Probing the mental number line: A between-task analysis of spatial-numerical associations

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Abstract

The mental number line (MNL) hypothesis is that numbers are mentally represented in spatial format, particularly in left-to-right orientation among Westerners. The MNL has received support from various paradigms, but it remains controversial as it is challenged by alternative models. Here we used an individual differences approach to assess spatial-numerical associations (SNAs) across a variety of tasks. The MNL hypothesis predicts correlations across SNA tasks because they should tap a common MNL representation. Control tasks were included to account for effects not specific to SNAs. Correlation analyses revealed significant associations across several SNA tasks, even when controlling for general cognitive abilities or individual differences in response time (RT). These findings provide unique support for the MNL hypothesis, and begin to shed insight on potential explanations that may contribute to variation in the strength of the correlations among SNA tasks.

Keywords: Spatial-numerical associations, SNARC effect, mental number line (MNL), polarity correspondence, working memory, individual differences

Introduction

The associations between space and number have been demonstrated by countless experiments across various contexts (for a recent review, see Fischer & Shaki, 2014). A dominant explanation for these spatial-numerical associations (SNAs) is that numbers are mentally represented in spatial format, also known as a 'mental number line' (MNL, Dehaene, Bossini, & Giraux, 1993). The notion of a MNL, which in Westerners has been shown to orient from left-to-right, implies a systematic, long-term mapping between numbers and space. Zorzi, Priftis, and Umilta (2002) further suggested a functional isomorphism between the MNL and physical lines; that is, a common metric underlying numerical and spatial representations. Moreover, it has also been suggested that there is a common system for deploying attention to both external space and along the MNL (Fischer, Castel, Dodd, & Pratt, 2003).

The existence of a left-to-right MNL is supported by a plethora of findings. In the classic work of Dehaene and colleagues (1993) and related replications (Wood, Willmes, Nuerk, & Fischer, 2008), participants made parity judgments or magnitude comparisons of Arabic numerals by pressing either left or right response keys. They produced faster left responses for small numbers and faster right responses for large numbers. In a variant of the magnitude comparison task, other researchers demonstrated similar left-to-right orientation when participants judged the magnitude of a number presented in either the left or right visual field (LVF/RVF) (Lavidor, Brinksman, & Göbel, 2004), which suggested that the left-small and right-large mappings were not restricted to left/right manual responses but that it might involve a global left-right reference frame that cuts across modalities (e.g., hands, eyes, and so on; Viarouge, Hubbard, & Dehaene, 2014).

Other findings have revealed that numbers bias spatial attention in that individuals are faster at detecting a left target when it is preceded by a centrally presented smaller number and faster at detecting a right target when preceded by a centrally presented larger number (Fischer et al., 2003). Participants also show relatively more leftward bias on a line bisection task (leftward bias being the norm for bisecting plain/physical lines) when lines are made up of smaller numbers compared to larger numbers (Calabria & Rossetti, 2005). Conversely, spatial attention has also been found to affect number processing. For instance, in a random number generation task, participants generate more smaller numbers when their heads are oriented leftward compared to rightward (Loetscher, Schwarz, Schubiger, & Brugger, 2008). Taken together, these effects provide evidence for a relationship between numerical values and spatial attention that is consistent with a left-to-right oriented MNL among Westerners.

Nevertheless, not all researchers agree that the MNL theory provides the best account of these SNAs. Proctor and Cho (2006), for instance, suggested that SNAs in parity and magnitude comparison tasks could be driven by polarity correspondence (i.e., the compatibility between the polarity [+/-] of stimulus and response categories, which facilitates response selection). Although a plausible explanation for classification tasks that involve binary categories, it remains unclear how it would account more generally for SNAs outside the context of binary category classification, such as random number generation or number bisection. Others such as van Dijck and Fias (2011) have argued that SNAs are task-specific associations established within verbal working memory (WM) rather than long-term associations supported by a MNL.

Given the competing hypotheses, the current study was designed to shed insight on the mechanism underlying

SNAs using an individual differences approach. In this study, a large sample of participants were given multiple tasks, each known to elicit SNAs, so that we could assess the between-task correlations. The MNL theory predicts significant correlations, as the different tasks should tap a common representation (MNL). It was less clear what to predict from the verbal WM account, the main alternative here. One possibility is that there would be no significant correlations among these tasks because SNAs are task specific, so different tasks should elicit different patterns of SNAs. Another possibility is that these tasks would recruit the same WM mechanism to create SNAs on-line, such that correlations would be due to individual difference in WM rather than a shared MNL. To directly address this possibility, we measured participants' WM capacity alongside with their SNAs (see Method below).

A strength of the current design was the inclusion of additional control tasks that allowed us to rule out effects due to similar task demands or general cognitive abilities. The control tasks were divided into two groups: 'parallel' and 'general cognitive' tasks. The parallel tasks were included based on their similarity to specific SNA tasks (see Method below). General cognitive tasks assessed a variety of abilities, including working memory (WM), visual processing speed and the acuity of non-symbolic number representations (i.e., the approximate number system [ANS]; see below). This particular collection of tasks afforded us the opportunity of sorting out the relations among SNA tasks using individual differences in performance within and across tasks.

Method

Participants

Results of the current paper are based on 125 Emory undergraduates (76 females) who participated for course credit, though data collection remains ongoing. Participants were mostly right-handed (Edinburgh Handedness Inventory, EHI: *M*= 69.11, range: -100 to 100; Oldfield, 1971). The majority of participants (93.6%) reported native languages that are left-to-right oriented (English: 68.8%; Chinese: 11.2%; Korean; 9.6%). Only one participant reported the reverse orientation (Arabic). Seven participants (5.6%) did not indicate their native language. Experimental procedures were approved by the local ethics committee.

Table 1: List of SNA and Parallel tasks.

SNA tasks	Parallel Tasks
Parity	Simon
Magnitude Comparison	Simon
Lateralized Comparison	-
Numerical Posner	Classic Posner
Number bisection	Line bisection
Random number generation (spatial condition)	Random number generation (baseline condition)
General cognitive tasks**:** Corsi, Verbal WM, Retro-Cued, Visual Search, ANS acuity	

Design

All participants completed a collection of SNA tasks and control tasks (see Table 1 for groupings according to parallel and general cognitive tasks) in a 90-minute session. All tasks were adapted from existing studies. Tasks were arranged in a pseudo-random order with the following constraints: 1) No more than two consecutive SNA tasks; 2) Random number generation was administered either first or last (counterbalanced across participants) because unlike the other tasks, this task required experimenter administration; 3) Tasks that required a chinrest (lateralized comparison, numerical Posner, classic Posner) were blocked and randomized within block. The chinrest block either came before or after the remaining computerized tasks (counterbalanced across participants). Viewing distance for chinrest tasks was 35 cm and for the others was approximately 60 cm. Participants filled out questionnaires related to handedness and language experience after completing the full battery of SNA and control tasks.

Parity and magnitude comparison tasks (adapted from Dehaene et al., 1993). Participants judged parity (odd/even) or compared magnitude to a standard (< or > 5) for numbers between 1 and 9 (5 excluded in the magnitude comparison task) on each trial. Both tasks shared the same task structure: each trial began with a central fixation cross (500 ms, H: 0.3°, W: 0.4°), which was replaced by an Arabic numeral (H: 0.4°, W: ≈ 0.3°) that remained on screen until one of two response keys (P/Q) was pressed (left/ right index fingers, respectively). In the parity task, the keys corresponded to odd/even; in magnitude comparison task, the keys corresponded to < or > 5. Key mapping alternated across four blocks (parity: 9 practice trials, 36 test trials; magnitude comparison: 8 practice trials; 32 test trials) on each task. Block order was counterbalanced across subjects.

Lateralized comparison task (adapted from Lavidor et al., 2004). Participants judged whether stimulus numbers (31 to 79, 55 excluded) were smaller/larger than a standard (55). Each trial started with a blank screen (1000 ms). Then, a central fixation cross was shown for 500 ms, which was followed by lateralized number presentation (100 ms, H: 0.**7**°, W: ≈ 1.1°, 4.2° from center). Participants responded by pressing either the left or right mouse buttons with their dominant hand. Magnitude (< or > 55) and location (left/right) were fully crossed across the 96 test trials.

Numerical Posner and classic Posner tasks. The numerical Posner task is a SNA task adapted from Fischer et al. (2003). The classic Posner task (Posner, 1980) was used as the parallel control task. Both tasks required pressing the spacebar as quickly as possible when a target (black dot, size 1°, 3.1° from center) appearing to the left or right of the central fixation is detected. Preceding the target was either a centrally presented arrow (classic Posner task; arrow pointing left or right; H: 0.7°, W: 2.7°) or a centrally presented Arabic numeral (numerical Posner task; 1, 2, 8, or 9; H: 2.8°, W: ≈ 2°) that lasted 300 ms. The delay between the number/arrow and target (SOA) was either 350, 450 or 600 ms. Each task included 120 trials, among them were 20% catch trials in which the target never appeared. The remaining trials were evenly split between congruent and incongruent trials. In the classic Posner task, congruent trials involved arrows pointing to the target location; in the incongruent trials, the arrow pointed to the opposite direction. In the numerical Posner task, congruent trials were ones in which smaller numbers (1, 2) preceded the left target and larger numbers (8, 9) preceded the right target; this pattern was reversed in the incongruent trials.

Number and line bisection tasks. The number bisection task is a SNA task adapted from Calabria and Rossetti (2005). The line bisection task was used as the parallel control task (Longo & Lourenco, 2006). In both tasks, participants indicated the midpoints of horizontal lines (length: 25.4 or 12.7 cm; thickness: 0.5 cm for number, 0.3 cm for plain lines). In the number bisection task, lines were formed by a repetition of the same number word (“one”, “two”, “three”, “eight”, “nine” or “ten”) or Arabic numerals (1, 2, 3, 8 or 9), whereas standard lines were used in the line bisection task. Each trial started with a central red square; once participants pressed a spacebar, a line appeared either on the left or right side of the computer screen (vertical position randomized). Participants bisected the line with a cursor, which could be adjusted with a mouse. Line length (short/long), location (left/right of the screen) and number (number bisection only) were fully crossed across 44 trials on each task.

Random number generation task (adapted from Loetscher et al., 2008). Participants were asked to generate random numbers ranging from 1 to 30 on pace with a metronome (0.5 Hz) with their eyes closed. In the baseline condition, participants generated 40 numbers facing straight ahead. In the spatial condition, participants rotated their heads in alternation from left to right, generating a number each time they faced left and right (40 numbers on each side). Participants’ scores in the spatial condition contributed data to the set of SNA tasks, whereas the baseline condition was treated as the parallel task.

Simon task. The Simon task (Simon, 1969) was included as the parallel task for parity and magnitude comparison tasks because researchers have suggested that these tasks share structural similarity (e.g., Gevers, Caessens, & Fias, 2005). In the Simon task, participants indicated the color of a square (blue/red) by pressing one of two response keys (P/Q, left and right hand respectively). Each task began with a central fixation cross (500 ms, H: 0.3°, W: 0.4°), which was replaced by a square (size 1°, 500 ms) shown either on the left/right side of the screen (10.7° from center). Color and location of the squares were fully crossed to create 4 practice and 24 test trials in each block. Key mapping (i.e., the mapping between P/Q keys and blue/red colors) alternated between 2 blocks of trials (order counterbalanced across participants).

Corsi task and Verbal WM task. Participants’ visuospatial and verbal WM spans were measured respectively by these two tasks. Stimulus parameters and procedure were the same as those of van Dijck, Gevers, and Fias (2009). The number of trials in both tasks was contingent on participants’ performance, with a minimum number of 3 trials and a maximum number of 18 trials.

Visual search task (adapted from Hermer-Vazquez, Spelke, & Katsnelson, 1999). This task was used as an index of processing speed. On each trial, participants judged whether the letter “L” was present in an array of “T”s by pressing the “Yes” button (onscreen) as quickly as possible if they detected the target or the “No” button if they did not. Corrective feedback was provided after a response. Each trial consisted of 24 letters (≈ 0.4° × 0.4°, rotated in an angle ranging from 0° to 315°), randomly positioned within a display of fixed size (height: 13.5°, width: 18.2°, white background with black border) that was located at the center of the screen. The presence of the target letter “L” was randomized on each trial.

ANS acuity task. Stimulus parameters and procedure followed those of Lourenco, Bonny, Fernandez, and Rao (2012). In summary, participants were asked to judge which of the two rapidly presented arrays was larger. The rapid presentation (200 ms) prevents participants from counting and thus requires that they rely on their approximate number system (ANS) to make their judgments. This task measures the precision of this cognitive system.

Retro-cued task (adapted from Griffin & Nobre, 2003). This task was included as a measure of individual differences in spatial attention. In this task, spatial attention within working memory is manipulated by presenting participants with a location cue after they are instructed to memorize a visual image. In this task, each trial started with a central fixation cross (200 ms, H: 0.3°, W: 0.3°), which was followed by a variable ISI (400-600 ms). Then, an array made up of four crosses (H: 0.7°, W: 0.8°, each) of different colors appeared for 100 ms, which was followed by another variable ISI (1500-2500 ms). Then, a retro-cue, which appeared at the center of the screen (100 ms, H: 0.8°, W: 0.8°), either pointed to one of the four cross locations, or none (neutral cue). Finally, after a variable ISI (500-1000 ms), a probe, which was either a cross from the array, or a novel cross, was shown at the center of the screen. Participants had to decide whether the probe was part of the array shown earlier in the trial and responded with the left or right mouse button. There were 104 trials (50% chance that the probe was presented in the array). Among the “present” trials, 32 were valid trials such that the cue pointed to the correct location. Sixteen trials were invalid such that the cue pointed to a wrong location. Four trials were neutral trials. Among the “probe absent” trials, the cue pointed to one of the corners on 48 trials (a neutral cue was shown on 4 trials).

Results

Preliminary analyses. Data were trimmed in each task for outliers (> 2.5 SDs). Data were also trimmed based on accuracy; more specifically, in each task, participants with accuracy under 60% were dropped from subsequent analyses for the given task. The expected pattern of results (measured at the group level) was observed for most SNA tasks. Significant negative slopes of dRT (dRT = right RT – left RT) were found for both parity and magnitude comparison tasks (i.e., regressing dRT on stimulus numbers, see Fias, Brysbaert, Geypens, & D'Ydewalle, 1996 for details for this measure): parity, M= -5.52, SD= 11.2, $t(111)$= -5.21, p < .001, d = 0.49; magnitude comparison, M= -5.89, SD= 11.06, $t(115)$= -5.73, p < .001, d = 0.53. In the lateralized comparison task, there was the expected significant interaction between magnitude (> or < 55) and side (LVF/RVF), $F(1,111)$= 5.72, p = .018, η_p^2= .05. In the random number generation task (spatial condition), significantly more small numbers (< 16) were generated when participants faced left than when they faced right: $t(124)$= 3.36, p = .001, d = 0.3. These results showed that we replicated the expected effects for these SNA tasks. In contrast, significant effects were not observed in the numerical Posner task (magnitude × side: p = .66; magnitude × side × SOA: p = .92) or number bisection task. In the number bisection task, the main effect of magnitude (small, large) was not significant, $F(1, 121)$= 2.22, p = .14. However, there was a significant interaction between number type (Arabic numerals, number words), line length (short, long) and magnitude, $F(1,121)$= 4.11, p = .045, η_p^2 = .03, which we explore further below.

Analyses of participants' performance on the parallel tasks revealed the expected pattern of effects on all tasks (measured at the group level). Congruent trials were significantly faster than incongruent trials in both the Simon, $t(112)$= -2.8, p = .006, d = .26, and classic Posner, $t(114)$= -3.04, p = .003, d = .28, tasks. Participants showed a significant leftward bias on the line bisection task, $t(120)$= -5.84, p < .001, d = 0.53, consistent with lateralized visuospatial attention. On the baseline condition of the random number generation task, there was significant bias, such that participants generated significantly more small numbers than the chance level (half of the trials), $t(124)$= 9.25, p < .001, d = 0.83, as has been previously found.

Analyses of the general cognitive tasks indicate that participants' performance was within the normal range for most tasks. Corsi task: M= 5.64, SD= 1.03; Verbal WM: M= 5.73, SD= 1.17; visual search, M_{RT}= 3848.95 ms, SD= 1163.03; ANS task, $M_{accuracy}$= 68.32%, SD= 9.1%. The retro-cued task, however, failed to show the typical facilitation effect when the RT of valid trials was compared to that of invalid trials, $M_{\text{difference}}$= -9.48 ms, SD= 111.81 ms, $t(89)$= -.81, p = .42. We therefore excluded the retro-cued task from further analyses.

Correlation analyses. The main analyses were the correlations across the SNA tasks. To allow for these analyses, we computed indices of the strength and direction of individuals' spatial-numerical associations for each task. For parity and magnitude comparison tasks, this is summarized by the slopes of dRT for each participant (Fias, Brysbaert, Geypens, & D'Ydewalle, 1996). The sign of the slope indicates the direction of the SNA (+ slope = right-to-left; - slope = left-to-right); the absolute value of the slope indicates the strength of the SNA. On the lateralized comparison task, the stimulus numbers were split into 6 equal groups (31-38, 39-46, 47-54, 56-63, 64-71, 72-79), with the mean stimulus values and dRTs calculated for each group. Each participant's dRT slope was then computed by regressing dRT on the mean of stimulus values. In the numerical Posner task, we calculated the dRT for small (1,2) and large (8,9) numbers. A negative sign was assigned to the index if the small number group had the higher dRT value and vice versa. The absolute value of the index (which indicates the strength of the SNA) equals the absolute difference between the dRTs of the small and large number groups. (Note that although this task did not show the expected effect at the group level, we included it in these analyses because it was one of the tasks of interest.) In the number bisection task, we first calculated the bisection bias of each line (bias divided by line length, negative value = left bias). Then, we calculated the correlation between the stimulus numbers and its mean bisection bias (positive correlation indicates left-to-right SNA). To equate the sign with those from the other tasks, the index for number bisection was obtained by multiplying the correlation by -1. Because the analyses above revealed a significant type × length × magnitude interaction on this task, we subsequently examined correlations related to this task for each combination of type (Arabic numerals vs. number words) and length (short vs. long). One-sample t-tests revealed that only the short lines made up of Arabic numerals showed a significant correlation between stimulus values and percent bias, M= -0.1, SD= 0.5, $t(120)$= 2.41, p = .02, d = 0.2. We thus only included these trials in subsequent analyses. In the random number generation task, we first counted how many small numbers were generated when participants faced left and right. The index of the strength and direction of the SNAs was obtained by subtracting the left count from the right count.

Using the above indices, we first conducted zero-order correlations among the SNA tasks (see Table 2) to exam the extent to which individual differences across these different tasks overlapped with one another. We followed up on this by partialling out different variables to rule out associations shared with other (parallel or general cognitive) tasks.

Zero-order correlations were significant (all ps < .05, with outliers that were specific to each correlation removed, see Table 2 and Figure 1) across a collection of SNA tasks. These significant correlations are consistent with the view that different SNA tasks tap a common representation, namely the MNL. However, it is possible that these correlations were driven by task specific features that do not pertain specifically to these SNA tasks. To test this, we next partialled out the effects of the parallel tasks. For example, the parallel tasks of the numerical Posner and number bisection tasks were the classic Posner and line bisection tasks, respectively (see Table 1). All partial correlations remained significant (all ps < .05; see Table 2 and Figure 1), suggesting that the overlap among the SNA tasks were not exclusively driven by superficial task similarities.

Another possibility is that the correlations were driven by individual differences in general cognitive abilities rather than SNAs per se. To test this possibility, we partialled out the effects of all general cognitive tasks (i.e., Corsi, verbal WM, visual search and ANS acuity). We were especially interested in effects of WM given its pivotal role in the verbal WM explanation of SNAs. All partial correlations remained significant (all ps < .05), except for the one between numerical Posner and lateralized comparison tasks (Table 2 and Figure 1). This analysis suggests that individual differences in general cognitive abilities cannot fully account for the SNAs observed here.

Table 2: Zero-order and Partial Correlations.

		Controls†			
		Zero	Parallel	Gen Cog	RT
Parity	Mag Comp‡	.25*	.26*	.24*	.25*
	Num Posner	.27*	.21*	.33*	.31*
	Lat Comp‡	.22*	.21*	.23*	.11
	Random Num	-.07	-.15	-.04	-.05
	Num bisection	-.1	-.12	-.09	-.08
Mag Comp	Num Posner	.13	.12	.11	.1
	Lat Comp.	.26*	.27*	.3*	.22*
	Random Num	.14	.09	.14	.16
	Num bisection	.24*	.27*	.29*	.23*
Num Posner	Lat Comp	.2*	.23*	.11	.18
	Random Num	.13	.12	.15	.13
	Num bisection	-.04	-.03	-.05	-.04
Lat Comp	Random Num	.26*	.26*	.32*	.23*
	Num bisection	.27*	.25*	.33*	.28*
Random Num	Num bisection	.03	.05	.04	-

*p < .05; †Controls: Zero = zero order correlations; Parallel: parallel tasks partialled out; Gen Cog: general cognitive tasks partialled out; RT: RT partialled out. ‡Mag Comp = magnitude comparison task; Lat Comp = lateralized comparison task.

Yet another possibility is that the correlations between SNA tasks may be driven by individual differences in RT shared across tasks. Though this issue may be addressed by including a task designed to asses processing speed (visual search), we nevertheless included an additional analysis that partialled out RT from all the correlations (except for number bisection and random number generation tasks, in which RT was not a valid measure for processing speed because participants were not required to respond as quickly as possible). All partial correlations remained significant (all ps < .05) except for two correlations involving the lateralized comparison task (see Table 2 and Figure 1). This analysis suggests that although RT can account for some variance in the associations between particular tasks, it does not fully account for the observed SNAs.

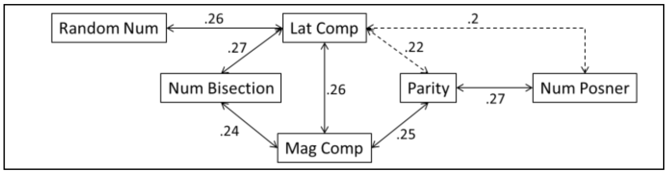

Figure 1: Graphical summary of correlations. Numerical values indicate significant zero-order correlations. Solid lines indicate significant effects across all partial correlation analyses. Dotted lines indicate an insignificant effect in at least one partial correlation.

Discussion

The MNL hypothesis has received support from a variety of paradigms that demonstrate small-left and large-right SNAs in Westerners. However, the extent to which these paradigms tap a common construct remains controversial given one especially viable alternative for SNAs (i.e., verbal WM explanation). The current study addressed this issue by examining individual differences across several SNA tasks. Moreover, we included a collection of control measures that allowed us to account for superficial task similarities, as well as general cognitive abilities, including individual differences in WM capacity.

As summarized in Figure 1, there was a collection of significant correlations among SNA tasks, even when partialling out effects of performance on the parallel tasks, general cognitive tasks, or participants' RTs. It is unclear how task-specific WM effects might explain the shared individual differences across SNA tasks. The WM alternative to the MNL theory (van Dijck & Fias, 2011) suggests that SNAs are constructed on-line when all the stimuli of a task are stored in verbal WM as a task set. According to this proposal, the rank of items in verbal WM is represented spatially, so that earlier ranks are associated with the left and vice versa. Given the important role of verbal WM in this hypothesis, it is reasonable to expect controlling for verbal WM capacity may have had detrimental effects on the correlations among SNAs. This was not the case, however. With only one exception, all the SNA tasks remained significant after verbal WM capacity was partialled out even when controlling for other cognitive abilities.

Another important issue related to this explanation concerns with the type of WM involved in SNAs. Though verbal WM explanation can account for SNA in parity judgment and numerical Posner tasks (van Dijck, Abrahamse, Acar, Ketels, & Fias, 2014; van Dijck & Fias, 2011), it remains unclear how this proposal can account for SNAs in other tasks. Specifically, it has been shown that loading verbal WM can remove the spatial-numerical association in parity judgment but not magnitude comparison tasks (van Dijck et al., 2009), which suggests that the verbal WM account likely does not apply to the magnitude comparison task. Nevertheless, we found a significant correlation between parity judgment and magnitude comparisons, suggesting that verbal WM alone is not responsible for the associations between SNAs in these two tasks.

Other than challenging WM's role as a common mechanism behind SNAs, the current findings also call for a fine-tuning of the MNL theory so as to explain the potential differences in the correlations among SNA tasks. One possibility is that different SNA tasks may be supported by different spatial frames of reference (Viarouge et al., 2014). According to this view, the meanings of 'left' and 'right' are derived from the reference frame that is activated within a specific context. There are at least three types of reference frames that may contribute to SNAs: 1) a global left-right oriented reference frame; 2) reference frames based on body parts, e.g., hand- or head-based frames; and 3) reference frames based on objects. Different spatial reference frames may be activated in different contexts based on factors such as stimulus attributes, or response requirements (e.g., bimanual or unimanual responses). Viarouge and colleagues argued that the parity task is based on a global reference frame, whereas other tasks may be more strongly associated with other references frames. The implication of this is that although the MNL refers to the spatial mapping of number, the spatial reference frames implicated in these representations may be task-specific, which could affect the strength of the correlations across SNA tasks.

In summary, the current study demonstrated significant correlations across SNA tasks, though differences in the strength of these correlations may prove critical for understanding the nature of these effects. An important area for future research will be to tease apart the factors, such as different spatial frames of reference, that may contribute to the MNL.

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