PARITY AND MAGNITUDE IN NUMERICAL COMPARISONS:
A DIRECT CONTRAST

Daniel Fitousi and Daniel Algom
Tel-Aviv University
dannyfit@post.tau.ac.il, algomd@freud.tau.ac.il

ABSTRACT

The theoretical status of two attributes of number differs in the literature: Numerical magnitude is considered to be automatic and obligatory, parity is considered to be controlled and demanding attention. The difference serves to explain a novel powerful effect in numerical perception associating side of responding with number magnitude. In this study, we pitted judgments of magnitude against judgments of parity in the Garner paradigm, challenging the alleged automaticty of numerical magnitude. We offer an alternative explanation of the effect.

In the parity judgment task, people decide, while timed, whether a digit is odd or even. In a typical manual version of the task, the participant holds two lateralized response keys, one in the left hand (for, say, even numbers) and the other in the right hand (for odd numbers). Presented with a centrally located digit, the participant indicates parity status by pressing one of the two keys. Using this setup, Dehaene, Bossini, and Giraux (1993) discovered an association between the side of the response and numerical magnitude. For small numbers, people pressed the left-hand key faster than the right-hand key; for large numbers, they pressed the right-hand key faster than the left-hand key. Responses to digits 0 and 1 were approximately 30 ms faster with the left than with the right hand and responses to the digits 8 and 9 were roughly 30 ms faster with the right than with the left hand. With many a participant, the right hand is always faster than the left hand. Nevertheless, the noted association does appear: The larger the number, the larger the right hand advantage in speed. Echoing Lewis Carroll's poem, "The Hunting of the Snark," Dehaene (1997) called this effect the SNARC effect, acronym for Spatial-Numerical Association of Response Codes. The SNARC Effect has been firmly established in the numerical perception literature (Fias, 2001; Fischer, 2003). The effect has also played an important theoretical role, supporting the automatic activation of numerical magnitude. In this study, we challenge that traditional account by directly comparing magnitude and parity judgments.

By traditional theorizing, magnitude information is processed in an obligatory fashion in all instances of numerical perception. People must recover the respective magnitudes in each and every case of performing tasks with numerals even when the task at hand does not require magnitude processing or when such processing actually harms performance. Strong evidence for this view comes from numerical variants of the Stroop task in which people respond to the *physical* size of numerals (a nonsemantic attribute) while attempting to ignore their numerical magnitude (e.g., Algom, Dekel & Pansky, 1996). In these tasks, irrelevant numerical magnitude intrudes often on judgments of physical size, tapping the automatic activation of magnitude (but see, Pansky & Algom, 1999, 2002). The behavioral association of small numbers with the left side of space and large numbers with the right side of space (the SNARC effect) has also been taken to support the automatic activation of magnitude information. Note that magnitude information per se is not needed to perform the parity decision task. From a logical point of view, parity is not related to magnitude or to space. Nevertheless, the presence of the SNARC effect suggests that magnitude *was* retrieved by the participant to affect her or his performance.

The SNARC effect is obtained with overt judgments other than that of magnitude, yet it is precisely magnitude that is associated with side of space. Therefore, the case for automatic association between numbers and space seems strong. The assumption has been repeatedly stated in the literature, leading to the introduction of the powerful metaphor of "the number line." On that "line," the numbers are oriented in space, small numbers to the left and large numbers extending toward the right. The SNARC effect shows that the "reflex" of magnitude activation (upon viewing an Arabic numeral) is also "accompanied by an automatic orientation of numbers in space" (Dehaene, 1997, pp. 81-82). The SNARC effect thus strongly augments the case for automatic processing of magnitude information.

Pitting parity and magnitude judgments against one another can provide decisive evidence supporting (or rejecting) this interpretation of the SNARC effect. The traditional prediction is that of an asymmetric pattern of interference. Magnitude is expected to intrude on judgments of parity, but parity is not expected to interfere with judgments of magnitude. Considering such an experiment, it must be realized that parity and magnitude do not comprise Stroop dimensions. There exists no conflict (or agreement) between values of these dimensions. The correlation between magnitude and parity of numbers is zero. Pairs of parity and magnitude values do not create congruent and incongruent combinations. As a result, one cannot perform a Stroop experiment entailing these two attributes of number. To bypass the difficulty, Sudevan and Taylor (1987) created a response conflict between parity and magnitude judgments by assigning the same two response keys to parity (odd, even) and magnitude (small, large) decisions. Parity and magnitude judgments alternated randomly from trial-to-trial depending on a cue presented at the start of each trial. Sudevan and Taylor found that magnitude responses affected parity responses but not vice versa. This study is suggestive, but not truly decisive. As we just recounted, no true conflict exists between parity and magnitude. The artificial response conflict introduced by Sudevan and Taylor is vulnerable to many biases including those of hand and laterality. In this study, we pitted parity and magnitude against one another in an authentic fashion by applying Garner's (1974) speeded classification paradigm.

In the Garner paradigm, a single numeral is presented on a trial. The participant's task is to classify it on the relevant dimension (say, parity) ignoring its value on an irrelevant dimension (magnitude).

Performance is tested in two separate blocks of trials. In the *baseline* condition, values on the irrelevant dimension are held constant (e.g., magnitude is small on all of the trials) and the numerals change from trial-to-trial only on parity. In the *filtering* condition, the participant again responds to parity but the numerals change from trial-to-trial on the irrelevant dimension of magnitude, too. If performance is on a par in the baseline and the filtering conditions then selective attention to the target attribute of parity is perfect. The comparable performance means that the participant was not affected by the presence of irrelevant variation (in the filtering task). If performance in the filtering condition is worse than that in the baseline condition then selective attention to parity has failed. The difference means that the participant could not ignore irrelevant variation in magnitude and that this variation took a toll on his performance with parity. The difference in performance between the baseline and the filtering conditions is called Garner Interference. Dimensions that do not yield Garner interference are called *separable dimensions*. Selective attention is good with separable dimensions. Those dimensions that yield appreciable amounts of Garner interference are called *integral dimensions*. With integral dimensions, the cross-talk in processing makes selective attention to any one stimulus attribute impossible.

Given a pair of dimensions, they can be separable when processing one dimension, integral when processing the other. Precisely such an asymmetry is predicted for the numerical dimensions of parity and magnitude. The traditional view holds that judgments of parity suffer Garner interference from irrelevant magnitude, but that judgments of magnitude are immune of intrusions from irrelevant parity. To evaluate these predictions, we tested both parity and magnitude in turn as target dimensions in the present investigation. In a separate session with the same participants, we also tested the SNARC effect using parity judgments with lateralized manual responses. Sixteen Tel-Aviv University undergraduates, all native speakers of English participated.

To recap, the participants performed in the Garnerian tasks of baseline and filtering twice, once judging parity and once judging magnitude (deciding whether the single digit presented was smaller or larger than 5). Response mode was manual with key assignment counterbalanced across target dimensions and participants. The participants also performed in a separate task judging parity for the digits between 0 and 9. This task replicated the standard task used in the literature to produce the SNARC effect.

Let us first consider the standard parity judgment task. In Figure 1 we plotted the difference in reaction time (RT) between the right and the left hand against the digits presented. The negative slope of the regression line depicts an appreciable SNARC effect. The RT advantage of the right hand responses over the left hand responses grows noticeably larger as one moves from small toward larger digits. Therefore, our group of participants demonstrated the classic form of the SNARC effect in the standard manual parity judgment task.

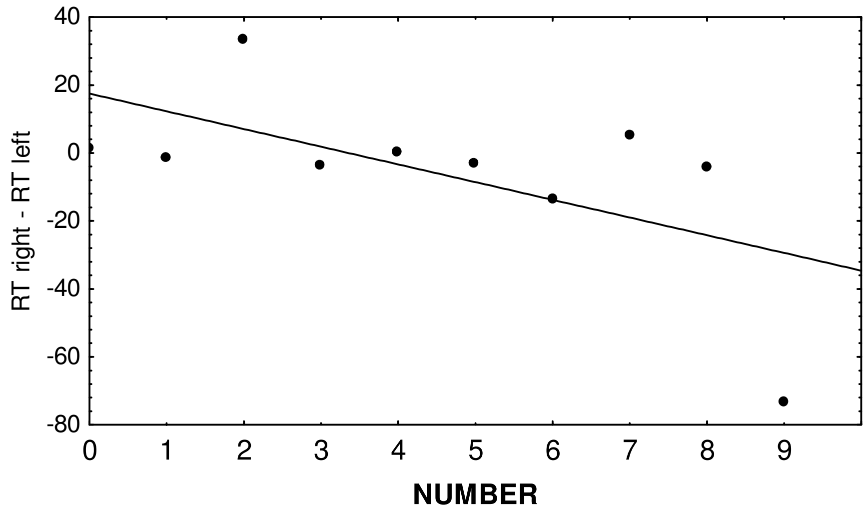

Figure 1: The Difference, RT (Right Hand) – RT (Left Hand), plotted against number. The negative slope of the regression line demonstrates the presence of the SNARC effect in the data.

The outcome of the Garner experiment composes the main result of the present study. Consider first the judgments of magnitude. Magnitude (smaller or larger than 5) was judged in two conditions, with (filtering) or without (baseline) concurrent variation in parity. As the pair of left-hand columns in Figure 2 shows, the judgments did not differ across the two conditions. Our participants decided magnitude with parity varying from trial-to-trial as fast as they did with parity held constant throughout the sequence of trials. Therefore, selective attention to magnitude was good, a result consistent with similar findings in the literature.

Next consider the judgments of parity depicted by the pair right-hand columns in Figure 2. Clearly, response latencies were approximately the same in the baseline and the filtering conditions. Our participants decided parity with magnitude varying concurrently in a random fashion (filtering) as fast as they did when magnitude was held constant (all numbers smaller than 5 or all numbers larger than 5; baseline). Irrelevant variation in magnitude did not affect the judgments of parity. Our participants ignored magnitude successfully when they judged parity. Therefore, selective attention to parity was good, indeed as good as that to magnitude.

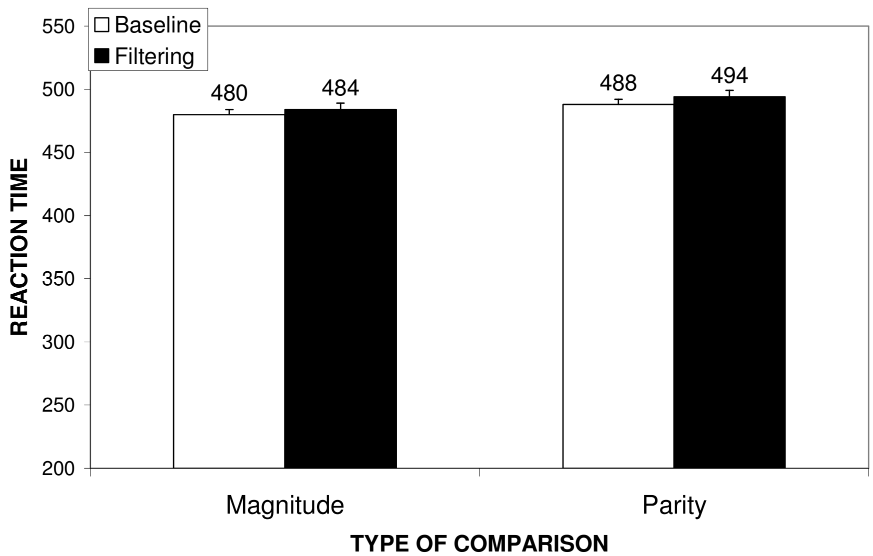

Figure 2: Outcome of the Garner paradigm. Mean RTs in baseline and filtering conditions for judgments of magnitude (left) and parity (right). The comparable RTs across baseline and filtering show that Garner interference was absent in both types of judgments.

Conclusion

The present results show that parity and magnitude are separable dimensions. Parity did not interfere with judgments of magnitude. Notably, judgments of parity, too, were free of intrusions from magnitude. This latter result cast doubt on the alleged automaticity of numerical magnitude and, consequently, on the validity of the traditional interpretation of the SNARC effect. The symmetrical pattern of results (i.e., the mutual lack of interference) shows that values of magnitude were not called up in an automatic fashion when the participants responded to parity. Magnitude was neither more nor less automatic than parity. Because these dimensions were separable selective attention to either one was good.

Whence the SNARC effect? Given the present results, its traditional interpretation in terms of automatic activation of magnitude is untenable. The traditional interpretation holds that the association of side of space with speed of parity judgments occurs because number magnitude was ineluctably activated. In contrast with this account, our participants demonstrated the SNARC effect (Figure 1) in tandem with the absence of automatic activation of magnitude (Figure 2). Again, whence the SNARC effect?

Based on the present results, we suggest that the SNARC effect is the result of an extremely overlearned stimulus-response mapping. Our rulers, computer keyboards, and houses (to cite very few examples of a ubiquitous physical Gestalt) are all organized by a left-right structure with small numbers appearing on the left side of space and large numbers extending toward the right side of space. Long-term experience has taught people to reach to the left for the numbers 1-4, but to reach to the right for other numbers. This specific stimulus-response habit is highly overlearned. However, the habit is one associating specific stimuli and specific responses, not numerical magnitude and those responses. Viewing digital watches, people respond to the numbers 1-3 faster with their right hand than with their left hand and they respond to the numbers 7-9 faster with their left hand than with their right hand (Bachtold, Baumuller, & Brugger, 1998). Enjoying their dinner, people reach faster for the knife with the right than with the left hand, but the reverse holds when the fork is needed. The SNARC effect is yet another example of such highly exercised habits. It does not demonstrate the automatic activation of numerical magnitude, and pertinent theory should be rectified accordingly.

References

Algom, D., Dekel, A., & Pansky, A. (1996). The perception of number from the separability of the stimulus: the Stroop effect revisited. *Memory & Cognition*, 24, 557-572.

Bachtold, D., Baumuller, M., & Brugger, P. (1998). Stimulus-response compatibility in representational space. *Neuropsychologia*, *36*, 731-735.

Carroll, L., (1891). *The hunting of the snurk, an agony in eight fits*. New York: Macmillan.

Dehaene, S., (1997). *The number sense*. New York: Oxford University Press.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and numerical magnitude. *Journal of Experimental Psychology: General*, 122, 371-396.

Fias,W., (2001). Two routes for the processing of verbal numbers: Evidence from the SNARC effect. *Psychological Research, 65*, 250-259.

Fischer, M. H., (2003). Cognitive representation of negative numbers. *Psychological Science*, *14, 278-282.*

Garner, W. R., (1974). *The processing of information and structure*. Hillsdale, NJ: Erlbaum.

Pansky, A., & Algom, D. (1999). Stroop and Garner effects in comparative judgments of numerals: the role of attention. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 39-58.

Pansky, A., & Algom, D. (2002). Comparative judgment of numerosity and numerical magnitude: Attention preempts automaticity. *Journal of Experimental Psychology: Learning Memory and Cognition, 28*, 259-274.

Sudevan, P., & Taylor, D., (1987). The cuing and priming of cognitive operations. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 89-103.