

BAD-GOOD CONSTRAINTS ON A POLARITY CORRESPONDENCE ACCOUNT FOR THE SNARC EFFECT

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Abstract

Thirty-eight participants judged whether single digit stimuli were odd or even using either left and right manual key-press responses or vocal voice-key responses. Half of the participants used “Left” and “Right” as vocal responses, whereas the other half responded using the words “Bad” and “Good”. SNARC-like effects were found in the results for the “Left-Right” vocal response group but not for the “Bad-Good” vocal response group. That is, for the former group, smaller magnitude digits were responded to faster with the response “Left” and larger digits with the response “Right”. For the latter group, no consistent association between smaller-larger digit magnitudes and “Bad-Good” vocal responses was present. As will be discussed, such findings do not seem to be very supportive of a polarity correspondence view of the SNARC effect.

One extremely important notion regarding the representation of numerical magnitude has been that it contains a spatial component akin to a mental number line. A key stream of evidence for such a notion has been the robustness of the well-known and (by now quite) well-researched spatial numerical association of response codes (SNARC) effect (for reviews see Fias & Fischer, 2005; Hubbard, Piazza, Pinel, & Dehaene, 2005; Wood, Willmes, Nuerk, & Fischer, 2008). The modal form of this effect is characterized by the case in which, when making simple binary judgments to number stimuli, responding tends to be faster with the left hand than with the right hand for relatively small (in magnitude) numbers while the opposite is generally true for relatively large numbers. Because a spatially based, image-like, number line representation is likely to have smaller numbers encoded on the left and larger numbers encoded on the right for most European and North American participants, the SNARC effect can be assumed to arise as a natural consequence of the compatibility between a left-right visuospatial coding of number magnitude and a left-right visuospatial coding of the response alternatives.

Recently though, some categorical-based theories have been proposed as accounts for the SNARC effect (Gevers, Verguts, Reynvoet, Caessens, & Fias, 2006; Proctor & Cho, 2006). Moreover, some recent key empirical findings by Gevers et al. (2010) have provided some convincing support for both of these accounts. For example, in their first experiment, Gevers et al. (2010) showed that a SNARC effect can be obtained even when responding is made verbally using the words “Left” and “Right” as responses (demonstrating that verbal-spatial coding alone is sufficient to obtain the SNARC effect). Importantly, such findings are consistent with the presence of a categorical component in the dual-route computational model of the SNARC effect of Gevers et al. (2006). Similarly, Proctor and Cho (2006) have proposed a categorical-based, polarity correspondence account for the SNARC effect. According to their account, the SNARC effect arises simply as a consequence of the fact that both small and left are coded as – polarity and large and right are coded as + polarity. Note that although both the Gevers et al. (2006) and the Proctor and Cho (2006) views both incorporate binary categorical coding of the stimuli and response alternatives, they can be

distinguished by the fact that the former model assumes that SNARC effects arise as a consequence of a natural semantic association between the concepts of small-large and left-right, respectively, whereas the latter view assumes that SNARC effects arise as a consequence of a polarity coding principle that is applied more generally when dealing with any kind of binary attribute dimension.

In the present study, a replication of Gevers et al.'s (2010) first experiment was first undertaken such that one group of participants were required to say the words "Left" and "Right" in response to the odd or even parity of presented single digits (with the mapping of odd and even to the two verbal responses flipped half-way through the session in order to ensure that an index of the SNARC effect could be obtained for each individual participant). Second, another group of participants performed this same task except for the fact that the words "Bad" and "Good" were now used as the verbal responses. Given that it could be assumed that bad should naturally be coded as – polarity and good as + polarity, according to the polarity correspondence view analogous SNARC-like effects (i.e., faster bad responses for smaller numbers and faster good responses for larger numbers) should clearly be predicted to occur for this second group of participants. In addition, the use of both odd and even number stimuli allowed for an examination of the related linguistic markedness association of response codes (MARC) effect (Cho & Proctor, 2007; Nuerk, Iverson, & Willmes, 2004). In general, this effect refers to the presence of an odd-left and even-right stimulus-response advantage (analogous to the small-left and large-right advantage that characterizes the SNARC effect). Finally, as a control condition, all participants also subsequently performed the numerical parity task using counterbalanced left and right manual key presses.

Method

Participants. Forty participants from Carleton University participated for course credit. Seventeen participants were male and 23 female with a mean age of 20.31 years ($SD = 4.07$). Each participant performed the task individually, and each session took approximately 75 min.

Stimuli and Apparatus. The tasks were programmed and ran on a 486 PC using MEL 2.0 (Psychology Software Tools, Pittsburgh, PA). The stimuli were the digits 1, 2, 3, 4, 6, 7, 8 and 9 presented in the centre of the computer screen in white against a black background (4 mm in width and 6 mm in height). In the first part of the experimental session, participants made vocal responses into a microphone that was connected to a PST serial MEL response box, and the experimenter recorded the identity of those responses by pressing horizontally arrayed buttons on that same response box. In the second part of the experimental session, participants made manual responses by pressing either the "z" or "/" keys with their left and right index fingers.

Procedure. On each trial of verbal response task, a single digit was presented on the screen. Twenty of the participants were instructed to provide either a "Left" or "Right" vocal response depending on whether the digit was even or odd. Half of those participants were first instructed to say "Left" for even digits and "Right" for odd digits, but were then asked to reverse these response-digit mappings half-way through the experimental session. The order of usage of these two mapping types was reversed for the other half of those participants. The remaining 20 participants were instructed to provide either a "Bad" or "Good" vocal response depending on whether the digit was even or odd. Half of these participants were first instructed to say "Bad" for even digits and "Good" for odd digits, but were then asked to reverse these response-digit mappings half-way through the experimental session. The order

of usage of these two mapping types was reversed for the other half of these participants. Throughout, whenever the experimenter heard the participants say either “Left” or “Bad” he pressed the first response button on the response box, and whenever he heard the participants say either “Right” or “Good” he pressed the second button. A third button was used whenever the experimenter noticed that the participant had coughed/sneezed or had made either a task-unrelated anticipatory or a task-related but unintelligible vocal response.

Each half of the verbal response task (i.e., with each type of digit-response mapping) began with a block of 16 practice trials followed by three blocks of 64 test trials. The order of presentation of the digits within each block was completely randomized. The stimulus presentation was always terminated as soon as the vocal response was made. The experimenter then manually recorded the response, at which point a plus-sign fixation stimulus appeared for 2500 ms followed by the stimulus for the next trial.

This task was followed by a manual response task that was the same for all 40 participants. The procedure for this task was analogous to that for the verbal response task except for the fact that left and right manual responses were now made by the participants themselves in place of verbal responses keyed. The left-right/even-odd response mappings were reversed halfway through the manual response task (with the order of the mappings used first counterbalanced across all of the participants). Each half of the manual response task (i.e., with each type of digit-response mapping) began with a block of 16 practice trials followed by two blocks of 64 test trials. For both tasks, participants were instructed to emphasize both accuracy and speed and they were given ample opportunities to take breaks between blocks of trials.

Results

Response times (RTs) were determined by the time taken to make the vocal microphone responses or the manual key-press responses. These RT results were analyzed by first computing either the “Right” minus “Left” or the “Good” minus “Bad” RT differences in the mean correct RT data obtained for each individual participant for each digit in the verbal response task, as well as the corresponding right key minus left key RT differences in the mean correct RT data for the manual task (where for each task any RTs more than 3 SDs above a participant’s mean correct RT for each digit were first removed). Next, for each response task separately, the RT differences for each individual were regressed against two orthogonal predictors. The first predictor was numerical magnitude (re-centered around 0) and the second was an index of parity status (effect coded as -1 for odd numbers and 1 for even numbers). Finally, in each of the four conditions defined by verbal response group (“Left” and “Right” or “Bad” and “Good”) and type of response (verbal or manual), the two resulting sets of unstandardized regression coefficients for the numerical magnitude and parity status predictors were then tested to determine whether they differed from 0 using one-sample *t*-tests (Lorch & Myers, 1990). Significant results for each of these tests signal the presence of either SNARC or MARC, respectively. Before performing these analyses, 2 participants were dropped because their overall accuracies in the verbal response task were 48 and 55%, respectively. In the analysis of the manual response task, 2 participants could not be included because they had to leave the session before completing it).

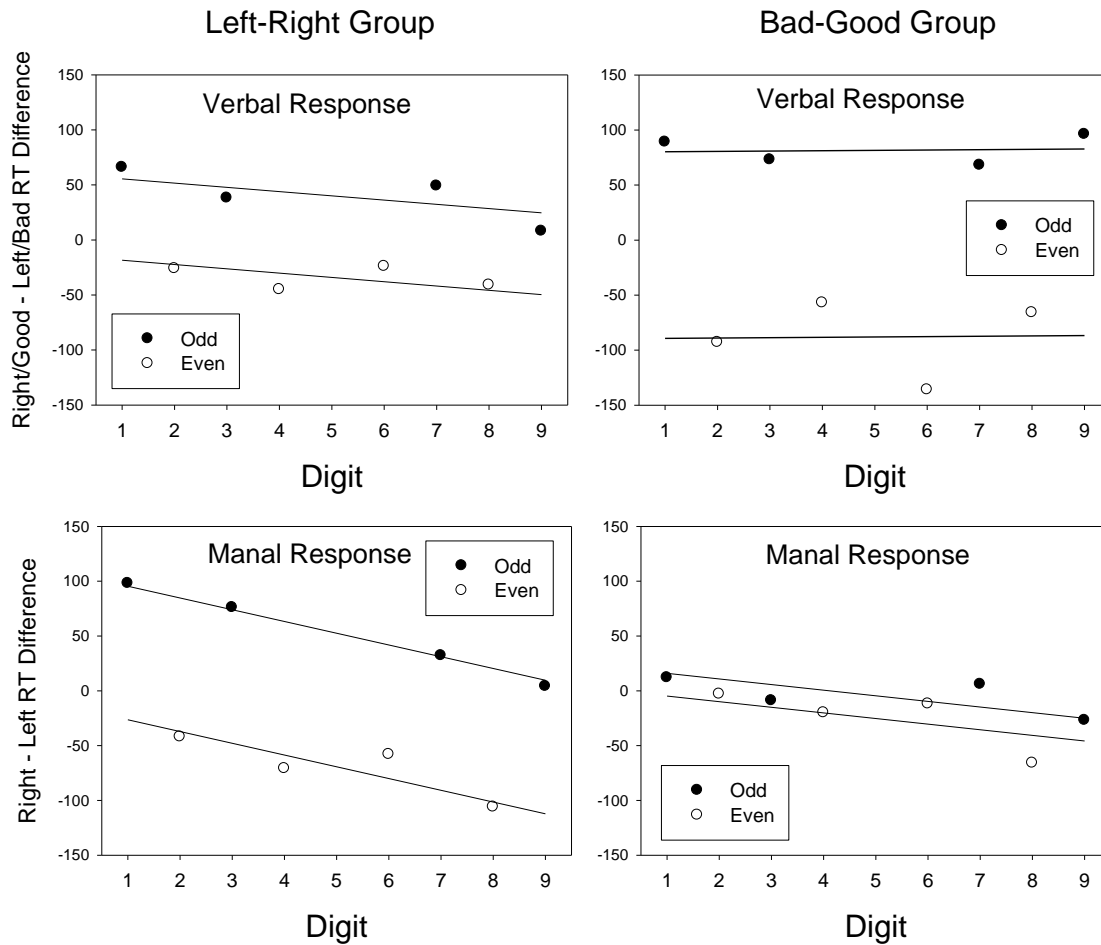


Figure 1. “Right” – “Left” and “Good” – “Bad” RT differences for the verbal response task (top plots) and right – left key RT differences for the manual response task (bottom plots) plotted as a function of number magnitude. Regression lines for the relation between number magnitude and RT difference are given separately for the odd and even numbers.

Verbal Response Task

For the “Left” and “Right” verbal response group, the mean of the individual participant regression coefficients for the numerical magnitude predictor ($M = -3.79$, $SD = 6.86$) differed reliably from zero, $t(18) = -2.41$, $p < .05$, indicating that a SNARC effect in the standard direction was present for this task. Indeed, for 15 of the 19 participants, the slope of the regression line for digit magnitude was negative (indicating that the “Right” minus “Left” RT difference decreases, with “Right” RTs becoming increasing faster in comparison to “Left” RTs, as the digits increased in magnitude). For this same group, the mean of the individual participant regression coefficients for the parity status predictor ($M = -37.72$, $SD = 141.17$) did not differ reliably from zero, $t(18) = -1.17$, $p > .10$, indicating that a significant MARC effect was not present for this task (even though the negative mean value of the regression coefficient for this predictor does indicate that the “Right” minus “Left” RT difference was lower, with “Right” RTs tending to be faster than “Left” RTs, for the even digits).

For the “Bad” and “Good” verbal response group, the mean of the individual participant regression coefficients for the numerical magnitude predictor ($M = 0.34$, $SD = 6.49$) did not differ reliably from zero, $t(18) = 0.22$, $p > .50$, indicating that no SNARC-like effect occurred for this task. For 9 of the 19 participants, the slope of the regression lines for

digit magnitude was negative. For this same group, however, the mean of the individual participant regression coefficients for the parity status predictor ($M = -85.23$, $SD = 109.80$) was now reliably different from zero, $t(18) = -3.39$, $p < .01$, indicating that a significant MARC-like effect (i.e., a tendency for “Good” responses to be faster than “Bad” responses for even numbers and vice versa for odd numbers) was present for this task.

Manual Response Task

For the “Left” and “Right” verbal response group, the mean of the individual participant regression coefficients for the numerical magnitude predictor ($M = -10.767$, $SD = 12.62$) differed reliably from zero, $t(16) = -3.49$, $p < .01$, indicating that a SNARC effect in the standard direction was present for this task. Indeed, for 15 of the 17 participants (note that, as mentioned, two participants were not able to be run on this subsequent manual-response control task), the slope of the regression line for digit magnitude was negative. For this same group, the mean of the individual participant regression coefficients for the parity status predictor ($M = -60.92$, $SD = 94.89$) also differed reliably from zero, $t(16) = -2.65$, $p < .05$, indicating that a significant MARC effect in the expected direction was also present for this task.

For the “Bad” and “Good” verbal response group, the mean of the individual participant regression coefficients for the numerical magnitude predictor ($M = -5.08$, $SD = 18.93$) did not differ reliably from zero, $t(18) = -1.17$, $p > .10$, indicating that a significant SNARC effect did not occur for this task. Even so, for 12 of the 19 participants, the slope of the regression line for digit magnitude was negative. For this same group, the mean of the individual participant regression coefficients for the parity status predictor ($M = -10.31$, $SD = 87.09$) also did not differ reliably from zero, $t(18) = -0.52$, $p > .50$, indicating that a significant MARC effect was not present for this task.

Discussion

The finding of a significant SNARC effect in the verbal response task results for the “Left” and “Right” verbal response group represents a clear replication of Gevers et al.’s (2010) Experiment 1 findings. On the other hand, the fact that an analogous SNARC-like effect did not occur in the verbal response task results for the “Bad” and “Good” verbal response group could be regarded as not being consistent with what would have been expected according to the polarity correspondence view, especially given that a rather large MARC-like effect did occur. That is, according to this account, the presence of a MARC-like effect would indicate that “Bad” and “Good” were indeed being coded as – and + polarity, respectively, in order to account for the correspondence effects that were observed in the responses made to the odd and even numbers (which are assumed to receive – and + polarity codes, respectively, by Proctor & Cho, 2006). If so, then analogous correspondence effects in the responses to the numerically smaller and larger digits (which are also assumed to receive – and + polarity codes, respectively, by Proctor & Cho, 2006) should also have been observed. Hence, the results obtained in the verbal response task for this latter verbal response group are more consistent with the notion that it is conceptual correspondence that is the important factor in determining the presence of such correspondence effects. In other words, these results suggest that although bad and good seem to be conceptually associated with odd and even, they do not seem to be associated with the concepts of small and large.

However, for the group who responded using “Left” and “Right” verbal responses, quite substantial, significant SNARC and MARC effects were now observed when responding manually. Given that the size of these two effects was greatly enhanced over those

obtained when responding verbally, such results suggest that, for our participants at least, visuospatial coding of the response alternatives was indeed more potent than verbal-spatial coding with respect to eliciting such effects. Conversely, for the group who responded using “Bad” and “Good” verbal responses, both the SNARC and MARC effects obtained when responding manually were not significant. With respect to the MARC effect, the decided lack of much of a MARC effect in the manual response task results for this group contrasts markedly with the finding of a large MARC-like effect in their verbal response task results.

With respect to this latter state of affairs, we can only hypothesize that the repeated association of the odd and even numbers with the “Bad” and “Good” verbal responses in the half of the experiment subsequently served to override and wash out the effect of any natural (or saliency-, or markedness-related Cho & Proctor, 2007) correspondence between the visuospatial coding of the left and right manual responses and the coding of the odd and even numbers. Similarly, it could also be hypothesized that the presence of such transfer-based associations could have served to diminish the potential for SNARC effects in this condition by diluting the contributions made by the natural small-left and large-right associations to the manifestation of this effect. Note that the possibility that both visuospatial and (carry-over) verbal response codes were active in the manual response task could also account for the finding of enhanced manual SNARC and MARC effects for the “Left” and “Right” verbal response group because, in that case, the effects of such dual coding on responding would then have been compounded.

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