Short Communication

Setting the stage subliminally: Unconscious context effects

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ABSTRACT

An important approach to understand how the brain gives rise to consciousness is to probe the depth of unconscious processing, thus to define the key features that cause conscious awareness. Here, we investigate the possibility for subliminal stimuli to shape the context for unconscious processing. Context effects have generally been assumed to require consciousness. In the present experiment, unconscious context processing was investigated by looking at the impact of the context on the response activation elicited by a subliminal prime. We compared the effects of the same subliminal prime on target processing when the prime was embedded in different unconscious contexts. Results showed that the same prime can evoke opposite responses depending on the unconscious context in which it is presented. Taken together, the results of this study show that context effects can be unconscious.

1. Introduction

Things are not always what they appear to be. A nice illustration is the famous visual illusion created by Hermann Ebbinghaus in which a central circle is judged to be smaller when it is surrounded by larger circles than when it is surrounded by smaller circles. Similarly, the lightness of a stimulus can be judged as light or dark depending on the context in which it is presented (e.g., Anderson & Winawer, 2005). Indeed, there is ample evidence that the judgment of a stimulus is not absolute but depends on the characteristics of the series of stimuli to which the judgment stimulus belongs. When squares are judged in size, for example, the categorization of a square as being large or small will depend on the range and frequencies of the squares in the experiment (Parducci, 1954). Similar observations of contextual effects on judgments have been made in a variety of sensory modalities such as weight, temperature, and loudness (for a review, see Eiser (1990)), but also in higher cognitive domains such as economical decisions (e.g., Tversky & Kahneman, 1981) and numerical cognition. A number, for example, can be judged to be small or large, depending on the range in which it is presented. In a previous study, for example, we demonstrated that when participants were instructed to judge a square as small or large, their decision time was influenced by a number that was presented in the middle of the square. Crucially, when the numbers ranged from 1 to 5, the numbers 4 and 5 facilitated the response to a large square. The same numbers (i.e. 4 and 5), however, facilitated a response to a small square when the numbers presented in the squares ranged from 4 to 9 (Van Opstal, Moors, Fias, & Verguts, 2008). What makes the range- or context-dependence especially intriguing in this study is the fact that the numbers in the squares were irrelevant for the task: Participants were instructed to respond to the size of the squares with no instructions on the numbers. These results show that this effect of context is automatic and unintentional. It is, however, unclear if a context can influence stimulus processing without awareness of the context.

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The possibility of unconscious context processing is a debated issue in consciousness research. Although many lab studies have already shown that unconscious stimuli can be processed up to semantic and motor levels (e.g., Dehaene et al., 1998; Kiesel, Kunde, Pohl, Berner, & Hoffmann, 2009; Van Opstal, Reynvoet, & Verguts, 2005), at the same time many theorists hold that unconscious processing is fundamentally limited. According to the global neuronal workspace theory, for example, effects of context or instructions would require conscious thinking (Dehaene & Naccache, 2001). To investigate this, Heinemann and colleagues (Heinemann, Kunde, & Kiesel, 2009) looked at the context-specific congruency effect, which refers to the finding that the prime-target congruency effect (in response times) depends on some contextual feature (e.g., a cue). They only observed this context-specific congruency effect when the context was processed consciously. In their experiment a cue could be a context in which the proportion of congruent trials (75%) was much higher than the proportion of incongruent trials (25%), or a context in which these proportions were reversed (i.e., 25% incongruent trials, 75% congruent trials). Results showed that the contextual cue only affected the size of the prime-target congruency effect when the cue was presented consciously. Similarly, unconscious processing of Arabic digits or number words can be modulated by the proportion of consciously perceived Arabic digits versus number words, but not by the proportion of unconscious Arabic digit versus number word primes (Van den Bussche, Segers, & Reynvoet, 2008). Again, this illustrates that the context does not influence unconscious processes when the context is unconscious.

Some authors, however, did present data in favor of unconscious context effects. In a series of studies, subliminal repetition priming effects were modulated by the proportion of repetition trials (Bodner & Masson, 2003, 2004; Bodner, Masson, & Richard, 2006). None of these earlier studies were completely convincing, however, because the prime always led to some traceable change in behavior (e.g., slower RT on incongruent trials) which could be (consciously) tracked by the subject and used for purposes of cognitive control. This is the core of the adaptation to the statistics of the environment theory (Kinoshita, Forster, & Mozer, 2008). Based on this theory, the existence of unconscious context effects was discredited.

In sum, despite the great importance of contexts in decision making and the great theoretical interest for contextual processing in consciousness research, so far there is no convincing evidence for unconscious context effects. We therefore designed an experiment to address this issue, taking into account the criticisms raised against earlier work. We adapted the design of a previous study in which participants had to decide if two target numbers were the same or different (Van Opstal, Gevers, Osman, & Verguts, 2010; Experiment 3). Unknown to the participants, these target numbers were preceded by an unconscious prime consisting of a pair of letters of which one was presented in lower case and one in upper case (e.g., ‘a D’). The prime consisted of a pair of same letters (e.g., ‘a A’; mixed-case letters; henceforth, denoted aA-type) or a pair of different letters (e.g., ‘a D’; henceforth, aD-type). Results from this study revealed a significant congruency effect: Responses on same-target number pairs (e.g., ‘1 1’) were faster when they were preceded by unconscious aA-type primes compared to when they were preceded by unconscious aD-type primes. These aA-type primes thus evoked a ‘same’ response. Here we propose that this ‘same’ response evoked by aA-type primes was determined by the context in which the primes were presented. In particular, they are in a low similarity context because aD-type primes have overall low similarity, both

![Fig. 1. Design of: (A) low similarity context experiment and (B) high similarity context experiment. In (A) a prime was sandwiched between two masks and consisted of a pair of letters presented in mixed case only. In (B) the prime could consist of a pair of letters presented in the same case or a pair of letters presented in mixed case. Targets were Arabic digits. Results of the low similarity context experiment are presented in (C) and show that responses to ‘same’ targets are faster when they are preceded by an aA-type prime. In (D) the results of the high similarity context experiment are shown. Error bars denote the standard error of the mean.](image_url)
physically and semantically. However, other contexts can be created: If a prime with aA-type primes would be presented mixed with a set of primes with a higher similarity (e.g., identical same-case letters; e.g., 'a a' or 'A A', henceforth, aa-type; a high similarity context), aA-type primes would be relatively less similar (more different). Accordingly, they may prime a 'different' response in this case. If so, it would imply that unconscious primes (aa-type versus aD-type) can establish a cognitive context to modulate cognitive processing (of aA-type primes). To test this, we supplemented our earlier experiment where aA-type primes were presented in a low similarity context (aD-type primes; Van Opstal et al., 2010, Experiment 3; see Fig. 1A) with a new one in which aA-type primes were presented in a context with high similarity (aa-type primes; see Fig. 1B).

2. Participants

Nineteen University students from Ghent University and the Université Libre de Bruxelles (5 males, aged 18–31) participated in this experiment for course credits and were tested in their native language (Dutch or French). None of the participants was aware of the purpose of the experiment.

3. Apparatus and stimuli

A 60 Hz monitor was used and stimulus presentation was synchronized with the refresh rate (16.7 ms). Key presses were registered with a response box. Primes were letters, targets were Arabic digits. To avoid effects due to a specific stimulus set and to remain as close as possible to our previous experiment, two letter sets were used between participants (ADEG and LMQR). Primes were pairs of letters with the same abstract identity, either aa-type or aA-type. Targets were pairs of numbers. Similar to our previous experiment we used two different target sets between participants (odd: 1, 3, 5, 7; even: 2, 4, 6, 8). Primes and targets were 6 mm high and 4 mm wide. The two prime or target stimuli were separated by a distance of 8 mm.

4. Procedure

Before the experiment, participants were told that on each trial they would see a brief series of flashes ending with two numbers. Their task was to judge whether the two numbers were the same or not, by pressing the corresponding key. Unknown to the participants, the two target numbers were preceded by a prime display (33 ms) sandwiched between two mask displays (67 ms; see Fig. 1B). Response mapping (same/different to left/right), letter set, and number set were counterbalanced between participants. The experiment consisted of 768 trials. There were equal numbers of aa-type and aA-type primes, and same (e.g., '1 1') and different (e.g., '1 3') targets. These factors were systematically crossed, so each combination was equally likely.

5. Results

Fig. 1C presents the results of the low similarity context experiment (taken from Van Opstal et al. (2010)): As can be seen, there was an interaction between prime type and target response (same/different), $F(1,15) = 7.07, p = .018$, $MSE = 75$. The "different" response is faster than the "same" response for context primes (aD-type), but "same" is faster than "different" for aA-type primes.

The data of the new, high similarity context experiment are shown in Fig. 1D. The effect is completely switched here ($F(1,18) = 172.4, p < .001$, $MSE = 87$): Whereas now "same" is faster than "different" for context primes (aa-type), "different" is now faster than "same" for aA-type primes.

To investigate the influence of an unconscious context on prime processing we analyzed trials with aA-type primes across the two experiments, which were exactly the same except for the different unconscious context they were embedded in (aD-type versus aa-type primes). Crucially, a 2 (Target: Same or Different) x 2 (Context: High or Low similarity) ANOVA on the median correct RTs with Context as a between participants factor revealed a significant interaction, $F(1,33) = 6.79, p = .014$, $MSE = 386$. There were no main effects of Context ($p = .30$) or of Target ($p = .48$), ruling out an explanation in terms of adaptation to the statistics of the environment. Planned comparisons (one-tailed $t$-tests) on the congruency effect in the two contexts separately revealed a significant priming effect in the high similarity context, $t(18) = 2.19, p = .021$, and an effect that fell just short of significance in the low similarity context, $t(15) = −1.54, p = .071$. Fig. 1C and D clearly shows the reversal of the priming effect across the two contexts.

6. Prime awareness

Subjective awareness was measured by asking participants after the main experiment to name any symbol they saw on the screen before presentation of the target stimulus. None of the participants could name a prime symbol, and only mentioned the hash masks. Then, participants were informed about the prime stimuli, and objective awareness was measured using a forced-choice test identical to the main experimental task, i.e. with both primes and targets presented. Here, participants were instructed to judge the similarity of the primes rather than the targets (e.g., Dehaene et al., 1998). The
prime awareness test consisted of 144 trials. As described in our previous study, primes were unconscious in the low similarity context (see Van Opstal et al., 2010, p. 1004). Average prime visibility (d’) in the high similarity context was 0.05 and was not significantly different from 0, t(18) = 0.94, p = .36 indicating no awareness of the primes (51% correct responses). The absence of subjective awareness of the primes and the performance at chance level in the objective visibility task demonstrate that the primes remained unconscious.

7. Discussion

This study is the first to demonstrate unequivocally that an unconscious context can influence prime processing. Across the two conditions, response times were equated, ruling out an explanation in terms of adaptation to the statistics of the environment (Kinoshita et al., 2008).

In line with the global neuronal workspace theory (Dehaene & Naccache, 2001), Heinemann et al. (2009) and Van Den Bussche et al. (2008) reported no context effects when the context was changed without awareness. The absence of an unconscious context effect by Heinemann and colleagues could, however, be caused by the specific paradigm they used. In their experiment a cue was matched with a specific context in a training phase before the start of the real experiment. In the unconscious condition, however, the cue was also presented unconsciously in the training phase. It can, however, be assumed that unconscious associative learning is much slower compared to conscious learning. As a result, the absence of a context effect in the main experiment could have been caused by insufficient training in the unconscious condition rather than the impossibility of unconscious context effects. Van den Bussche and colleagues (2008) performed a block-level manipulation, and reported that the proportion of Arabic versus verbal number primes in a numerical priming experiment does not modulate prime processing. In particular, there was no proportion × prime notation × congruency interaction. Importantly, there was a proportion × target notation × congruency interaction. Although not stressed by the authors, the latter interaction suggests an unconscious context modulation on the targets. Hence, rather than being contradictory, the data from that paper already hint at the point of view expressed in the current paper.

The results presented in this paper clearly show unconscious context effects, but do not allow drawing strong conclusions on the exact mechanisms behind the process. One account could be that participants unconsciously decide on the similarity between the two prime letters as they would do in psychophysical experiments. Behavior in this type of experiments can be formalized by relative judgment models (e.g., Laming, 1984; Stewart, Brown, & Chater, 2005). These models assume there is no stable, long-term representation of the absolute value of a physical dimension of a stimulus, but only relative values (depending on the stimulus set used in the experiment) form the basis for pairwise comparisons along the relevant dimension. If physical similarity is the relevant dimension, we may assume, in line with such models, that (physical) similarity of two letters is judged as same or different according to the letters that were presented before. This would mean that in the low similarity context, the physical similarity of aD-type trials is judged less similar than the physical similarity of aA-type trials, and aA-type trials are judged as less similar than AA-type trials in the high similarity context (average physical similarity ratings on a scale from 0 to 500 for aD, aA, and AA-type trials are 160, 247, and 500; Boles & Clifford, 1989).

Another possibility is that different levels of representation are active in different contexts. Object recognition has been shown to involve the activation of multiple levels of representation (e.g., Dehaene et al., 2001; Vuilleumier, Henson, Driver, & Dolan, 2002). Because it can be assumed that letters are also represented at different levels, e.g., at the shape level and the symbolic level (Shin, Fabiani, & Gratton, 2006), it could be that the similarity judgment originates at different levels depending on the context. More specifically, in the low similarity context, the similarity judgment might arise from the symbolic level, and thus aA is judged as “same”. In contrast, in the high similarity context the symbolic level is matched (each pair consists of the same letters, e.g., aa, aA), and so aA is judged on the shape dimension (i.e., “different”). According to this view, the context defines the level at which a response is being made. Future research, however, will be necessary to shed more light on the exact nature of the context effect found in this study.

Interestingly, previous studies that failed to find unconscious context effects explained this by assuming that unconscious stimuli operate in a bottom-up fashion and are therefore unable to establish a context for later processing (Heinemann et al., 2009). Following this line of reasoning, the observation that unconscious stimuli can establish a context for later processing might suggest unconscious top-down processes. Indeed, because the bottom-up information for aA-type trials is identical in both the high and low similarity context, it can be argued that the context influences the unconscious processing stream in a bottom-up fashion. Unconscious top-down control was shown before in a series of studies that demonstrated that unconsciously presented primes were able to trigger a cognitive control system (Lau & Passingham, 2007; van Gaal, Ridderinkhof, Fahrenfort, Scholte, & Lamme, 2008; Van Gaal, Ridderinkhof, Scholte, & Lamme, 2010). For example, van Gaal et al. (2008) used a Go/NoGo paradigm and demonstrated that unconsciously presented NoGo cues can slow down processing on Go trials. However, the relationship between a NoGo cue and slowing was presumably learned during the consciously presented NoGo trials, with aftereffects on unconscious trials (Custers & Aarts, 2011). Although interesting of itself, this can be implemented by a (bottom-up) connection between the NoGo cue and a cortical area leading to overall inhibition of motor areas (e.g., subthalamic nucleus). Because there was no conscious learning of the context in the present experiment, the results presented here might make a purer case of unconscious top-down processes.

An influential approach to gain theoretical leverage on a complex cognitive concept is to spell out the features that are typically ascribed to it, and investigate which features are crucial and which are not (Moors & De Houwer, 2006). Applied
to consciousness, top-down processing has been suggested as a key feature (Dehaene & Naccache, 2001). Here, we argue that it is not crucial because these processes can occur outside consciousness. Also, the current study demonstrates that top-down processing can be differentiated from ‘mental effort’, another feature that is proposed to be critical to consciousness (Dehaene et al., 1998): Top-down modulation changed unconsciously, so it can hardly be qualified as effortful. This does not, of course, imply that other features of consciousness are not crucial either. For example, recent research demonstrates that ‘seriality’ may be crucial in the sense that chaining mental operations requires consciousness (Sackur & Dehaene, 2009; Van Opstal, de Lange, & Dehaene, 2011).

A theory of consciousness should clarify which features are crucial for consciousness. Developing such a theory is obviously beyond the scope of the current paper, but the paper does show that a feature which standardly has been assumed to be crucial, actually is not. As such, it underscores the power of unconscious processes.

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