

SNARC EFFECTS FOR POSITIVE AND NEGATIVE NUMBERS REPRESENTING TEMPERATURE

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Abstract

Previous experiments suggest that the direction of SNARC is fixed for numbers based on overlearned reading and writing habits. Our experiments show that in the context of temperature, the direction of SNARC is dependent on instruction such that faster responses were always associated with the most extreme temperature. In our three experiments, participants were required to pick the warmer or colder digit from pairs representing relatively high or low temperatures. Presentation of pairs and responses were horizontal in Experiment 1 but vertical in Experiments 2, and 3. An instruction-dependent SNARC effect occurred such that responses to the “coldest” and “warmest” pairs were always fastest to the right, in the horizontal experiment, and fastest in an upward direction in the vertical experiments. These experiments suggest that the mental number line does extend past zero for negative numbers and the orientation of the line is reversible based on instruction.

There is strong evidence to suggest that numerical magnitude is represented spatially along a mental number line. Dehaene, Bossini and Giraux (1993) found that when participants made parity judgments for numbers between 1-9, using a keypad, leftward responses were faster compared to right for relatively smaller numbers, but rightward responses were faster than left for relatively larger numbers. Dehaene et al. termed this the SNARC effect (Spatial Numerical Association of Response Codes) and argued that it was evidence that numbers were mentally represented from smallest on the left to largest on the right, at least in Western society, and this facilitates manual responses to numbers in the corresponding direction. In addition to the horizontal plane, the SNARC effect has also been found in the vertical direction (Ito and Hatta, 2004) suggesting that the mental number line may be flexible and adaptable to the task.

It is not clear from previous studies whether or not the mental number line extends past zero to include negative numbers. Shaki and Petrusic (2005) found that when participants compared negative numbers exclusively, the direction of the SNARC effect suggested that participants processed magnitude according to their absolute value. However, when trials of negative comparisons were intermixed with trials of positive comparisons, the direction of SNARC for negative numbers changed such that, it was reflective of processing of magnitude according to a full mental number line.

SNARC has also been found for stimuli other than numbers. Shaki and Petrusic (2005b) found SNARC for animal size and line length. Interestingly, unlike numbers, the direction of SNARC was dependent of instruction.

The Present Experiments: Overview

In these three experiments we assess SNARC effects using temperatures presented as positive and negative digits. These experiments test if the magnitude of negative numbers in the context of temperature will be processed according to their absolute value or according to the numerical value between blocked and intermixed conditions. It is possible that in the context of temperature, polarity will have a perceived increase in importance, and therefore will be consistently processed with magnitude.

Experiment 1: SNARC Effects for Temperatures Presented Horizontally

Method

Participants. Forty Carleton University students participated in a single session lasting approximately 45 minutes, in exchange for course credit.

Stimuli and Design. Stimulus pairs were constructed from digits that were categorized as relatively small positive (1, 2), (2, 3), (3, 4); large positive (6, 7) (7, 8), (8, 9); small negative (-9, -8) (-8, -7), (-7, -6); and large negative (-4, -3), (-3, -2), (-2, -1). Each pair was presented in each of the two possible left-right position orders, an equal amount of times. Pairs were presented in a condition in which all trials are either positive or negative (Blocked) as well as a condition in which trials alternated randomly between negative and positive trials (intermixed). The two instructions, “warmer” and “colder” each occurred for half of the trials and appeared in separate blocks. The twelve stimulus pairs by two orders by two instructions by two conditions were presented eight times. The order of condition (blocked, intermixed) and instruction blocks (colder, warmer) were counterbalanced between participants.

One temperature of the pair appeared to the left of centre and the other appeared to the right of centre in the approximate upper third of the screen. The instruction appeared under the stimuli in the approximate centre of the screen. The instructions and stimuli were printed in black (Arial font, size 36) on a white background on a 17 inch (43 cm) View Sonic monitor. The experiment was programmed and executed using SuperLab 2 software on a PC with Pentium III microprocessor. The keypad used was the Cedrus model RB-620 (keys 2 and 5).

Procedure. Participants were tested individually seated at a desk, approximately 90 cm from the computer monitor. On each trial either the instruction “colder” or “warmer” appeared on the screen. After a 500 ms delay, the number pair appeared, while the instruction remained on the screen. Participants were required to pick either the colder or warmer temperature, depending on the instruction, by pressing either the left key or the right key corresponding to the location of the correct answer.

Results and Discussion

After aggregating medians for each condition and combining data over two orders, we conducted repeated measures regression analyses as outlined in Lorch and Myers (1990). SNARC was tested for each combination of instruction (colder, warmer), polarity (positive, negative), and condition (blocked, intermixed).

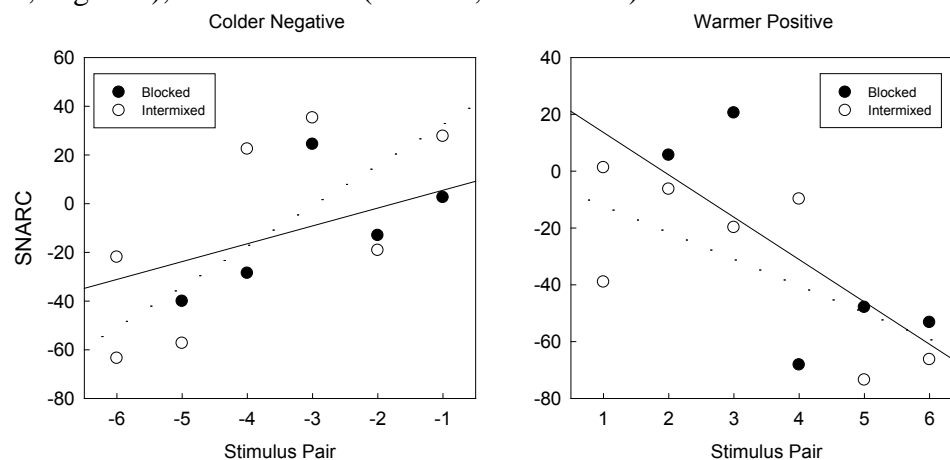


Figure 1. Mean leftward response time subtracted from median rightward response times as a function of each stimulus pair. The x-axis represents the order of temperature with -6 representing pair (-9, -8) progressing to 6 representing (9, 8). The left panel represents negative pairs for the instruction “colder” and the right panel represents the positive pairs for the instruction “warmer”.

As seen in the left panel Figure 1, a significant SNARC effect occurred for the colder-negative-blocked condition ($M = .24$, $SD = 0.059$), $t(39) = 4.000$, $R^2 = .349$ and the intermixed condition ($M = .160$, $SD = 0.492$), $t(39) = 2.053$, $R^2 = .501$, which seemed to be dictated by the absolute magnitude of numbers. When the temperatures were the highest, (-2, -1) participants were faster to respond to the left compared to the right. However, as the pairs decreased in temperature, and absolute magnitude increased (-8, -9), participants were faster to respond to the right compared to the left.

As seen in the right panel of Figure 1, there was also a significant SNARC effect when the instruction was “warmer” for the positive-blocked condition ($M = -.243$, $SD = 0.489$), $t(39) = -.3.140$, $R^2 = .565$ as well as the positive-intermixed condition, ($M = -.170$, $SD = 0.365$), $t(39) = -2.950$, $R^2 = .369$. Again, it seemed as though the direction of SNARC was dictated by the absolute magnitude of numbers. Participants were faster to respond left compared to right for lower temperature pairs, but faster to respond right compared to left for higher temperature pairs.

Unlike Shaki and Petrusic (2005), we found no difference in the direction of SNARC between blocked and intermixed conditions. It seems as though in all conditions, SNARC for negative numbers is dictated by the absolute magnitude of numbers and this suggests that the mental number line does not extend past zero.

Experiment 2

This experiment tests if SNARC occurs for negative numbers in the vertical dimension, and if the results from Experiment 1 which suggest that negative numbers are not represented on the mental number line, will be replicated.

In the second half of the experiment, a picture of a thermometer was added and remained on the screen. We reasoned that by emphasizing the context of temperature, the strength of SNARC may be enhanced or altered in some conditions.

Method

Participants. Thirty-three Carleton University students participated in a single session lasting approximately 45 minutes, in exchange for course credit.

Stimuli and Design. The stimuli and design were the same as Experiment 1 except for several differences:

- 1) The temperature pairs were presented in a vertical plane. One number was presented up from the centre point and one was presented down from the centre point in “Arial Black” font, size 24.

- 2) We eliminated the written instructions and instead participants were expected to determine the instruction based on the colour of the stimuli. Blue pairs indicated that participants were required to choose the colder temperature and red pairs indicated that participants were required to choose the warmer temperature of the pair.

- 3) For the second half of the experiment a picture of a thermometer, created in PowerPoint, appeared to the left of the digit pair and remained on the screen for each trial.

- 4) The twelve stimulus pairs by two orders by two instructions by two conditions (blocked, intermixed), by two thermometer conditions (present or not) were presented six times.

Procedure. The procedure was the same as in Experiment 1 except that instead of responding on a keypad, participants used a standard computer keyboard and were instructed to press the upper “Y” key to choose the upper digit on the screen or to press the lower “B” key to choose the lower digit. The keys were covered with silver tape

The monitor used was a 19 inch (48.3 cm) NEC monitor. The experiment was programmed and executed using SuperLab 4 software on a PC with Pentium IV microprocessor.

Results and Discussion

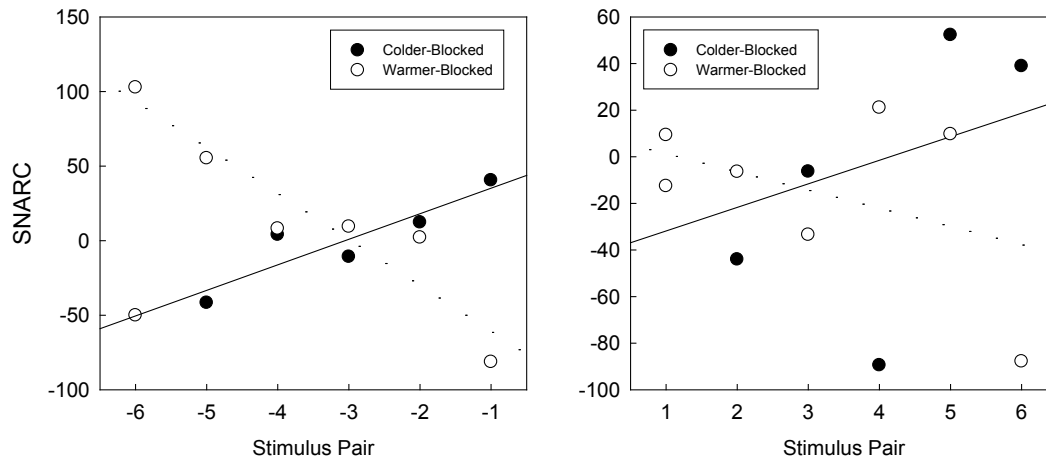


Figure 2. Mean downward response time subtracted from mean upward response times as a function of each stimulus pair. The left panel represents negative pairs for the instruction colder with a thermometer and warmer without a thermometer, and the right panel represents positive pairs for each instruction with a thermometer.

In this experiment we observed SNARC effects that were reflective of number processing on a full number line. Also, in contrast to previous experiments with numbers we found an instruction-dependent SNARC effect, such that more extreme temperature pairs corresponding to the instruction were always responded to faster in the upward direction compared to downward, and more moderate temperatures facilitated downward responses compared to upward.

SNARC was significant when the instruction was “colder” for the negative-blocked condition, $M=.213$, $SD=.362$, $t(32)=3.383$, $R^2=.884$. As seen in the left panel of Figure 2, upward responses were faster compared to downward, when the numbers were most negative but as the pairs increase in temperature, downward responses became faster compared to upward. However, when the instruction was “warmer” the direction of SNARC reversed such that upward responses were faster than downward for the higher temperature pairs but downward responses were faster than upward responses for relatively lower temperature pairs, $M=-.259$, $SD=.463$, $t(32)=-3.21$, $R^2=.882$.

As can be seen in the right panel of Figure 2, for the instruction “colder” there was a significant SNARC effect for positive numbers in the blocked condition, with a thermometer, $M=.153$, $SD=.427$, $t(33)=2.066$, $R^2=.127$. The lower temperature pairs were responded to faster in an upward direction compared to downward, but the higher temperature pairs were responded to faster in a downward direction.

Also seen in the right panel of Figure 2, for the instruction “warmer”, Figure 2, SNARC was significant in the positive-blocked condition with a thermometer present, $M=-.152$, $SD=.347$, $t(32)=-2.51$, $R^2=.141$. Upward responses were faster compared to downward, for the relatively higher temperature pairs. However, downward responses were faster than upward for the relatively lower temperature pairs.

The results from this experiment suggest that the SNARC effects we found in Experiment 1 may not have been representative of the processing of numbers according to their absolute value but rather, processing of numbers according to their value on a full number line. The direction of SNARC however, was influenced by instruction. It seems that the most extreme temperatures corresponding to the instruction facilitated rightward responses while more moderate temperatures facilitated leftward responses.

Therefore, the results from the first two experiments suggest that negative numbers are indeed included in the mental number line. Also the fact that SNARC was dependent on instruction suggests that temperatures are processed differently than “normal” numbers.

Experiment 3

As far as we know, the results of Experiment 2 are the first time SNARC effects have been found for negative numbers in the vertical plane. To confirm our results we repeated the experiment with some slight modifications.

Method

Participants. Thirty-two Carleton University students participated in a single session lasting approximately 45 minutes, in exchange for course credit.

Stimuli and Design. The stimuli and design were the same as Experiment 2 except that stimuli were coloured black and the written instruction was included below the digit pairs at approximately the bottom third of the screen in “Arial” font, size 36.

Procedure. The procedure was the same as in Experiment 2 except that participants used the Cedrus response pad (model RB-620). The response pad was positioned and taped to the desk, such that the keys were arranged in a vertical plane. Also, the experiment was executed using SuperLab 2 software.

Results and Discussion

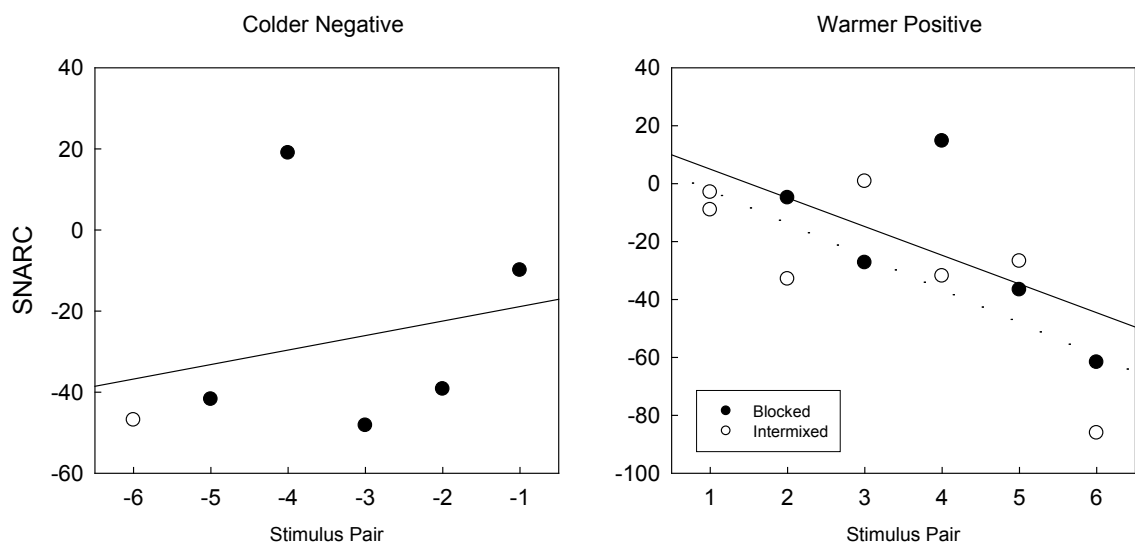


Figure 1. Mean downward response time subtracted from mean upward response times as a function of each stimulus pair. The left panel represents data for the instruction “colder” in the blocked condition, with a thermometer, and the right panel represents data for the instruction “warmer” for the blocked and intermixed conditions with a thermometer.

Generally, the results of Experiment 3 replicated those of Experiment 2. Again we found SNARC effects that were dependent on instruction such that more extreme temperature pairs corresponding to the instruction were always responded to faster in the upward direction compared to downward.

As seen in the left panel of Figure 3, SNARC was significant for the instruction “colder” in the negative-blocked condition, with a thermometer present, $M=.152$, $SD=.362$, $t(31)=3.383$, $R^2=.062$.

As seen in the right panel of Figure 3, SNARC was significant for the instruction “warmer” in the positive-blocked condition, with a thermometer present, $M=-.239$, $SD=.401$, $t(31)=-3.368$, $R^2=.453$ and for the positive-intermixed condition, with a thermometer, $M=-.171$, $SD=.447$, $t(31)=-2.166$, $R^2=.503$.

Summary and Conclusions

In all three experiments we found SNARC effects that were reflective of a mental representation of numerical magnitude on a full mental line for both positive and negative numbers. The SNARC effects we found were dependent on instruction suggesting that numbers representing temperature are processed differently than numbers without a semantic reference.

Unlike the results Shaki and Petrusic (2005a) we failed to find a difference in the direction of SNARC for negative numbers between conditions in which polarity was blocked or intermixed. They suggested that in their experiment participants could predict polarity in the blocked condition and therefore delayed its processing until after magnitude was processed and therefore was not included in the representation of SNARC. It is possible that in our experiment that although polarity was predictable in the blocked condition, it may be integrated with the concept of temperature such that delaying its processing may have been less efficient.

Unlike previous experiments, we found a SNARC effect for numbers that was dependent on instruction. Bächtold, Baumüller, and Brugger (1998) found SNARC when participants made number judgements while imagining a ruler and reverse SNARC when they imagined a clock face. Like their experiment, it is possible that in our experiment, the normal left to right or downward to upward overlearned ordering of numbers may have been circumvented due to context.

It is unclear at this point however, why participants seemed to order temperatures in the directions that were reflected by our results. The instruction-dependent SNARC effect Shaki and Petrusic (2005b) found for nonnumerical magnitude was in the opposite direction of what we found. They found the most extreme comparison corresponding to the instruction favoured leftward responses, compared to rightward.

Future experiments should try to determine if numerical magnitude is the origin of SNARC or if it originates from participants' perception of least to most, which may coincide or contradict numerical order. Additionally a common principle needs to be established to explain why participants find it ideal to order stimuli in one direction (animal size) or the other (temperature) despite seemingly similar experimental conditions.

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