Short Report

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Unconscious Processing of an Abstract Concept

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At any single moment, people are bombarded with arrays of information, some entering conscious awareness (supraliminal), fueling a rich phenomenal experience of the environment, and some hidden from awareness (subliminal), unavailable for report. This observation raises fundamental questions regarding the function of consciousness. Accumulating evidence shows that processing of certain visual features and objects does not require consciousness (Kouider & Dehaene, 2007; Lin & He, 2009), but processing of abstract concepts seems to depend on conscious evaluation (Baumeister & Masicampo, 2010; Baumeister, Masicampo, & Vohs, 2011). In the experiments reported here, we found novel evidence of unconscious processing of the abstract concept of the same-different relation.

Consider two distinct items, A and B, and the pairs formed from them, AA, BB, AB, and BA. The items in the first two pairs belong to the category of sameness and the items in the last two pairs to differentness. This same-different concept holds at an abstract level; that is, the concept is derived from specific instances (such as the four pairs just given) and can be applied to novel ones (CC, CD, etc.). The ability to reason about abstract sameness and differentness has long been thought to be the "keel and backbone" of human thinking and reasoning (James, 1890, p. 459). Some researchers suggest that it may be a uniquely human ability (Penn, Holyoak, & Povinelli, 2008; but see Wasserman & Young, 2010). In line with this view, it has been suggested that consciousness is necessary for evaluating conceptual relationships, such as the sameness and differentness of objects (Crick & Koch, 2003; Tononi & Edelman, 1998).

Method

We tested this hypothesis in the current experiments, in which participants first performed a masked go/no-go task (van Gaal, Ridderinkhof, Scholte, & Lamme, 2010) and then an objective-awareness test.

Experiment 1

Eighteen participants (6 men, 12 women; mean age = 19.6 years) were recruited for Experiment 1. In the masked go/no-go task, two target objects were presented simultaneously and then masked by two annuli (Fig. 1a). The target objects were either presented briefly (for 16.7 ms or 33.3 ms) and were thus strongly masked and imperceptible to the participants' conscious awareness (nonvisible trials), or they were presented for a longer time (200 ms) and were thus visible to the participants (visible trials). The visible objects were selected from among four novel shapes, and the nonvisible objects were either square or diamond shapes (Fig. 1a). On each trial, the shape of the two target objects could be the same or different. The task was to press a button as quickly as possible when the shapes were either (a) visible and the same or (b) nonvisible (go trials), but to withhold response when the shapes were visible and different (no-go trials). Our primary research question was this: When shapes are nonvisible, do participants respond more slowly when the shapes are different than when they are the same, even though none of the shapes can be consciously differentiated and both trial types are go trials? After the completion of this go/no-go task, participants' awareness of the masked shapes was tested: They were asked to differentiate the strongly masked shapes and say whether they were the same or different (see the Experiment 1 Method section in the Supplemental Material available online).

Experiment 2

Twenty-three participants (9 men, 14 women; mean age = 19.9 years) were recruited for Experiment 2. The method

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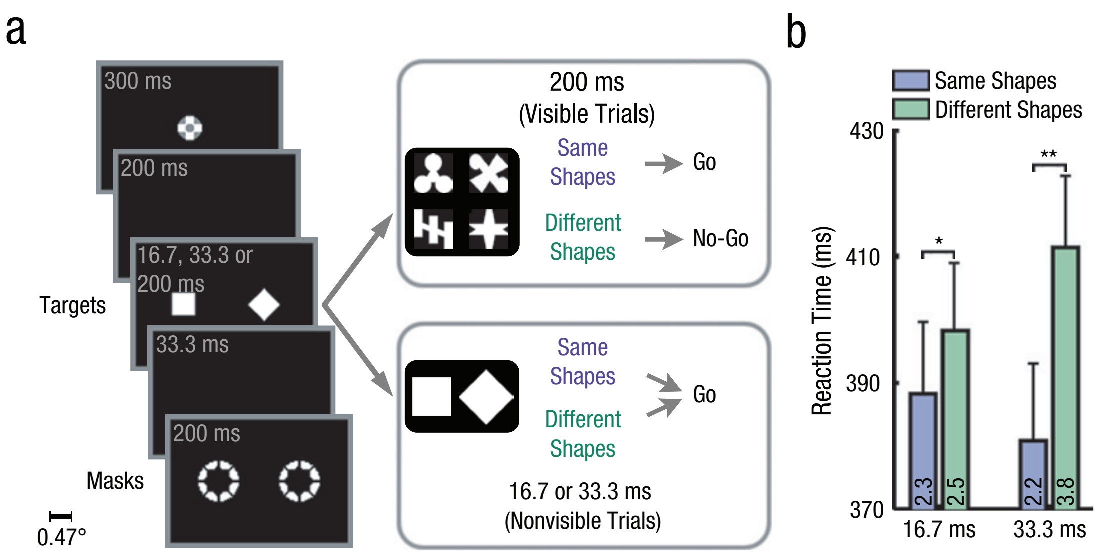

Fig. 1. Procedure and design of Experiments 1 and 2 (a) and results from Experiment 1 (b). In the metacontrast masking procedure (a), a central fixation point was followed by the presentation of two target objects, which were then masked by two annuli. On each trial, the shape of the two targets could be the same or different. Targets appeared for either a long duration (visible trials) or a short duration (nonvisible trials). In the visible condition, the task was to press a button as quickly as possible if the shapes were the same (go trials) or withhold response if the shapes were different (no-go trials); in the nonvisible condition, all trials were go trials regardless of whether the shapes were the same or different. Results for the two presentation durations for nonvisible trials are shown in (b), in which mean reaction time is plotted as a function of presentation duration and shape similarity (same or different). The values in the columns are error rates. Error bars show standard errors of the mean. Asterisks represent significant differences between conditions, as determined by two-tailed *t* tests (**p* < .05, ***p* < .001).

was the same as in Experiment 1 except that participants were asked to rate, on a 4-point scale (1 = *no experience*, 2 = *brief glimpse*, 3 = *almost clear impression*, and 4 = *clear impression*), their subjective awareness of each target before it was masked. This was done to provide a trial-by-trial assessment of subjective awareness in the go/no-go task. In addition, the objective-awareness test included not only nonvisible trials but also visible trials (Lin & Murray, 2013). For more details, see the Experiment 2 Method section in the Supplemental Material.

Results and Discussion

Our data analysis was first restricted to participants in Experiment 1 who were objectively unaware of the object relations (see Awareness of Object Relations in the Experiment 1 Results section in the Supplemental Material). As expected, these participants did well on the go/no-go task: The mean percentage of correct no-go responses was 83.8 (*SEM* = 2.5%) for different-shapes trials in the visible condition. For same-shapes trials in the visible condition, the mean percentage of correct go responses was 97.2 (*SEM* = 0.5%), and the mean reaction time (RT) was 270.8 ms (*SEM* = 14.7 ms). The crucial question here concerned the nonvisible targets: When shapes are nonvisible, do participants respond more slowly when the shapes are different than when they are the same, even though none of the shapes can be consciously differentiated and both trial types are go trials? In the nonvisible condition, RTs were slower for different shapes than for the same shapes for both target durations: For the targets presented for 16.7 ms, the mean RT was slower by 10.1 ms (*SEM* = 3.7), $t(15) = 2.65$, $p = .018$, $d = 0.66$, and for the targets presented for 33.3 ms, the mean RT was slower by 32.0 ms (*SEM* = 7.2), $t(16) = 4.30$, $p < .001$, $d = 1.04$ (Fig. 1b). These results were reflected in the RT distribution, which was shifted rightward in the different-shapes condition compared with the same-shapes condition, which suggests that the slowing effect was not due simply to a few outlier trials (see Fig. S1 in the Supplemental Material). This finding was supported by convergent evidence from a different method (regression analysis based on all the participants; see Experiment 1 in the Supplemental Material). The same pattern of results was observed in Experiment 2, in which only trials that were rated as subjectively invisible were included and in which the awareness test mixed both visible and nonvisible trials (see Experiment 2 in the Supplemental Material).

Taken together, these results demonstrate that even though participants objectively could not differentiate any of the shapes in the nonvisible condition (and subjectively rated them as nonvisible in Experiment 2), the two conditions left a marked behavioral signature of unconscious processing of the same-different concept: Participants were slower in responding to different shapes than to the same shapes in the nonvisible condition. Because this slowing effect was based on computing object relations, it could not be attributed to differences at the level of a single object—that is, individual square and diamond shapes did not determine the response and could be associated with either a go or no-go response in the visible condition depending on the other object (i.e., same or different). Such unconscious computing of object relations provides evidence against the idea that integration of stimulus meaning is uniquely conscious (Baumeister et al., 2011; Baumeister & Masicampo, 2010; but see Dijksterhuis & Aarts, 2010), but is consistent with the unconscious binding hypothesis (Lin and He, 2009). In sum, our results demonstrate the unconscious processing of an abstract concept that is thought to be a fundamental component of human thinking and reasoning.

Author Contributions

Z. Lin conceived, designed, and conducted the research. Z. Lin and S. O. Murray wrote the manuscript.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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