numbers. Second, for negative numbers, magnitude information is accessed first, and polarity is not processed until the comparison has been completed. Consequently, the SCE will be evident for the negative numbers as if they were positive numbers; that is, when

plotted on the number line, the SCE will be reversed. Comparisons with negative numbers proceed just as with positive numbers, but when polarity is activated, after the comparison process, the overt response is a translation of the outcome of the comparison process, also adding time to the overall RT.

METHOD

Participants

Twenty-two Carleton University students participated in a single session of approximately 1 h to satisfy course requirements. All the subjects reported normal or corrected-to-normal vision.

Apparatus

Graphics production, presentation of instructions and stimuli, event sequencing and timing, and the recording of responses and RTs were controlled by a Pentium III computer running under SuperLab control. The digits in each pair, presented in Times New Roman font, size 30, appeared at the respective centers of the left and right hemifields on a white background of a 17-in. (43-cm) ViewSonic video monitor with 800×600 pixel resolution, and the comparative instructions appeared at the center of the upper third of the screen. Responses were made on a keyboard, with all the keys covered except the A and L, which were used to indicate left and right responses, respectively.

Stimuli and Design

The stimulus set was composed of a set of three relatively small positive digits and zero (0, 1, 2, 3), four relatively large positive digits (6, 7, 8, 9), four relatively small negative digits (−9, −8, −7, −6), and three relatively large negative digits and zero (−3, −2, −1, 0). In each set, the stimulus pairs for the comparison task were defined by the 3 pairs of digits one step removed from one another (e.g., [0, 1], [1, 2], [2, 3]). Each of the 3 pairs in each of the four sets was presented in each of the two left–right orders, resulting in a total of 24 pairs. As well, on half of the trials the instruction to select the *smaller* number was used, and on the other half the instruction was to select the *larger* digit.

Each of these 48 basic cells in the design was replicated 10 times in each of two within-participants conditions. In one condition, the pairs involving positive and negative digit pairs were intermixed, and in the other they were blocked. The order in which the blocked and intermixed conditions were presented, the order of the positive and negative digit pairs used in the blocked condition, and the order in which the two instructions were used were counterbalanced. Precisely the same sequence of blocks of trials was used for the practice trials as for the experimental trials for each participant. The participants were not aware of the partition into practice and experimental trials. The order of presentation of the stimulus pairs within blocks was random and was different for each participant.

Procedure

The presentation of either the word *smaller* or the word *larger* served as a warning for the next trial, indicating the direction of the comparison. The pair of digits appeared 750 msec later, and the comparative instruction remained on the screen. The participant's task was to press the labeled key on the keyboard (the A or L key) corresponding to the side of the larger (smaller) digit in the pair. The participant's response cleared the screen. The next trial began 1,000 msec later.

The participants were explicitly instructed to respond in terms of numerical magnitude and were given two examples while in the presence of the experimenter. In addition, the participants were encouraged to respond quickly but accurately. The 60-min session included three planned breaks, which ended with the participants' decision to continue.

RESULTS

RT analyses are presented first, followed by error analyses. The RT-based findings are presented in two main sections. The first explores SNARC effects, and the second the SCE. Separate overall ANOVAs were conducted, with mean correct RT and mean error rate for each participant as the dependent variables and condition (blocked vs. intermixed), polarity, digit pair, instruction, and hand of response as the within-participants factors after the data over the two presentation orders were combined. A Huynh–Feldt epsilon adjustment of degrees of freedom was used, although the degrees of freedom and mean square errors indicated in the text are those defined by the design. Level of significance was set at .05.

Response Time Analyses

SNARC effects. The plots in Figure 1 for both the intermixed and the blocked conditions with the positive numbers show that comparative judgment RTs provide strong converging evidence of the SNARC effect. For example, as the plot for the positive number pairs in the blocked condition shows, RTs are shorter for the right hand than for the left hand with relatively large digit pairs (e.g., 8 and 9), but RTs are shorter for the left hand than for the right hand with the relatively small positive digit pairs (e.g., 1 and 2), paralleling precisely the SNARC effects obtained with parity judgments. Overall, this SNARC effect reveals itself in terms of a best-fitting straight line with a slope of -8.33 and an intercept of 41.39 and a highly reliable index of linear fit [$r^2 = .939$; $t(4) = 7.60$, $p < .002$].

Evidence for the extension of the number line hypothesis to the negative digits is presented in the plot provided in Figure 1 for the intermixed condition. As the plot shows, RTs are longer with right-hand responses than

with left-hand responses to the negative number pairs (e.g., -9 and -8), but the converse occurs with positive number pairs (e.g., 8 and 9); overall, the linear regression equation plotted shows a slope different from zero [$r^2 = .502$; $t(10) = 2.249$, $.05 < p < .10$, two-tailed]. Interestingly, the evidence is clear in refuting the extension of the number line hypothesis to the negative numbers in the blocked condition. A highly reliable *reverse* SNARC effect is obtained with the negative number pairs [$r^2 = .974$; $t(4) = 12.08$, $p < .001$]; that is, the negative number pairs have the same underlying spatial representation as the positive numbers. Thus, the two-dimensional, magnitude–polarity hypothesis is supported when the number pairs are presented in blocks. Further statistical support for the conclusions above is provided by a significant interaction involving condition, polarity, pair, and hand of response [$F(5,105) = 3.90$, $MS_e = 6,354.9$].¹

In the blocked condition, the points at each end of the subset of the continuum are clustered closely together, with a substantial distance between the two clusters, and the linear regressions are close to fitting the regression line through just two points. Thus, the actual values of the correlation coefficients must not be taken too seriously. Nevertheless, the evidence for SNARC in each case is clear and strong. For example, an additional ANOVA conducted with just the blocked condition, with polarity, the six pairs, and the hand of the response as within-participants factors, was conducted.

Individual participant analyses. In each condition, we conducted repeated measures regression analyses as outlined in Lorch and Myers (1990). In each case, we first obtained standardized beta regression coefficients for each participant with the SNARC index [$RT(\text{Right}) - RT(\text{Left})$] as the dependent variable and magnitude as the predictor. We then tested the hypothesis (two-tailed) that the mean of these weights differed from zero, using the t

Figure 1. Mean response times (RTs) with the left hand subtracted from mean RTs with the right hand (SNARC index) as a function of stimulus pair for the intermixed and the blocked conditions.

distribution. For the intermixed condition, the mean beta weight ($M = -.246$, $SD = .296$) differed reliably from zero [$t(21) = -3.89$, $p < .001$], affirming the extension of the number line leftward with the negative digits. In the blocked condition with the positive digits, the mean beta weight ($M = -.479$, $SD = .329$) differed reliably from zero [$t(21) = -6.83$, $p < .00001$], affirming reliable SNARC effects. Finally, reliable reverse SNARC effects were obtained with the negative digits in the blocked condition [mean beta weight = .511, $SD = .472$; $t(21) = 5.08$, $p < .00002$].

Obtaining mean beta weights significantly different from zero was not an artifact of a few extreme weights. Rather, in each case, the preponderance of participants showed comparable effects. For example, in the intermixed condition, the best-fitting regression line had a negative slope for 18 of the 22 participants. In the blocked condition, with the positive numbers the slopes were negative for 19 of the 22 participants, and they were positive for 19 of the 22 participants for the negative pairs. The interaction of pair and hand of response, defining the SNARC effect, was statistically significant [$F(5,105) = 12.19$, $MS_e = 3,519.28$]. The absence of a significant interaction involving polarity, pair, and hand of response [$F(5,105) = 0.20$, $MS_e = 3,523.67$] indicates that SNARC effects are the same with the positive and the negative numbers and reflects the fact that SNARC effects with negative number pairs involve processing of magnitude and not polarity.

Semantic congruity effects. Figure 2 provides a view of the RTs with each pair and each instruction in each condition, after combining the data over the hand of the response and the two presentation orders. A number of effects are especially evident. First, RTs are substantially and significantly longer in the intermixed (829.4 msec) than in the blocked (643.4 msec) condition [$F(1,21) = 58.69$, $MS_e = 597,734.4$]. Second, RTs are reliably longer with negative digit pairs (829.4 msec) than with positive digit

pairs [743.4 msec; $F(1,21) = 48.89$, $MS_e = 79,849.1$]. Third, the pairs also differed reliably [$F(5,105) = 15.93$, $MS_e = 19,917.6$]; RTs increase as the pairs increase in absolute magnitude, evidence of the compression in the mental representation of large numbers. However, this magnitude effect was more pronounced in the blocked condition than in the intermixed condition and more evident with the positive pairs than with the negative pairs, reflected in reliable interactions of pair with condition [$F(5,105) = 6.51$, $MS_e = 13,703.8$] and with sign of the pair [$F(5,105) = 6.49$, $MS_e = 14,421.9$], respectively. Identical forms of the SCE are evident in both conditions, substantiated by the reliable interaction between polarity and instruction [$F(1,21) = 22.65$, $MS_e = 77,293.9$] and the nonreliability of the three-way interaction of condition, polarity, and instruction [$F(1,21) = 0.82$, $MS_e = 16,117.4$]. As well, the interaction involving polarity, instruction, and hand of response was not significant [$F(1,21) = 0.19$, $MS_e = 11,805.1$], indicating that comparable overall SCEs occurred with the left- and the right-hand responses. For the negative number pairs, RTs are almost always longer with the instruction to choose the larger than to choose the smaller digit in the pair in both the intermixed and the blocked conditions. On the other hand, RTs are longer with the instruction to choose the smaller digit than with the instruction to choose the larger in every case for the positive digit pairs.

Error Rates

Overall, as was expected, error rates were low (2.36%). No speed–accuracy trade-off was evident. The correlation between mean RT and mean error rate is .552 [$t(46) = 2.48$, $.01 < p < .02$, two-tailed] taken over the 48 cells arising from the factorial combination of condition, polarity, pair, and hand of response (the factors entering into the critical interaction effects evident in Figure 1). The reliable main effects obtained with RTs were also evident with the error data. For example, significantly more errors were made in the intermixed condition (3.06%) than in the blocked condition [1.65%; $F(1,21) = 19.19$, $MS_e = 1,142.3$]. As well, a number of two-way, three-way, and four-way interactions and the five-way interaction attained significance. Generally, these interactions paralleled the RT effects, as would be expected given the absence of a speed–accuracy trade-off.

DISCUSSION AND SUMMARY

The present findings establish that SNARC effects can be obtained with pairwise comparative judgment RTs. Moreover, these SNARC effects are clear in implicating a contextual dependence of the spatial representation that is activated when a pair of digits is presented for comparison. Notably, when both positive and negative pairs are intermixed, a full SNARC effect is obtained, in support of the number line hypothesis. On the other hand, in the blocked condition, a strong and clear reverse SNARC effect is obtained with the negative digits, thereby denying the generality of the number line hypothesis and the in-

Figure 2. Mean response times in each condition with each stimulus pair and each instruction.

exorable activation of the number line upon presentation of a digit pair. Indeed, our findings converge nicely with recent work by Fitousi and Algom (2004), who showed, using Garner's (1974) speeded classification paradigm, pitting parity against numerical magnitude, that numerical magnitude information is not automatically activated, as would be expected on the basis of SNARC effects.

Evidently, the negative numbers have a number line representation only when they are encountered in the context of positive numbers. Moreover, it should be noted that only a weaker form of the number line hypothesis is supported, because comparisons with negative digit pairs are appreciably slower than those with positive pairs. The strong form of the number line hypothesis denies differences in speed of processing of positive and negative numbers.

The SCEs obtained are not entirely consistent with either the number line or the two-dimensional, magnitude–polarity hypothesis. On the one hand, the occurrence of the full SCE across the positive and negative digit pairs would appear to be consistent with the SNARC effect obtained in the intermixed condition. On the other hand, the effect is not graded as required. Rather, it is categorical. The occurrence of the full SCE across the positive and negative digit pairs in the blocked condition is entirely inconsistent with the two-dimensional, magnitude–polarity hypothesis, which predicts a reverse SCE effect for the negative digit pairs. As well, it is inconsistent with the reverse SNARC effect obtained with the negative digits in the blocked condition. However, we offer a unifying, albeit speculative, account of both the patterns of SNARC and the pattern of SCEs in both the blocked and the intermixed conditions.

Contextually based encoding and retrieval factors may have played a key role in how the negative number pairs were processed in the blocked and in the intermixed conditions. In the intermixed condition, participants must interrogate each pair for polarity, thereby ensuring that polarity is processed together with magnitude, a condition sufficient for the full SNARC effect and extension of the number line leftward with the negative numbers. The determination of polarity also gives rise to a semantic coding of the pair, perhaps as in the semantic coding theory developed in Banks et al. (1976). For example, the digits in the pair -9 and -8 might be coded as *SMALL++* and *SMALL+*, respectively, and these codes are congruent with the instruction to select the *smaller* number and incongruent with the instruction to select the *larger*. As well, if all the negative number pairs are coded in precisely the same way, the nongraded categorical SCEs obtained arise. Similarly, the digits in the pair 9 and 8 may be coded as *LARGE++* and *LARGE+*, respectively, and these codes are congruent with the instruction to select the *larger* number and incongruent with the instruction to select the *smaller* number. If all the positive pairs are coded in the same way, then nongraded categorical SCEs will also be obtained with the positive number pairs.

On the other hand, in the blocked condition, because polarity is known in advance, magnitude can be processed

first, polarity subsequently retrieved, and the semantic codes are then generated precisely as in the intermixed condition. Consequently, reverse SNARC will be obtained with negative numbers, because the absolute magnitudes are activated in the first stage of processing. Moreover, precisely the same pattern of SCEs in the blocked and the intermixed conditions will also be obtained, because the semantic codes generated in the blocked and the intermixed conditions are the same.

The present findings stand in contrast to those reported in Fischer and Rottmann (2005). Given an absence of SNARC effects for the parity judgments with negative digits and the possibility that the participants ignored the sign of the number, they conducted a second experiment, with a view toward ensuring that the participants attended to the minus sign. Accordingly, they required the participants to categorize digits in terms of polarity. RTs were not significantly different with the two hands for the negative digits, and they were slower with the left hand than with the right hand with the positive digits, although the interaction of side of the hand and the polarity of the digits failed to attain statistical significance. As well, the slope of the regression line typically defining the SNARC effect was not significantly different from zero. Nevertheless, Fischer and Rottmann concluded that their categorization data provided evidence of a SNARC effect for the positive numbers and that the absence of a SNARC effect with the negative numbers reflected the fact that negative numbers are processed less automatically than positive numbers.

The extension of the number line leftward in the intermixed condition of the present experiment provides a clear failure to replicate Fischer and Rottmann's (2005) absence of SNARC effects with negative digits. However, the absence of SNARC effects with the negative digits in their experiment is not surprising. The binary categorization task is also not ideally suited for the examination of SNARC effects with the negative numbers. Participants can perform the categorization by simply determining whether a minus sign is present or not, thereby precluding the processing of magnitude information. The absence of distance effects with the negative digits and with the left-hand responses with the positive numbers is entirely consistent with the lack of processing of magnitude information.

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NOTE

1. The five-way interaction involving condition, polarity, pair, instruction, and response was statistically reliable [$F(5,105) = 2.84$, $MS_e = 10,529.43$]. The interaction arose from idiosyncratic changes in the sign of the SNARC effect for some of the pairs with each polarity set and for each condition. In both conditions, the basic patterns of effects shown in Figure 1 are evident with both instructions.

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