Polarity correspondence does not explain the SNARC effect

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Abstract

Conceptual metaphor congruency effects have been interpreted as evidence for the notion that the representation of abstract conceptual dimensions (e.g., power, evaluation) rests on more concrete dimensions (e.g., space, brightness). However, an alternative account based on the notion of polarity correspondence has recently received empirical support from studies about the mapping between affective evaluation and morality on vertical space. We tested the polarity correspondence account in the domain of number, which shows well-known congruency effects with lateral left-right space (the SNARC effect). Response polarity was manipulated by varying keyboard eccentricity in both parity (odd-even) and quantity (larger-smaller than 5) tasks. Response eccentricity did not modulate the SNARC effect. In a final experiment, the orthogonal Simon effect was modulated by the manipulation of response eccentricity. We conclude that polarity correspondence does not provide an adequate explanation of conceptual congruency effects in the domain of number.

Keywords: conceptual metaphor; polarity correspondence; SNARC; number; space; response eccentricity; orthogonal Simon.

Introduction

Recent years have witnessed a strong interest in the possibility that the mental representation of abstract concepts relies in a deep sense on more concrete concepts (see Landau, Meier, & Keefer, 2010, and Santiago, Román, & Ouellet, 2011, for reviews). Under this view, an abstract concept or conceptual domain imports structure and content from a better understood, more clearly delineated, more concrete conceptual domain. For example, time is understood as physical motion from one location to another (Clark, 1973), and power is linked to physical size (Sorokowski, 2010). Such a view suggests that the mental representation of concepts is hierarchically structured, such that more concrete concepts are more directly linked to perceptual-motor experiences, and these in turn are used to support the understanding of more abstract levels. Therefore, the whole human conceptual structure is anchored to, or founded upon our embodied interaction with the external world, which is why Santiago, Román, and Ouellet (2011) called it the Solid Foundations view.

An important source of evidence for such a view comes from conceptual congruency tasks. In these tasks, a concrete and an abstract dimension are factorially crossed.

Participants' main task requires the processing of the abstract dimension, and the effects of the concrete, task-irrelevant dimension are measured. Typically, both dimensions interact, such that a particular combination of concrete and abstract conditions shows better performance. This metaphorical congruency effect is often interpreted as revealing the use of underlying concrete representations to support the abstract judgment. A well-known example is the Spatial-Numerical Association of Response Codes (SNARC) effect (Dehaene et al., 1993). In a typical SNARC task, the participant has to make a numerical discrimination, such as deciding whether a number is odd or even, by means of key presses. The responding hand (left or right) is the task-irrelevant concrete dimension: in some blocks the "odd" response is given by a left-hand key press and the "even" response by a right-hand key press. In other blocks, the mapping is reversed. The standard result, now widely replicated, consists in better performance when responding to a small number with the left hand and to a large number with the right hand versus using the reverse mapping (see Wood, Willmes, Nuerk, & Fischer, 2008, for a review). The SNARC effect has most often been interpreted as evidence for the use of a spatial left-right line to mentally represent number magnitude.

However, Lakens and coworkers (Lakens, Semin, & Foroni, 2012; Lakens, 2012) have proposed that it may not be necessary to resort to concrete representations of any kind in order to account for many of the published metaphorical congruency effects. Their view rests on purely structural features of dimensional concepts based on the concept of markedness and on the principle of polarity correspondence proposed by Proctor and Cho (2006), which applies when two or more dimensions are simultaneously manipulated in a task. The concept of markedness has a long standing tradition in linguistics (Greenberg, 1963) and psycholinguistics (Clark, 1969). The two poles of most conceptual dimensions (e.g., happiness or tallness) do not seem to enjoy the same representational status. One of them, which we will refer to as the *+pole*, is used to refer to the whole dimension, whereas the other, the *-pole*, is used to refer only to itself (e.g., compare "how tall is John?" versus "how short is John?": the former does not presuppose that John's height is in any specific range, whereas the second question suggests that John is short). The *+pole* is more frequent in language and enjoys a processing advantage compared to the *-pole* (Clark, 1969). Proctor and Cho

(2006) proposed a *polarity correspondence principle* that predicts an extra processing advantage in those conditions where the pole signs match. Thus, a polarity correspondence account of conceptual congruency effects does not require the postulation of concrete mental representations.

One key piece of evidence for Proctor and Cho's argument (2006) relies on how response eccentricity modulates the orthogonal Simon effect. In a typical orthogonal Simon task, participants are presented with a stimulus in one of two vertical locations (e.g., above or below fixation) and are asked to discriminate its location by means of a left or right key press or a leftward or rightward response. The standard result is that the mapping of the upper location with the right response and down with left produces better performance than the up-left down-right mapping (e.g., Proctor & Cho, 2003). Proctor and Cho (2006) proposed that the up-right advantage is due to polarity correspondence, being up and right the *+poles* of the vertical and lateral spatial dimensions, respectively.

Supporting this conclusion, response eccentricity interacts with the up-right advantage. Response eccentricity refers to the lateral displacement of the response set. Placing the response box, keyboard, or joystick to the right of the screen makes the up-right advantage to grow stronger, while it turns into an up-left advantage when the response set is located on left space (Proctor & Cho, 2003). Proctor and coworkers suggested that response eccentricity changes the saliency of the right and left poles of the lateral spatial dimension, effectively turning the left pole into the *+pole* when the responses are placed on left space and thus generating the up-left advantage through polarity correspondence.

These results illustrate an important characteristic of the polarity correspondence account: polarities are not fixed, but can be changed by attentional and saliency factors, which opens the possibility of manipulating them experimentally. Lakens (2012) and Lakens et al. (2012) applied this perspective to conceptual congruency effects between the concrete dimensions of vertical location (up-down) and brightness and the abstract dimensions of power and affective evaluation. They showed that those conceptual congruency effects require the simultaneous presence of the two contrasting poles in the task and that it is possible to change the effect by changing the frequency of use of each pole.

To summarize the argument so far, there seems to be good support for the idea that conceptual congruency effects are of a flexible and contextual nature (Lakens et al., 2012; see also Santiago, Ouellet, Román, & Valenzuela, 2012), thus contradicting their interpretation as indexes of stable semantic memory mappings favoured by the Solid Foundations view. There is also evidence that suggests that polarity differences and cross-dimensional polarity correspondence can account for some conceptual congruency effects without resorting to underlying concrete dimensions, or even to any internal alignment of the relevant dimensions. However, the relevant evidence so far

has concentrated on a small set of conceptual dimensions, namely morality, power and affective evaluation. Can these conclusions be generalized to other abstract dimensions? Such is the question that we seek to answer in the present experimental series.

In order to increase the contrast with already available studies, and therefore the generalizability of our results, we decided to test the abstract dimension of numerical magnitude. In contrast to morality, power and evaluation, which are thought to be associated to vertical space, numbers have been linked to lateral left-right space. Proctor and Cho (2006) explicitly argued that polarity correspondence might explain the standard SNARC effect that obtains in parity tasks. They argued that number processing in parity judgment does reveal markedness effects. Responding "odd" is slower than responding "even", especially in contexts that foster a comparison between odd and even numbers (Hines, 1990). Moreover, responding "odd" with the left hand and "even" with the right hand is faster than vice versa (Nuerk, Iversen, & Willmes, 2004, called it the Markedness Association of Response Codes, or MARC effect). The SNARC effect would arise because large numbers would be *+polar* and small numbers *-polar* and these polarities would match with the *+polar* right response and the *-polar* left response. Therefore, Experiment 1 used a parity judgment task on Arabic numerals.

In contrast to parity tasks, Proctor and Cho (2006) suggested that magnitude comparison tasks (e.g., to say whether the number is smaller or larger than 5) induce a continuous representation and, as a result, neither a SNARC nor MARC effect are observed in them (they cite Ito & Hatta, 2004, Experiment 3, as a relevant case). However, other studies have successfully reported SNARC effects in magnitude judgments, including some which have interpreted their results as support for the polarity correspondence hypothesis (Santens & Gevers, 2008). We believe that, if polarity correspondence effects underlie the SNARC effect in parity judgments, they should be even clearer when the task explicitly asks participants to categorize the stimuli into the two polar opposites "small" and "large". So, we decided to extend our observations to a magnitude judgment task in Experiment 2.

The rationale of the current set of experiments relies on the manipulation of response eccentricity, thereby influencing the polarities of the left or right hand response alternatives. We manipulated response eccentricity in a procedure that closely followed the procedure used by Proctor and Cho (2003, Experiment 1), but instead of presenting stimuli in upper or lower locations, digits were presented in the centre of the screen. Participants discriminated their parity (Experiment 1) or magnitude (Experiment 2) by means of left or right key presses. Response set location was manipulated within-participants by placing the input device left, centre, or right of the computer monitor. If the left-right numerical and/or temporal congruency effects are due, in all or in part, to

polarity correspondence, then changing the polarity of the response dimension should influence the observed reaction time pattern. The polarity correspondence account predicts standard congruency effects when the response set is either central or to the right. Crucially, it predicts a reduced or inverted effect when the response set is located on the left side. Under this condition, the left response would be +*polar* and the right response -*polar*. Therefore, the polarity correspondence principle should induce an advantage for up-left and down-right mappings. To preview the results, response eccentricity failed to interact with the SNARC effect in any task. We concluded this series of experiments by showing that it is possible to replicate the interaction between response eccentricity and the orthogonal Simon effect when upper and lower stimuli are used instead of numbers (Experiment 3).

Experiment 1

Experiment 1 used centrally presented single digits from 1 to 9 (with the exception of 5) in a parity judgment task. Responses were left and right key presses in a keyboard which could be located at either the left, centre, or right of the screen.

Method

Participants Twenty Psychology students (17 women, all right-handed, age range 18-39 y.) from the University of Granada volunteered to participate, and received course credit in return.

Materials and Procedure The single digits 1 to 4 and 6 to 9 were centrally presented on a computer screen. A single digit was presented in each trial, and the participant's task was to decide whether the digit was odd or even. The participant responded by pressing the keys F (left) or J (right) on a standard computer keyboard. Each trial consisted of a central fixation cross (1000 ms) followed by the target digit (until response). Incorrect trials were followed by the word "Incorrecto" for 500 ms in red font, also at the same location. Each was followed by a 1000 ms blank screen. Experimental trials were divided into six blocks of 54 trials. All digits were presented once every eight trials. The mapping of responses (odd-even) to keys (left-right) was kept constant during three blocks, and then reversed in the following three blocks. The order of presentation of the two mappings was counterbalanced over participants. Keyboard location was varied within-participants. In the left and right locations, the keyboard was moved 30 cm to each side (as in Proctor & Cho, 2003). Half the participants experienced the three locations in the order left, centre, and right, and the other half in the reversed order. The sequence of keyboard locations was repeated twice over the six blocks.

Design and Analysis Data were analyzed using a factorial ANOVA with the following factors and levels:

Parity (odd-even) X Magnitude (smaller-larger than 5) X Response (left-right) X Keyboard location (left-centre-right). Counterbalance group was also included as a factor in the design in order to exclude noise due to order of conditions, but because its effect and interactions are theoretically uninteresting, they will not be reported below (but note that the inclusion of this factor in the analyses leads to a reduction in the degrees of freedom of the error). Markedness effects would be evident in the main effects of Parity (with faster responses to even than odd numbers) and Magnitude (with faster responses to larger than smaller numbers). A main effect of Response (with faster responses with the right than left hand) could also be interpreted as a markedness effect, although it could just be due to greater perceptuo-motor fluency of the preferred hand. Potential polarity correspondence effects would consist in significant interactions between Parity and Response (MARC effect) and Magnitude and Response (SNARC effect). Three-way interactions of either the MARC and/or the SNARC effects with Keyboard location would support the conclusion that polarity correspondence is indeed their underlying cause.

Results

Errors occurred in 280 trials (4.32%). Latencies in correct trials were trimmed by means of fixed cut-off points, set at 300 and 1300 ms after inspection of the RT distribution, which led to the rejection of 100 trials (1.54%) as outliers. Average latency and accuracy were analyzed independently.

The analysis of latency showed a very clear pattern. There were main effects of Parity ($F(1,16)=13.52$, $p<.01$) and Response ($F(1,16)=9.30$, $p<.01$), both in the direction predicted by a markedness effect (faster latencies for even and right-handed responses). There was a clear interaction between Magnitude and Response ($F(1,16)=8.12$, $p=.01$), which took the standard form of the SNARC effect. No other effect had a probability level smaller than 0.10. In particular, the interaction between Parity and Response (the MARC effect) and any second order interactions between either the SNARC and the MARC effects with Keyboard location were far from significance (all Fs < 1). Figure 1 (upper panel) shows the main results. These results were not qualified by the analysis of accuracy.

Discussion

Experiment 1 showed that keyboard location did not modulate the SNARC effect, what contradicts the predictions from a polarity correspondence account. The data also showed main effects of parity and response side such that the +*pole* (even and right) was easier to process. However, there were no interactions between these dimensions and keyboard location. Moreover, there was neither an interaction between parity and response side

(MARC effect) nor a modulation of this interaction at different keyboard locations.

SNARC Parity

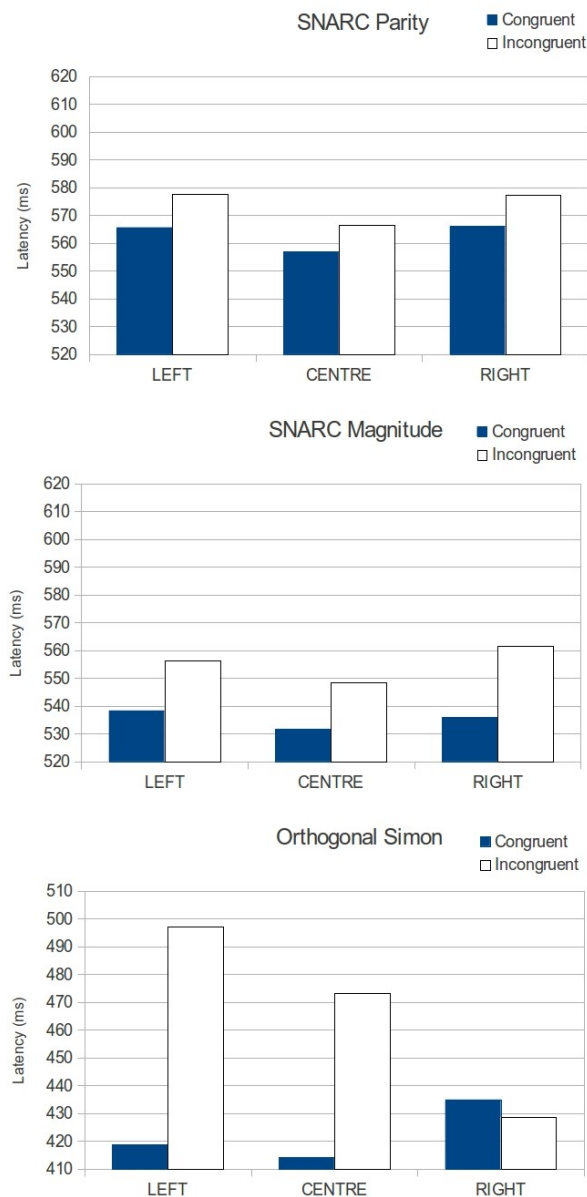

SNARC Magnitude

Orthogonal Simon

Figure 1: Average latencies (in ms) in the congruent vs. incongruent conditions in Experiment 1 (SNARC, parity task), Experiment 2 (SNARC, magnitude task), and Experiment 3 (orthogonal Simon task). Congruency in the SNARC experiments is defined with respect to numerical magnitude (smaller or larger than 5) and response (left or right), assuming a standard SNARC effect (smaller-left, larger-right). Congruency in the orthogonal Simon experiment is defined with respect to vertical location (up or down) and response (left or right), assuming a standard orthogonal Simon effect (up-right, down-left).

Thus, the full pattern of results shows no support for a polarity correspondence account. Experiment 2 extended these results to a magnitude judgement task.

Experiment 2

Experiment 2 was an exact replication of the Experiment 1 with a single difference: participants judged whether the central digit was smaller or larger than 5.

Method

Participants Twenty new participants (17 women, 1 left-hander, age range 18-39 y.) from the same population took part in the study and received credit course in return.

Materials and Procedure Everything was kept identical to Experiment 1 with the main exception of the task: participants judged whether the digit was smaller or larger than 5. Additionally, there were 56 trials in each block (exactly 7 presentations of each digit).

Design and Analysis Data were analyzed using a factorial ANOVA comprising Parity (odd-even) X Magnitude (smaller-larger than 5) X Response (left-right) X Keyboard location (left-centre-right) X Counterbalance group (not reported).

Results

There were errors in 216 trials (3.32%). Latencies of correct trials were trimmed by fixed cut-off points (300 and 1300 ms): 120 trials (1.78%) were rejected as outliers.

The analysis of latencies once again rendered a clear pattern. Only the main effect of Parity was significant ($F(1,16)=20.34$, $p<.001$), with faster responses to even numbers. Out of all possible two-way interactions, only Magnitude by Response was significant ($F(1,16)=6.55$, $p=.02$), taking the shape of a standard SNARC effect. These were the only findings that reached standard reliability levels. Keyboard location did not modulate the SNARC effect at all. Figure 1 (middle panel) shows the main results.

The accuracy measure showed a clear effect of Parity ($F(1,16)=10.15$, $p<.01$) which went in an unexpected direction: even numbers had more errors than odd numbers. However, an inspection of accuracy means for each number indicated that this is due to a distance effect that concentrates on the two numbers that surround 5 (4 and 6), which are both even. Because this reduced accuracy was associated to faster latencies, it may be revealing a speed-accuracy trade-off. There was also a significant interaction between Parity and Response ($F(1,16)=7.32$, $p=.02$), which was in the direction expected for a MARC effect: greater accuracy for the even-right and odd-left mapping. No other effect added to or qualified the findings from the latency analysis.

Discussion

Experiment 2 found a clear SNARC effect. In contrast to the prior experiment, there was also a MARC effect on accuracy. None of those potential polarity correspondence effects where modulated by the location of the keyboard. There was also a main effect of parity, both in latency and accuracy, but its interpretation is complicated because it went in opposite directions (even numbers were both faster and less accurate), what may suggest a speed-accuracy trade-off.

Summing up, Experiments 1 and 2 found SNARC effects which did not show any trace of being modulated by keyboard location. Other significant main effects and interactions also failed to provide clear indications of being related to markedness or polarity correspondence. Before turning to discuss the general implications of the present results, a final possibility must be discarded: that eccentricity effects on orthogonal Simon tasks cannot be replicated. Thus, our final experiment used a procedure that mirrored Proctor and Cho (2003, Experiment 1).

Experiment 3

Experiment 3 was an exact replication of our two first experiments with the single difference that the stimulus was a rectangle made of asterisks (as in Proctor & Cho, 2003, Experiment 1), which could be presented either above or below fixation. Participants' task was just to discriminate its location by pressing the right or left key.

Method

Participants Participants were 18 Psychology students from the University of Granada (all female, 2 left-handers, age range 18-30 y.), who received course credit for their participation.

Materials and Procedure The target stimulus was an array of 3x3 asterisks that looked like a rectangle. The target was presented horizontally centred midway between fixation and either the upper or lower border of the screen. Participant's task was to judge whether the target appeared above or below fixation.

Design and Analysis The design included Vertical location (up-down) X Response (left-right) X Keyboard location (left-centre-right) X Counterbalance group (not reported).

Results

There were errors in 137 trials (2.26%). Cut-off points were set at 250 and 1250 ms, which led to the rejection of 119 (1.85%) outliers.

The analysis of latency revealed an interaction between Vertical location and Response ($F(1,14)=11.05$, $p<.01$). Unexpectedly, this interaction took the form of an up-left advantage (possible causes are discussed below). However, the crucial aspect of the data is that such interaction was strongly modulated by Keyboard location ($F(2,28)=25.73$,

$p<.001$; see Figure 1, lower panel). The up-left advantage was present when the keyboard was located on the left and on the centre, and turned into a slight up-right advantage when the keyboard was moved to the right. Other significant findings of less theoretical importance were the interaction between Vertical location and Keyboard location ($F(2,28)=5.56$, $p<.01$) and the main effect of Keyboard location ($F(2,28)=6.81$, $p<.01$) due to slower latencies with the keyboard on the left. Accuracy data supported the findings of the latency measure.

Discussion

Experiment 3 allows very clear conclusions: an up-left advantage was observed both in latency and accuracy when the keyboard was placed at midline and on the left, and this turned into a small up-right advantage when the keyboard was placed to the right of the computer monitor. Proctor and Cho (2003) found an up-left advantage with the keyboard on the left, a very small up-right advantage with keyboard on the centre, and an up-right advantage with the keyboard on the right side. Therefore, we take the present results to constitute a successful replication of their findings (as well as those by Cho, Proctor, & Yamaguchi, 2008): keyboard eccentricity affects the saliency of the side of space where the keyboard lies, and the most salient side of the left-right dimension attracts the mapping of the *+pole* of the vertical dimension (up).

The main contrast between present results and those reported by Proctor and Cho (2003) and others is the finding of an up-left (instead of up-right) advantage when the response set is placed at midline. As a post-hoc speculation, we think that the cause may be related to the spatial arrangement of the experimental equipment with respect to the whole room. The computer and keyboard were located on a corner of the lab, with a window to the right of the participant, and the room extending to the left. This may have made the participant to conceptualize the equipment as being located to the left of the wall. Both Weeks, Proctor, and Beyak (1995) and Proctor and Cho (2003) have shown that environmental factors can increase the saliency of either left or right space: placing an unused response apparatus to the right of the response keyboard was enough to turn the up-right advantage into a (very small) up-left advantage. A similar phenomenon may have occurred in the present experiment with the highly salient window located on the right side of the participant. Alternatively, the wall on the right may have provided a clear boundary to lateral space, which may have made the unbounded left space *+polar*, conforming existing explanations for the asymmetry in vertical space (Clark, 1973; Tversky, Kugelmass, & Winter, 1991).

General Discussion

The present experiment series clearly showed that the SNARC effect, both in parity and magnitude judgements, is not modulated by response eccentricity. This occurred in the context of a successful modulation of the orthogonal Simon

effect by our manipulation of response eccentricity. Proctor and coworkers (Cho et al., 2008; Proctor & Cho, 2003, 2006; Weeks et al., 1995) accounted for eccentricity effects in the orthogonal Simon task as a consequence of a change in polarity in the spatial left-right dimension: Placing the response set on one side increases the saliency of that side, turning it effectively into the +*pole*. Then, that side now matches the +*pole* of the vertical dimension (up). If this interpretation is correct, and the SNARC effect is due to polarity correspondence between larger numbers and right responses, placing the response set on the left should reverse the SNARC. However, we found no traces of any influence of response eccentricity on the SNARC effect. This complete absence of eccentricity effects suggests that polarity correspondence is not affecting this particular congruency effect whatsoever, not even as an additional source of influence that acts together with other factors on number tasks. Many questions remain. As a first step, current work in our labs is focusing on extending present results to a different conceptual dimension which is also known to generate congruency effects with left-right space: the dimension of time.

Acknowledgements

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