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The same-different task as a tool to study unconscious processing

Filip Van Opstal

The function of consciousness has often been investigated by looking at the cognitive processes that can (not) be performed without conscious awareness. The most important processes — historically and theoretically — in this context are semantic processing and information integration. Here, I will argue that a subliminal priming version of the same-different task is a perfect tool to investigate these processes because it (i) allows a clear separation between the stimuli that are consciously processed and those that remain unconscious, and (ii) requires the unconsciously presented stimuli to be integrated. An overview of the work that has used the subliminal same-different task to target these processes is presented, and some suggestions for how the task could be used in future work are made. The potential of the subliminal same-different task to elaborate on the cognitive architecture needed to successfully perform a same-different task is also discussed.

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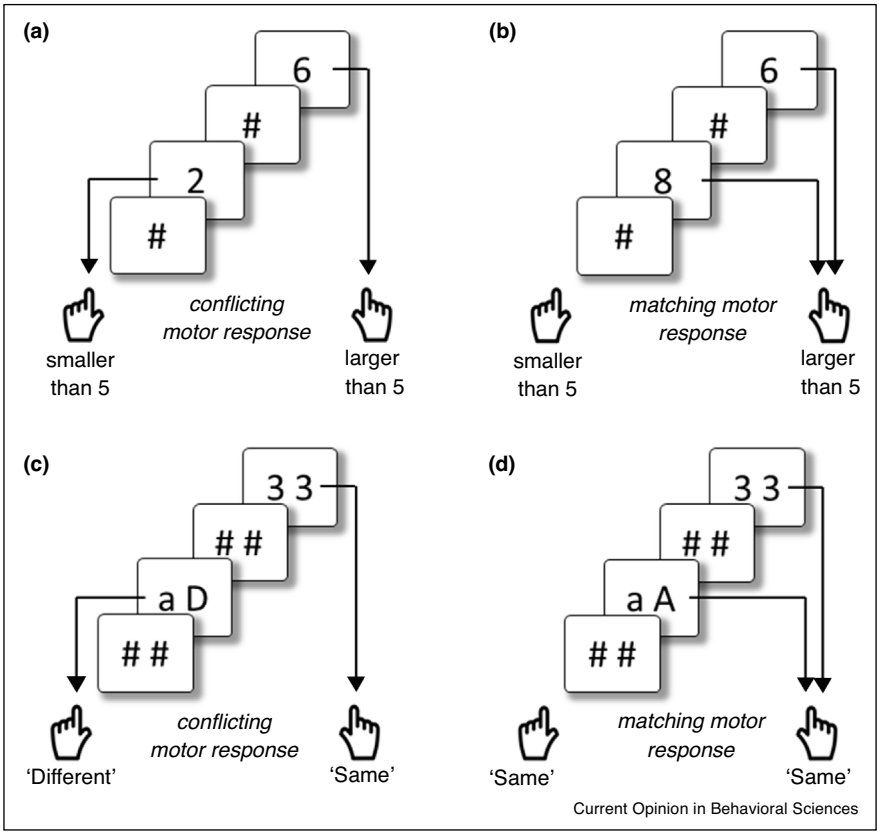
Introduction

The cognitive and neural correlates of consciousness have often been studied by looking at the scope and limits of unconscious processing. Numerous researchers have investigated the topic by presenting a stimulus below the threshold of conscious perception and measuring whether this unconscious stimulus affects a behavioral response (i.e. subliminal priming) [1,2]. In a typical subliminal priming experiment, participants are required to respond to a target stimulus that is preceded by a briefly presented prime stimulus that is 'sandwiched' between two mask stimuli. When the prime stimulus is presented for 50 ms or less and immediately followed by mask stimuli, participants have no awareness of the presence of this prime stimulus. Early results from such subliminal priming experiments proposed that responses to the target stimuli were influenced by the unconscious semantical processing of the prime stimuli. For example, if participants needed to classify a target number as smaller or larger than five, it was found that responses were facilitated if the prime number evoked the same response compared to when they evoked a different response [3] (Figure 1a and b respectively). Similarly, an early demonstration by Marcel showed that a target word was processed faster when it was preceded by a semantically related subliminal prime word [4]. Although these initial studies suggested that semantical processing does not require consciousness, it has been argued that they might not reflect genuine unconscious semantic processing. To investigate the effect of a prime on the target response, the primes and targets in these experiments came from an overlapping set of stimuli or from the same stimulus category. It is therefore possible that prime processing resulted from linking stimulus codes to responses during the course of the experiment [5] or by the conscious intention to create 'action triggers' [6] (for a full discussion, see Refs. [7–9]). In this case, a subliminal priming effect would originate from the activation of simple stimulus-response links rather than from genuine unconscious semantical processing. It has therefore been suggested that for genuine unconscious processing to take place, some criteria need to be met: First, primes should come from large categories or from a novel set outside of the task set so that subliminal priming effects cannot be attributed to the conscious preparation of response links. Second, primes and targets should be presented in different formats to avoid that any priming effect is caused by visual similarities [10,11]. Although a few studies that tried to meet these criteria by using pictures as primes (representing a virtually infinite set) and words as targets did find evidence for subliminal semantic processing [12,13], a recent study failed to replicate these results [14].

An experimental paradigm that allows for a clear separation of primes and targets was introduced by adapting the typical subliminal priming experiment to a subliminal same-different (SD) task [15•]. Instead of centrally presenting a single prime and a single target on every trial, in the subliminal SD task two masked primes and two targets are presented side by side (Figure 1c & d) and participants are required to judge if the two target stimuli are the same or different. This small change in the experimental design allowed the prime stimuli to be

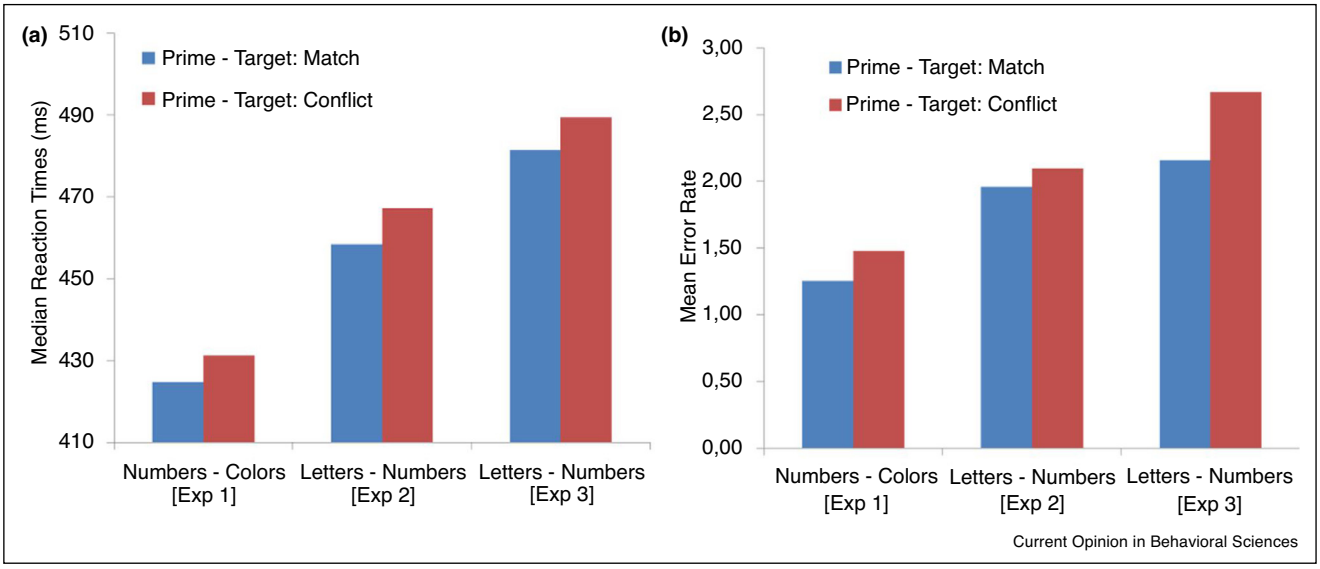
Figure 1



(a and **b)** Design of a simple subliminal priming experiment in which (a) a single masked stimulus evokes a motor response that conflicts with the response to the target, (b) a single masked stimulus evokes the same motor response as the response to the target. **(c** and **d)** The subliminal same-different task that requires subjects to indicate if the two target stimuli (here: Arabic digits) are the same or different. (c) The prime pair that consists of two different letters evokes a conflicting motor response with the response to the target; (d) the prime pair evokes a motor response that matches with the response to the target.

completely separated from the target stimuli. For example, in one instance of the subliminal SD task, participants had to judge the similarity of two targets that consisted of two colored squares. Unbeknown to the participants, these targets were preceded by two invisible Arabic digits. Results showed that the time needed to judge the similarity of the target colors was influenced by the similarity of the numbers: Participants were faster in judging if the two colors were the same (different) if they were preceded by two prime numbers that were the same (different) [15•]. This result means that the same-different judgement was not only performed on the target colors but also on the unconsciously presented numbers; the response evoked by the unconscious same-different judgment on the primes facilitates or interferes with the response required for the same-different judgment on the targets. Similar to previous subliminal priming experiments, the priming effect was only observed when the time between the presentation of the prime and target was short (i.e. 100 ms) but not when this time period was longer (i.e. 316 ms), indicating that it is rather short-lived [16]. The size of the effect was in the same order of magnitude as in other subliminal priming experiments (e.g. Refs. [8,9,17]): Participants were about 10 ms faster to respond to the targets when the response evoked by the primes matched that of the one to the targets (Figure 2a). The priming effect was also visible in the error rates with participants making less errors on trials in which the responses to the primes and targets matched (Figure 2b). The clear separation between the prime set (Arabic digits) and the target set (colored patches) in this experiment ensured that the subliminal priming effect could not be caused by a visual overlap between the primes and targets or by the potential to consciously create action triggers. The results of this experiment rather suggested that the same-different judgement was implemented as a generic algorithm to process completely different types of stimuli that could be

Figure 2



Subliminal SD task results adapted from the three experiments reported in Ref. [15•]. **(a)** Median reaction times are about 10 ms faster when the response evoked by the unconscious primes (same or different) matches the response to the targets. The results are highly similar across experiments with numbers as primes and colored patches as targets [Numbers – Colors] (Experiment 1 in Ref. [15•]) or with letters as primes and numbers as targets [Letters – Numbers] (Experiments 2 and 3 in Ref. [15•]). **(b)** Analyses of the error rates often show the same results with lower error rates on trials where the responses match compared to when they are conflicting.

presented below the threshold of conscious perception. Comparable results were later obtained in a similar paradigm in which the similarity between two subliminally presented abstract shapes cued a Go or No-Go response [18•]. Here too, the subliminally presented shapes bore no visual resemblance to those presented in conscious trials but the same-different algorithm was nevertheless properly executed.

While the unconscious same-different judgement on numbers (i.e. Arabic digits) and abstract shapes can be performed on perceptual features only (but see Ref. [19] for the automaticity of semantical processing of numbers in a same-different task), the observation that a generic algorithm is applied that fits very different types of stimuli allows the subliminal SD task to be used to unequivocally demonstrate unconscious semantic processing. In subsequent experiments, this was done by changing the prime stimuli to a small and capital letter (e.g. 'a D') and target stimuli to numbers [15•]. Because the subliminal prime letters were matched in visual (dis) similarity, judging the similarity between the letters could only be done based on their meaning, thus providing strong evidence for unconscious semantical processing. Interestingly, a follow-up study showed that the unconscious same-different judgment depended on the unconscious context created by the prime stimuli. When the prime stimulus pair 'a A' was presented in a context with low similarity (i.e. embedded in primes that were dissimilar both physically and semantically) it primed a 'same' response, but when the same prime was presented in a context with high similarity (i.e. embedded in primes that are very similar) it primed a 'different' response [20]. More recently, evidence for unconscious semantical processing in the subliminal SD task was extended even further by presenting two words instead of two letters [21]. In this study, participants had to judge if the two words belonged to the same semantic category or not. Results showed that the same-different judgement on the targets words was influenced by the judgement on the unconsciously presented prime words, indicating that the meaning of the two prime words were unconsciously processed, categorized and compared successfully. It should, however, be noted that in this study the prime and target words were not clearly separated which leaves open the possibility that the observed unconscious priming effect was at least partially caused by the conscious formation of stimulus-response mappings.

Another advantage of the subliminal SD task is that it can also target another cognitive feature that has been closely tied to consciousness, namely high-level information integration. Most prominent consciousness theories suggest that information integration and consciousness are strongly associated [22–24] (see Ref. [25] for a review): A conscious experience appears unified despite it being made up of individual parts, and consciousness is necessary for integration to occur. Information integration here

can be defined as '*the generation of a non-perceptual, abstract representation by associating distinct signals into a new one*' (see Ref. [25], p. 488), and consciousness would thus be a requirement to successfully perform this process. For example, when the words in the sentence 'I had cleaned my car' are integrated, the result exceeds the parts of the whole. This becomes apparent when considering the same words in a different order: 'I had my car cleaned'. Although the words in the sentence have not changed, integration of the words causes a change in the meaning of the whole sentence. Contrary to what most theories suggest, different studies have reported that information can be integrated without awareness of the stimuli to be integrated. It has, for example, been suggested that subliminally presented words can be integrated [26–28], or that basic arithmetic problems such as addition [29], multiplication [30] and even three-term subtractions (e.g. 9-3-4) [28] can be processed without awareness. Recently, however, some of the claims on unconscious information integration have been heavily disputed because of a re-examination of the original data or replication failures [31–38].

The results obtained from the subliminal SD task could also be argued to reflect evidence in favor of unconscious information integration. For example, to know whether a capital and small letter are the same or different requires both stimuli to be processed and to be integrated into a novel, abstract concept (same or different). Despite the current controversy around unconscious information integration, the evidence obtained from the subliminal SD task appears to be rather robust and compelling: the subliminal priming effect obtained with letters as primes and numbers as targets have been replicated within the same study [15•] and the results have been widely extended for other types of stimuli and across modalities. As mentioned before, the subliminal SD task has demonstrated the unconscious integration of abstract shapes [18•] and words [21], but further research showed the same results for the unconscious integration of low-level visual information such as arrows [39,40] and for emotional stimuli [41]. Liu *et al.* investigated if the relation of the emotional valence of two subliminally presented prime faces could influence the conscious processing of a pair of faces that was presented immediately after the primes. In two experiments they showed a negative priming effect, indicating that reaction times were slower on trials where the relation of the primes faces (same/different) was the same as the relation of the target faces (same/different). Also the relation between consciousness and the integration of information from different modalities (i.e. multisensory integration; [42]) has been investigated with the subliminal SD task. Whereas most studies investigating this relation used experimental tasks in which one of the two stimuli was always conscious [43,44], a recent study used a multimodal version of the subliminal SD task that allowed the unconscious presentation of both stimuli [45•]. On each trial, an audiovisual prime and target pair was presented that consisted of the simultaneous presentation of a visual and auditory number (as primes) or letter (as targets). Results showed that unconscious multisensory integration can occur, but only when subjects received conscious training before the experiment.

Why unconscious information integration is reliably found in the subliminal SD task but appears to be very fickle in other experimental designs is yet unclear. It has already been demonstrated that the temporal window in which the unconscious information is presented should be small for integration to occur [46]. It could be that also the spatial window should be sufficiently small to make unconscious integration possible [25] or that the complexity of the information should be limited.

The studies reviewed above demonstrate that the subliminal SD task is perfectly suited to address some crucial questions in consciousness research. The task could, however, also contribute to understanding the nature of same-different judgments. Similar to other same-different tasks, the subliminal SD task often shows the fast-same effect (i.e. the — counterintuitive — observation that same responses are faster than different responses) [47,48]. Judging the similarity of the emotional valence of two target faces shows a reaction time advantage for same faces compared to different faces [41]. Similar results were obtained when arrows were used as target stimuli [39] or when judging audiovisual letters as targets [45•]. Although there is no consensus on why this phenomenon occurs in a same-different task, conclusions from an overview of existing models suggested that same and different judgments depend on different processes: A same judgment would be a holistic (parallel) process whereas a different judgement would be serial [49]. According to the global neuronal workspace theory of consciousness, parallel processes can operate non-consciously, but serial processing requires conscious access [22,50–52]. If the dual process model of same-different judgements is correct, it could thus be hypothesized that priming in the subliminal SD task would work for primes that are the same, but less so for primes that are different. Although some of the studies reviewed above indeed indicate differences between same and different primes with priming effects limited to only same primes (e.g. Experiments 1 and 3 in [45•], and Experiment 3 in [15•], the evidence until now is very mixed (with opposite effects, i.e. priming only for different primes, in Experiment *2* in Ref. [45•] and Experiment *2* in Ref. [15•]).

Although the evidence reviewed here demonstrates that the subliminal SD task has already been proven a successful paradigm to investigate unconscious cognition, it remains unclear why this is the case. Future work could explore if this is due to the fact that the task allows

integration in small spatial windows as discussed above or that it is related to the relative simplicity of the stimuli used in the task. If the size of the small spatial window used in the subliminal SD task is determining feature of successful unconscious integration, it would be expected that the priming effect would disappear when the distance between the two prime stimuli increases. To investigate if unconscious integration could also be observed in the subliminal SD task when complexity increases, it would be interesting to see if the same results could be obtained when the prime stimuli are a combination of an arithmetic problem and the potential outcome of the problem (e.g., '6 + 5 11'). A priming effect in this case would mean that the arithmetic problem was unconsciously solved and compared to the outcome and that unconscious cognition might be more elaborate than assumed by most theories of consciousness.

Conflict of interest statement

Nothing declared.

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