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The Faulty Magnitude Detector: Why SNARC-Like Tasks Cannot Support a Generalized Magnitude System

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Abstract

Do people represent space, time, number, and other conceptual domains using a generalized magnitude system (GMS)? To answer this question, numerous studies have used the spatial-numerical association of response codes (SNARC) task and its variants. Yet, for a combination of reasons, SNARC-like effects cannot provide evidence for a GMS, even in principle. Rather, these effects support a broader theory of how people use space metaphorically to scaffold their understanding of myriad non-spatial domains, whether or not these domains exhibit variation in magnitude.

Keywords: SNARC effect; Space; Metaphor; Generalized magnitude system

What concepts do people spatialize in their minds, and why? To answer this question, hundreds of experiments over the past three decades have used variants of the Spatial Numerical Association of Response Codes (SNARC) task (Dehaene et al., 1993). In a typical SNARC effect, people respond faster to smaller numbers with the left hand and to larger numbers with the right, indexing a left-to-right *mental number line*. Beyond number, SNARC-like tasks have been used to test spatial mappings of many non-spatial domains, including size, brightness, auditory intensity, and even highly abstract domains like emotional intensity (Holmes, Alcat, & Lourenco, 2019; Macnamara, Keage, & Loetscher, 2018). These results have been widely interpreted as evidence of a "generalized magnitude system" (GMS; Walsh, 2003, p. 484).

A GMS is purported to represent "those dimensions that were described as *prothetic* by Stevens (1957), meaning dimensions that can be experienced as *more than* or *less*

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than" (Walsh, 2003, p. 484). In his initial proposal for a GMS, Walsh (2003) suggested that one of the "strong predictions" (p. 487) was that the numerical SNARC effect should generalize to other quantitative domains. Accordingly, SNARC and SNARC-like effects have been highlighted as an especially important source of evidence for the putative GMS (Bueti & Walsh, 2009; Macnamara et al., 2018; Walsh, 2015).

However, as we illustrate here, SNARC and SNARC-like effects cannot be interpreted as evidence for a GMS, for a combination of reasons. First, SNARC-like effects are not limited to prothetic domains. On the contrary, SNARC-like tasks have shown left-to-right mappings of musical pitch (Rusconi et al., 2006), emotional valence (de la Vega et al., 2012), days of the week (Gevers et al., 2004), months of the year, and letters of the alphabet (Gevers et al., 2003). All of these are *metathetic* domains, meaning domains in which people experience qualitative rather than quantitative variation (Stevens, 1957): C-sharp is not "more pitch" than C-natural; positive emotions like happiness do not have "more valence" than negative emotions like misery; Tuesday is not more than Monday; the letter B is not more than A. If SNARC-like effects were the product of a GMS, then they should not be found for metathetic domains.

Despite abundant evidence of SNARC-like effects in metathetic domains, SNARC-like tasks have continued to be used as a "magnitude detector": When significant effects in these tasks are found, researchers infer that the domain being spatialized in subjects' minds is represented by a GMS. According to a review of non-numerical SNARC-like effects, "The similarities in the response properties for the spatial mappings of numerical and non-numerical [including metathetic] domains support the concept of a general higher order magnitude system" (Macnamara et al., 2018, p. 335). This inference, now commonplace in the GMS literature, is exactly backward. The fact that SNARC-like effects are found even when the stimuli being spatialized do not vary in magnitude indicates that the magnitude detector is faulty. Treating SNARC-like tasks as a magnitude detector is like treating one's doorbell as a "pizza detector." It may be true that, when pizza gets delivered, your doorbell rings; but when your doorbell rings, it is not necessarily evidence of a pizza on your doorstep. Likewise, a positive result in a SNARC-like task is not necessarily evidence that magnitudes are being represented.

So, what are SNARC-like tasks detecting, if not magnitude? The answer appears to be: Ordinality. In every domain that has been tested, SNARC-like effects correspond to *ordinal relations* among the stimuli, no matter whether the stimuli are ordered according to prothetic distinctions (e.g., increasing size) or metathetic distinctions (e.g., successive days of the week). SNARC-like effects reflect ordinality even for judgments of stimuli that differ in magnitude. For example, in one study, subjects were asked to memorize a novel sequence of numbers (e.g., 8-2-6-1-7) before making SNARC-like judgments on them (van Dijck & Fias, 2011). Results showed that numbers were spatialized from left to right in subjects' minds according to their ordinal positions in the novel sequence, not their magnitudes.

Given these findings, it is clear that even SNARC-like effects for stimuli that vary in magnitude (including the classic number SNARC) cannot provide evidence for a GMS, because the results are consistent with two hypotheses: People could implicitly spatialize

magnitude, or alternatively, people could spatialize ordinal relations among the stimuli. In the majority of experiments, these two hypotheses have made the same prediction; therefore, the results cannot be interpreted as uniquely supporting either hypothesis. Notably, magnitude could only potentially account for a subset of SNARC-like effects, whereas ordinality can explain all known SNARC-like effects. In the few experiments that have pitted these two hypotheses against each other, the results show a spatial mapping of ordinality (e.g., van Dijk & Fias, 2011; Pitt & Casasanto, 2019).

Finally, even if magnitude *were* being spatialized in some SNARC-like tasks, the results still would not provide any evidence for a GMS. According to GMS theorists, SNARC-like effects support the theory because they reflect interactions between two prothetic domains: whatever domain is being spatialized, and space. Yet, although some aspects of space are prothetic, the aspect of space that is relevant to SNARC-like effects is left-right *position*. According to Stevens and Galanter (1957), position on a line is "one of the clearest examples" of a metathetic continuum (p. 401). If SNARC-like effects index mappings of non-spatial domains onto a metathetic spatial continuum, then they cannot possibly reveal interactions between two prothetic domains, no matter what domain is being spatialized.

In sum, SNARC-like effects cannot be interpreted as evidence for a putative GMS. Rather, they provide support for a broader theory of how people use space metaphorically to scaffold their understanding of myriad non-spatial domains, both prothetic and metathetic (Casasanto & Bottini, 2014; Gattis, 2001; Lakoff & Johnson, 1999).

References

Bueti, D., & Walsh, V. (2009). The parietal cortex and the representation of time, space, number and other magnitudes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1525), 1831–1840.

Casasanto, D., & Bottini, R. (2014). Spatial language and abstract concepts. *Wiley Interdisciplinary Reviews: Cognitive Science*, *5*(2), 139–149.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General*, *122*, 371–396. https://doi.org/10.1037/0096-3445.122.3.371

de la Vega, I., De Filippis, M., Lachmair, M., Dudschig, C., & Kaup, B. (2012). Emotional valence and physical space: Limits of interaction. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(2), 375.

Gattis, M. (Ed.). (2001). *Spatial schemas and abstract thought*. Cambridge, MA: MIT Press.

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition*, *87*(3), B87–B95.

Gevers, W., Reynvoet, B., & Fias, W. (2004). The mental representation of ordinal sequences is spatially organised: Evidence from days of the week. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*, *40*(1), 171–172.

Holmes, K. J., Alcat, C., & Lourenco, S. F. (2019). Is emotional magnitude spatialized? A further investigation *Cognitive Science*, *43*(4), e12727.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh*. New York: Basic Books.

Macnamara, A., Keage, H. A., & Loetscher, T. (2018). Mapping of non-numerical domains on space: A systematic review and meta-analysis. *Experimental Brain Research*, *236*(2), 335–346.

Pitt, B., & Casasanto, D. (2019). The correlations in experience principle: How culture shapes concepts of time and number. *Journal of Experimental Psychology: General*. https://doi.org/10.1037/xge0000696.

Rusconi, E., Kwan, B., Giordano, B. L., Umilta, C., & Butterworth, B. (2006). Spatial representation of pitch height: The SMARC effect. *Cognition*, *99*(2), 113–129.

Stevens, S. S. (1957). On the psychophysical law. *Psychological Review*, *64*(3), 153.

Stevens, S. S., & Galanter, E. H. (1957). Ratio scales and category scales for a dozen perceptual continua. *Journal of Experimental Psychology*, *54*(6), 377.

van Dijck, J. P., & Fias, W. (2011). A working memory account for spatial–numerical associations. *Cognition*, *119*(1), 114–119.

Walsh, V. (2003). A theory of magnitude: Common cortical metrics of time, space and quantity. *Trends in Cognitive Sciences*, *7*(11), 483–488.

Walsh, V. (2015). A theory of magnitude: The parts that sum to number. In R. C. Kadosh & A. Dowker (Eds.), *The Oxford handbook of numerical cognition* (pp. 552–565). New York: Oxford University Press.