BREAKING RANKS: SPACE AND NUMBER MAY MARCH TO THE BEAT OF A DIFFERENT DRUM

Elena Rusconi[1], Carlo Umiltà[2] and Giovanni Galfano[3]

([1]Institute of Cognitive Neuroscience, University College London, London, UK; [2]Department of General Psychology, University of Padova, Padua, Italy; [3]Department of Developmental and Social Psychology, University of Padua, Padua, Italy)

Abstract

Number processing can evoke spatial representations and cause lateralized attention shifts. The article by Wood et al. suggests interesting considerations about the mental space of numbers by pointing to a difference between physical and numerical space processing. We read Wood et al.'s findings in a perspective that takes into consideration a currently debated issue, that is the relation between Simon and SNARC effects. By pointing to a difference between peripheral onsets and numerical targets, indeed, their finding suggests that the hypothesis of a complete overlap between Simon and SNARC effects is less plausible than a partial overlap hypothesis.

Key words: attention, number line, Simon effect, SNARC effect, space processing, SRC

The fact that Wood et al. (2006, this issue) failed to replicate the Spatial-Numerical Association of Response Codes (SNARC) effect with crossed hands, prompts interesting speculations. Not only because it suggests the involvement of multiple spatial representations in number processing but also because it is relevant – if not conclusive – to a debated issue, that is the relation of the SNARC effect with the Simon effect, which instead manifests itself with crossed hands, as shown by a number of studies (see e.g., review in Umiltà and Nicoletti, 1990). The debate is about whether the two effects are different or rather they are identical and the SNARC effect differs from the Simon effect only because, in the former, stimulus location is imagined (on the mental number line), whereas in the latter stimulus location is perceived. It is clear that the notion of a qualitative difference between the two effects would receive decisive support if it were true that the Simon effect occurs when the effectors are crossed, whereas the SNARC effect occurs on condition that the effectors are uncrossed. Because the debate was not mentioned at all by Wood et al., (2006, this issue) we will summarize it here.

The Simon effect (Simon and Rudell, 1967; Kornblum and Lee, 1995) is characterized by the dependency of response times (RTs) on task-irrelevant spatial correspondence between stimulus and response. In an often used adaptation of the original Simon task, the participant is required to respond to a green light by pressing the left key and to a red light by pressing the right key. Although stimulus location is irrelevant to the task, left responses are faster to the green light on the left than on the right side. Similarly, right responses are faster to the red light on the right than on the left side, *irrespective of the specific effector* (left *vs.* right hand) that is used to press the left or the right key (Nicoletti et al., 1984; Riggio et al., 1986). In most theoretical accounts of the Simon effect (e.g., Umiltà and Nicoletti, 1990), it is assumed that a spatial code is generated for the irrelevant stimulus location attribute, which automatically activates its spatially corresponding response code (e.g., De Jong et al., 1994). On trials in which the automatically activated response code matches that signaled by the relevant stimulus feature, there is no competition at the response selection stage. The presence of two redundant but congruent response codes may be beneficial, speeding up RTs. When the two codes differ, instead, the competition must be resolved before the correct response is executed, which lengthens RTs. Two processing routes (Kornblum and Lee, 1995) are assumed to be active in parallel: the conditional route, by which the task is carried out in accordance with experimental instructions with and the unconditional route, triggered by the dimensional overlap (see Kornblum et al., 1990) between stimuli and responses, by which spatially corresponding responses are always pre-activated, irrespective of experimental instructions. Interesting analogies can be found between the Simon and the SNARC effects: (i) the fact that facilitation or slowing of RTs depends on the relation between a task-irrelevant attribute (position in space or number magnitude) of the stimulus and the response positional attribute (Kornblum and Lee, 1995); (ii) the fact that stimulus and response codes are encoded in spatial or numerical relative terms and thus are contingent to the experimental set (Umiltà and Liotti, 1987; Dehaene et al., 1993); (iii) the fact that the task-irrelevant attribute influencing performance is spatial in nature (physical or representational; Dehaene et al., 1993); and finally (iv) the fact that, with bimanual responses, both the Simon and the SNARC effects correlate with lateralized readiness potentials for the corresponding response hand, which likely represent the output of the non-conditional route (De Jong et al., 1994; Keus et al., 2005).

Whether the SNARC effect is simply an instance of the Simon effect that is produced by positions in representational rather than physical space, or an independent effect, is currently debated. By applying the additive factor method (AFM) (Sternberg, 1969) and on the basis of differences in time course (the Simon effect, indeed, decreases and eventually reverses with increasing RTs, whereas the SNARC effect either remains stable or increases with increasing RTs), Mapelli et al. (2003; see also Tlauka, 2002; Rusconi et al., 2005) argued in favour of the independence between the Simon and SNARC effects. In contrast, Gevers et al. (2005) found a significant interaction (see also Keus and Schwarz, 2005), and correctly pointed out that, because the Simon and SNARC effects are attributable to the competition between two parallel processes triggered by the same stimulus, they violate one of the core assumptions of the AFM, that is stage robustness. Therefore, neither additivity nor interactivity allows one to reach firm conclusions concerning the relation between Simon and SNARC effects. Interestingly, Gevers et al.'s results (2006) confirmed, instead, that there is a difference in time-course between the two effects. More recently, Gevers et al. (2006) have proposed a dual-route computational model of the SNARC effect, which might well be extended to modeling the Simon effect.

We share the view that Simon and SNARC effects are both generated by the same mechanism; that is that they both originate from two competing processing routes, an unconditional route and a conditional route. Also, it is widely accepted that the word-color Stroop effect (in which the word RED is read more quickly when written in red color than in standard black color and even more quickly than in green color; MacLeod, 1991) and the numerical Stroop effect (in which the larger number in a magnitude comparison task is chosen more quickly when written in a larger font than the smaller number, compared to when both numbers appear in the same font, and even more quickly than when the smaller number appears in a large font; Butterworth, 1999) originate from a similar mechanism, in which a task-irrelevant stimulus feature can interfere with or facilitate the processing of a task-relevant stimulus feature. However, we would like to draw the attention to a crucial distinction: that between functional mechanisms and neural circuits, and suggest that analogous cognitive mechanisms may well be instantiated in different neural circuits. For example, whereas it seems quite reasonable to assume that the mechanism of the word-color Stroop effect and the mechanism of the numerical Stroop effect are the same, it seems quite unlikely instead that the codes from which they originate (conflicting colors and color-words vs. conflicting numerical and physical size) are generated and processed by the same cortical circuit (e.g., Dehaene et al., 2003). The critical point here is that two effects (e.g., the Simon and the SNARC effect) can manifest themselves because of a similar mechanism (i.e., competition between the outcome of two processing routes, one conditional and the other unconditional) but nevertheless may depend on different neural circuits.

Once assumed that the general mechanism of the Simon and SNARC effects might be the same, there seem to be three theoretical possibilities for its neural instantiation: a) complete overlap, b) complete dissociation and c) partial overlap. The hypothesis of a complete overlap can rest on arguments pointing to behavioral (spatial stimulus-response compatibility, size effect, distance effect, rightward bias in neglect patients, etc.) and anatomical (the massive involvement of parietal lobes) analogies between space and number magnitude processing (e.g., Walsh, 2003) and on the finding that lateralized readiness potentials can be measured in concomitance with the Simon effect and with the SNARC effect as well (e.g., Keus et al., 2005). Behavioral analogies are less conclusive than anatomical analogies, since they may stem from an identical cognitive mechanism supported by independent neural circuits. The hypothesis of complete dissociation, although theoretically possible, is strongly dependent on the resolution of current neuroimaging techniques. The alternative hypothesis of partial dissociation, instead, has a crucial epistemological advantage: whereas many analogies are not sufficient to make a definitive case for complete overlap, one single, replicable dissociation can be enough to discard the complete overlap hypothesis. For example, Fias et al. (2001) argued that number magnitude processing must share neural circuits with space processing in the dorsal visual pathway, because number magnitude influenced performance (by producing the SNARC effect) only when their participants' main task supposedly rested on dorsal parietal circuits (e.g., an orientation judgment). When their participants were asked to judge the color of a digit, instead, no SNARC effect emerged. Number magnitude was task-irrelevant, exactly like stimulus position is task-irrelevant in a Simon task. However, whereas the Simon effect is consistently found in color discrimination tasks, the