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A SNARC in the mind or in the hand? A response to Shaki & Fischer

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In their commentary on our recent review of the origins of spatial-numerical associations (SNAs), Shaki and Fischer (this issue) raise a long-standing debate in the study of the SNARC effect, and for SNAs more generally: the degree to which SNAs reflect purely conceptual processes vs. response related effects (for a recent example, see Basso Moro et al., 2018). Over the past decade, researchers have attempted to control for the influence of response selection on SNAs using a variety of methods. However, in a recent empirical paper, Shaki and Fischer (2018) argue that all previous studies of SNAs that have attempted to isolate conceptual processing of numbers and space have still required some form of explicit spatial processing (either via stimulus or response orientation), even when these studies included only implicit magnitude processing.

Shaki and Fischer (2018) assert that they are the first to have truly succeeded in isolating purely conceptual processing of SNAs, finding evidence of a vertically-oriented—but not horizontally-oriented—conceptual SNA. To do this, they developed a novel go/no-go behavioral paradigm in which participants responded to intermixed numbers and arrows via response rules that were either congruent or incongruent with traditional horizontal and vertical SNAs. Shaki and Fischer argue that this paradigm allows them to identify purely conceptual associations between numbers and space. In the absence of spatially-oriented responses, they do not find horizontal (small-left, large-right) associations, leading them to argue that horizontal SNAs are “merely an artifact of the measurement method”.

While Fischer and Shaki’s paradigm is indeed innovative and the results compelling, we argue that their point should be considered in conjunction with other studies that have also investigated the respective roles of early conceptual processing vs. late-stage response selection as the basis for SNAs. Although we briefly discussed this topic in our original/target article (Toomarian and Hubbard, 2018), we would like to be more thorough in our discussion of this point in light of the recent challenge in the commentary. First, we would like to highlight a study (Nicholls et al., 2008) that was not discussed in either the commentary nor the author’s recent empirical study (Shaki and Fischer, 2018). Nicholls et al. (2008) used a “greyscales” task in which participants made numerical judgements while viewing light-to-dark (dark-right) and dark-to-light (dark-left) greyscale gradients. Lateralized response-related components were eliminated by having participants indicate the

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parity of a target digit by verbally reporting words (red/blue) and then indicating which of two vertically-oriented greyscales was darker by reporting the color of a box surrounding the greyscales (red/blue, counterbalanced between dark-left and dark-right greyscales). Even with stimuli oriented in the orthogonal (i.e. vertical) orientation and in the absence of any spatially-distributed responses, Nicholls et al. still found evidence of a horizontal SNA. This finding suggests that the absence of horizontal SNAs in Shaki and Fischer (2018) cannot simply be due to the elimination of spatially distributed responses and would be an important addition to the authors' argument.

Similarly, a study using transcranial magnetic stimulation has demonstrated a dissociation between response code associations (e.g. SNARC, STARC) and conceptual congruency effects (e.g. number-space, time-space) (Riemer et al., 2016). Specifically, neither time-space nor number-space response code associations were modulated by intraparietal sulcus (IPS) inhibition, whereas congruency effects for both time-space and number-space associations were significantly modulated by IPS inhibition. These findings similarly suggest that SNAs are not simply a result of response selection factors, but instead depend on interactions between representations of space and number housed in the IPS. Furthermore, claims that there is vertical dominance of the SNARC are inconsistent with previous work. For example, when horizontal associations were directly pitted against vertical representations, horizontal associations emerged as the dominant orientation (Holmes and Lourenco, 2012).

Lastly—and perhaps most critically—recent evidence as to whether the SNARC emerges as a result of semantics/stimulus properties or due to response selection suggests that the SNARC varies as a result of both factors (e.g. Basso Moro et al., 2018). Under this view, spatial-numerical associations cannot be considered a unitary phenomenon, but rather are more likely the result of a multitude of influences, including true conceptual associations and more superficial factors such as stimulus orientation and response selection. Basso Moro et al. (2018) further demonstrate that this is not simply a matter of multiple independent influences, but instead reflects complex interactions between these factors. Indeed, these findings suggest that any study that attempts to isolate a single factor as the sole origin of SNAs is likely to lead to misleading results.

In sum, Shaki and Fischer highlight an important and long-standing debate over what we are really measuring when we witness evidence of spatial-numerical associations. Overall, the weight of evidence suggests a kernel of pure conceptual mappings, even when response selection components are eliminated. As there is evidence for both vertical and horizontal mappings, additional studies are needed to both replicate Shaki and Fischer's results and extend them developmentally and cross-culturally. The history of psychology often teaches us that classic dichotomies are more complex than simple "either/or" resolutions; this seems to be the case with the origins of SNAs. The emerging consensus appears to be that both conceptual and contextual factors exert influence on the SNAs we witness across many circumstances. As such, while developmental and cross-cultural studies that follow methods similar to Shaki and Fischer's are an important next step in investigating the nature of SNAs, we should also consider the utility of isolating purely conceptual responses when, in reality,

SNAs will rarely emerge “in the wild” in the absence of any directional information at the response-selection stage.

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