How to trigger elaborate processing? A comment on Kunde, Kiesel, and Hoffmann (2003)

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Received 16 January 2004; accepted 13 December 2004

Abstract

Recently, [Kunde, W., Kiesel, A., & Hoffmann, J. (2003). Conscious control over the content of unconscious cognition. \textit{Cognition}, 88, 223–242] used a masked priming paradigm to argue that neither the ‘elaborate processing’ or the ‘evolving automaticity’ view can account for the processing of unconscious numerical stimuli. In our Experiment 1 we replicated [Kunde, W., Kiesel, A., & Hoffmann, J. (2003). Conscious control over the content of unconscious cognition. \textit{Cognition}, 88, 223–242] Experiment 4 and show that with a less demanding mask than that used by Kunde et al., ‘elaborate processing’ can explain priming results given that there are side conditions to trigger elaborate processing of unconscious stimuli. The second experiment further explores this influence of the masks by increasing the relevance of the symbols by which the mask is composed. The results show that an increase in relevance of the mask is accompanied by a decrease in the priming effect, though there was no significant change in conscious awareness of the prime.

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\textit{Keywords:} Masked; Priming; Number; Contextual; Influences

In a typical masked priming experiment, participants are unaware of the fact that a target stimulus is preceded by another stimulus, the prime, which is presented very shortly and masked immediately. For example, Dehaene et al. (1998) let their participants classify a number target as smaller or larger than 5. The target was preceded by a number prime, which was also smaller or larger than 5. If both prime and target were smaller (or larger)
than 5 (congruent trial, e.g. prime 1–target 4), response times (RTs) were faster than when prime and target did not evoke the same response (incongruent trial prime 6–target 4). This can be explained by the ‘elaborate processing’ hypothesis which holds that unconscious primes are processed up to a semantic level, just like the targets (e.g. Dehaene et al., 1998). In contrast, the ‘evolving automaticity’ hypothesis claims that congruency priming is the result of stimulus–response associations between target and response hands, learned during the course of an experimental session. Once formed, these associations are also applied to the unconscious primes (Abrams & Greenwald, 2000; Damian, 2001).

Recently, evidence has accumulated in favor of elaborate processing. For instance, Naccache and Dehaene (2001) showed that primes that were never consciously perceived nevertheless evoked congruency effects. Such a finding cannot be incorporated into an ‘evolving automaticity’ framework, because if the prime never requires a response, it cannot acquire a link to a specific response (see also Greenwald, Abrams, Naccache, & Dehaene, 2003; Kunde Kiesel, & Hoffmann, 2003, Experiment 1). However, Kunde et al. showed that this congruency effect does not occur with masked primes that are outside the range of the target set (Experiment 2), with a non-numerical rather than the typical ‘comparison to five’ instruction (Experiment 3), or with primes in a different notation than the target set (Experiment 4). These results led the authors to propose the action-trigger account, which holds the middle between the ‘elaborate processing’ and the ‘evolving automaticity’ views. In this view, conscious processes lead to a categorization of stimuli into appropriate action-trigger conditions for task-defined responses, and these conditions are formed dependent on the context and the instructions of the experiment.

We do not doubt that processing of unconscious information can be modulated by conscious processes (see Naccache, Blandin & Dehaene, 2002); however, the action-trigger account is inconsistent with some of our previous experiments. We will focus on Kunde et al.’s Experiment 4. Participants were confronted with only one target notation (Arabic or verbal), whereas primes were presented in both notations. A within-notation congruency effect was obtained, but no cross-notation congruency effect. In contrast, in one of our previous experiments (Reynvoet, Caessens, & Brysbaert, 2002, Experiment 3), we explicitly tested the existence of a cross-notation congruency effect, and found that such an effect does emerge even when participants are not confronted with the notation of the primes in the target set. In this Experiment, participants classified targets as odd or even. Targets were always digits, whereas the primes were word numbers. Response congruent trials (e.g. five–7) were reacted to faster than response incongruent trials (e.g. six–7) (see also Reynvoet & Brysbaert, 2004).

In this paper we intend to resolve the discrepancy between the results of Kunde et al. (2003) on the one hand and our experiments on the other, and show that the presence of cross-notational congruency effects depends on subtle methodological variations. In our Experiment 1a, we replicated Experiment 4 of Kunde et al. using their mask (a letter mask). Experiment 1b was the same, except that we used a hash mask (‘#####’), as in Reynvoet et al. (2002). The results with the letter mask mirrored theirs, and showed a within-notation effect congruency effect, but no cross-notation congruency effect. In contrast, the results using the hash mask did show a cross-notation congruency effect, although the primes were not consciously perceived as indicated by the visibility ($d'$) measures. This mask effect was further explored in Experiment 2, where we systematically
crossed notation of prime, target, and mask in a within-subject design. It was found that the extent to which the symbols of the mask are important for the task is a factor that should be considered in priming studies (cf. Verleger, Jaskowski, Aydemir, van de Lubbe, & Groen, 2004).

1. Experiment 1

Experiment 1a serves as a replication of Kunde et al.’s Experiment 4. The mask consisted of a string of six random letters (e.g., ‘LFKCNO’). Experiment 1b follows the same logic, except for the mask which consisted of five hash marks.

1.1. Method

1.1.1. Participants

Forty-seven volunteers (aged 18–30 years; twenty-three in Experiment 1a; twenty-four in Experiment 1b, all different from Experiment 1a) participated for course credit. None was familiar with the purpose of the experiment.

1.1.2. 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. The same experimental stimulus set as Kunde et al. (Experiment 4) was used (primes 1–9 excluding 5; targets 1, 4, 6, and 9). Primes were both in Arabic and verbal (in Dutch: EEN, VIER, ZES, and NEGEN) notation for all participants; targets were presented in one notation only (Arabic for half of the participants and verbal for the other half). All characters were presented in Courier font in white on a black background; a character extended approximately 1 cm in height and 0.8 cm in width. Following Kunde et al., we distinguish primes contained in the target set (primes 1, 4, 6, and 9) from primes not contained in the target set (2, 3, 7, and 8). Each trial was announced by a premask presented for 67 ms, followed by the prime for 33 ms and a postmask, presented again for 67 ms. Then, the target appeared on the screen for 200 ms. The intertrial interval was 1000 ms.

1.1.3. Procedure

Participants started with a set of 32 practice trials followed by two blocks of 320 trials. Half of the participants ($n = 12$ in both Experiment 1a and 1b) were asked to press the left index finger for a target smaller than five and the right index finger for a target larger than five. For the other half ($n = 11$ and 12 in Experiment 1a and 1b, respectively), the response mapping was reversed. After the main experiment, participants performed a detection task. Here, the same stimuli were shown, but participants were instructed to perform the task on the prime rather than on the target (cf. Naccache & Dehaene, 2001). For this task, there were 16 practice trials and 128 detection trials.
1.2. Results

1.2.1. Experiment 1a

We excluded RTs below 200 ms and above 1000 ms (6.65%). Mean correct RTs and error rates are shown in Table 1. An ANOVA was performed on the RTs and on error rates with variables Congruency, Prime Type (primes from target set or not), and prime-target Format Match as repeated measures. RTs were slower with incongruent than with congruent trials \( F(1, 22) = 19.57, p < .001 \). Congruency interacted with Format Match \( F(1, 22) = 22.75, p < .001 \); in particular, there was a congruency effect when prime and target had the same notation \( F(1, 22) = 45.74, p < .001 \), but not when prime and target had a different notation \( F(1, 22) = 0.27, p = .61 \). When prime and target had the same notation, there was a significant congruency effect for primes from the target set \( F(1, 22) = 34.74, p < .001 \), as well as for primes outside the target set \( F(1, 22) = 5.39, p = .03 \).

Prime visibility measures were calculated separately for verbal and Arabic primes. Mean \( d' \) for verbal primes was equal to \(-0.036, t(22) = -0.620, p = .54 \). Mean \( d' \) for Arabic primes was equal to 0.031, \( t(22) = 0.804, p = .43 \), meaning that primes were not identified. There was no significant difference between the two types of primes \( t(22) = 0.930, p = .362 \). A regression analysis was performed on the individual congruency effects with the \( d' \) measures as a predictor (Greenwald, Klinger, & Schuh, 1995). A significantly positive intercept in this analysis means that there is positive priming from unconscious primes. The results revealed a significant (positive) intercept \( (t(21) = 4.15, p < .001) \) and slope \( (t(21) = 2.137, p < .05) \) for verbal primes, and a significant intercept \( (t(21) = 3.73, p < .005) \) but non-significant slope \( (t(21) = 1.586, p = 0.128) \) for Arabic primes.

1.2.2. Experiment 1b

One participant was excluded because he failed to comply with the instructions. RTs faster than 200 ms or slower than 1000 ms were removed (5.94%). Mean correct RTs and error rates are shown in Table 2. There was an effect of Congruency \( F(1, 22) = 128.19, p < .001 \). As in Experiment 1a, the congruency effect was stronger for within-notation trials, as indicated by a significant Congruency×Format Match interaction \( F(1, 22) = 128.19, p < .009 \). Importantly however, there was an effect of congruency both with the same prime-target notation \( F(1, 22) = 107.83, p < .001 \), and with a different notation \( F(1, 22) = 33.41, p < .001 \). There was a significant effect of congruency both for primes from the target set \( F(1, 22) = 74.64, p < .001 \) and for primes outside the target set \( F(1, 22) = 71.55, p < .001 \). As for the error rates, incongruent trials were more error-prone.

Table 1

<table>
<thead>
<tr>
<th>Prime type</th>
<th>Prime—target notation</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same</td>
<td>Different</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Congruent</td>
<td>Incongruent</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>PE</td>
<td>RT</td>
<td>PE</td>
</tr>
<tr>
<td>From target set</td>
<td>462</td>
<td>5.60</td>
<td>481</td>
<td>7.45</td>
</tr>
<tr>
<td>Not from target set</td>
<td>464</td>
<td>7.01</td>
<td>472</td>
<td>7.07</td>
</tr>
<tr>
<td></td>
<td>Incongruent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>PE</td>
<td>RT</td>
<td>PE</td>
</tr>
<tr>
<td>From target set</td>
<td>469</td>
<td>6.58</td>
<td>469</td>
<td>6.58</td>
</tr>
<tr>
<td>Not from target set</td>
<td>471</td>
<td>6.85</td>
<td>471</td>
<td>6.85</td>
</tr>
</tbody>
</table>
than congruent trials ($F(1,22) = 10.19, p = .01$), but there was no Notation × Congruency interaction. Mean $d'$ for verbal primes was equal to 0.021 ($t(22) = 0.181, p = .86$) and equal to 0.269 for Arabic primes ($t(22) = 1.72, p = .10$). There was no significant difference between the two types ($t(23) = 1.62, p = .119$). Regression analyses revealed significant intercepts for verbal primes ($t(21) = 11.12, p < .001$) as well as for Arabic primes ($t(21) = 10.45, p < .001$), with non-significant slopes ($t(21) = -0.278, p = .784$ and $t(21) = -0.077, p = .939$ for verbal and Arabic primes, respectively).

Additionally, we performed an analysis on the data of the two experiments with Experiment (1a or 1b, letter mask or hash mask) as a between-subjects factor. The congruency effect was stronger in Experiment 1b, as revealed by a significant Congruency × Experiment interaction ($F(1, 45) = 36.6, p < .001$).

1.3. Discussion

Experiment 1a replicated the findings of Kunde et al.’s Experiment 4. A congruency effect was found overall, due to a congruency effect with prime-target notation match only. With prime-target notation match, there was a significant congruency effect for primes inside as well as outside the target set. Experiment 1b revealed qualitatively the same findings as obtained in Experiment 1a and in Kunde et al.’s Experiment 4. However, all congruency effects were much stronger. Importantly, even in the absence of conscious perception (see section on prime visibility), there was cross-notational priming, as predicted by the elaborate processing hypothesis.

These results are also relevant with respect to recent research proposing an active role for the mask in priming studies (Verleger et al., 2004; Lleras & Enns, 2004). In these experiments, the prime typically consists of a double arrow (e.g. ‘< <’) that is the same as (‘< <’) or opposite to (‘> >’) the target. The mask is composed of four arrow-heads, which are the two primes (or targets) overlaid on each other. A reversed priming effect is found, indicating that participants respond slower when the prime and target are in the same direction than when they point in different directions. Contrary to an earlier inhibition hypothesis (Eimer & Schlaghecken, 1998), Verleger et al. propose the active-mask hypothesis to explain this effect. Of crucial importance here is that the active-mask hypothesis postulates an active role of the mask, meaning that the mask will interact with processes evoked by the prime. In particular, we believe that the priming effect will depend on the meaning of the symbols used in the mask. Our Experiment 1 already

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### Table 2
Mean RTs and error rates, experiment 1b (hash mask)

<table>
<thead>
<tr>
<th>Prime Type</th>
<th>Prime - Target Notation</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Congruent</th>
<th>Incongruent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
<td>PE</td>
<td>RT</td>
<td>PE</td>
<td>RT</td>
</tr>
<tr>
<td>From target set</td>
<td>468</td>
<td>5.11</td>
<td>495</td>
<td>7.45</td>
<td>468</td>
</tr>
<tr>
<td>Not from target set</td>
<td>471</td>
<td>5.05</td>
<td>493</td>
<td>6.63</td>
<td>465</td>
</tr>
</tbody>
</table>
showed that changing a hash mask into a letter mask significantly reduced the priming effect. In accordance with the active-mask hypothesis, a mask consisting of letters, rather than hash marks, may evoke more activation of task-relevant responses. This larger activation may interrupt prime-induced activation more strongly, leading to smaller priming effects. We argue that this congruency-mask type interaction will further increase if the symbols in the mask evoke task-relevant responses even more. In a numerical decision task, a mask consisting of numbers will activate task-relevant responses more than letters, so according to this logic, a number mask should prevent priming effects more than a letter mask does.

2. Experiment 2

2.1. Method

2.1.1. Participants

Eighteen volunteers (aged between 20–36 years, 10 male) took part in this experiment and were paid 10 Euros for participation. None of the participants was familiar with the purpose of the experiment.

2.1.2. Apparatus and stimuli

Primes were limited to those contained in the target set (i.e., 1, 4, 6, and 9 and their corresponding Dutch word numbers). The type of mask (verbal or Arabic), prime notation (verbal or Arabic), and target notation (verbal or Arabic) were all varied within subjects. The mask consisted of either six letters or six numbers. Letter masks were composed of four different letters (C, D, H, and T; two letters were repeated in a mask) in a random order (e.g., ‘CTHCDT’); none of the letters of the mask occurs in the prime or target set, that is, none of the verbal number words contains any of the letters from the mask. A number mask was made of numbers outside the prime-target set (2, 3, 7, and 8) that were alternately small (2, 3) and large (7, 8) (e.g., ‘273837’). If the premask started with a small number, the postmask started with a large number, and vice versa. Premask and postmask differed both within a trial and between trials. Otherwise, the procedure was the same as in Experiment 1.

2.1.3. Procedure

Participants started with a practice block of 32 trials followed by three blocks of 256 trials. Response hand mapping was counterbalanced as in Experiment 1. The main experiment was again followed by a detection task containing 16 practice and 128 detection trials.

2.2. Results

Two participants were excluded because they failed to comply with the instructions. RTs outside the range from 200 to 1000 ms were removed (1.27%). Mean correct RTs are shown in Table 3. An ANOVA with Mask (verbal vs. Arabic), Prime (verbal vs. Arabic),
Target (verbal vs. Arabic), and Congruency as within-subject variables revealed a significant Congruency effect \((F(1, 15) = 64.17, p = .001)\): Congruent trials were responded to faster than incongruent trials. The interaction between Congruency and Mask was also significant \((F(1, 15) = 152.26, p < .001)\): The congeruency effect was significantly larger with letter masks than with number masks. Planned comparisons showed a significant congruency effect when using letter masks \((t(15) = 8.03, p < .001)\), and also when using number masks \((t(15) = 4.09, p < .001)\). Trials with an Arabic numeral as prime were responded to faster than trials with verbal primes, as indicated by the main effect of Prime \((F(1, 15) = 5.34, p < .05)\). There was also an effect of Target \((F(1, 15) = 152.26, p < .001)\): Participants were faster in responding to Arabic than to verbal targets.

An ANOVA on the error rates (3.26%) revealed a significant effect of Congruency \((F(1, 15) = 14.38, p < .005)\): More errors were made on incongruent than on congruent trials. The error data also showed a significant effect of Target type \((F(1, 15) = 16.66, p < .001)\), meaning that more errors were made on verbal targets than on Arabic targets: See Table 4.

Prime visibility measures \((d')\) were calculated for each mask type and prime format separately. None of them differed significantly from 0, as shown in Table 5. Regression analyses revealed significant intercepts and no significant slopes for all prime format—mask type combinations (Table 5).

### 2.3. Discussion

As in Experiment 1, the results from Experiment 2 clearly show an effect of mask type on the amount of priming. A mask consisting of symbols that strongly activate
task-relevant responses (i.e. digits), blocked the prime more strongly than a mask consisting of symbols (i.e. letters) that evoke task-relevant responses to a lesser degree.

3. General discussion

Using the same design as Kunde et al. (their Experiment 4), we replicated their within-notation congruency effect without a cross-notation effect (our Experiment 1a). However, with a different mask type, we obtained a cross-notation as well as a within-notation congruency effect (our Experiment 1b). Methodologically, this shows that even an apparent detail such as the composition of the mask, can lead to different results and should be taken into consideration in priming studies. Theoretically, this shows that even unconscious (as witnessed by the $d'$ studies) primes that are never responded to during the task are processed semantically, in line with the elaborate processing view.

However, the findings of Kunde et al. and our Experiment 1a also clearly show that unconscious primes are not always semantically processed. This effect was further explored in Experiment 2, where we showed that a number mask led to even smaller priming effects than a letter mask. We argue that the influence of the mask increases as the symbols of the mask become more meaningful for the task: This may be seen as a further elaboration of the active-mask hypothesis proposed by Verleger et al. (2004).

In conclusion, we argue in favor of elaborate processing of unconscious (number) primes, not in the sense of unavoidable processing but rather as “running without conscious monitoring”, while remaining subject to side conditions under which primes may not be processed semantically (e.g. Tzelgov, Yehene, Kotler, & Alon, 2000). These side conditions may involve temporal attention (Naccache et al., 2002), task context (Kunde et al., 2003), instructions (Kunde et al., Experiment 3), but also the particular parameters of the priming paradigm, such as font size or the characters that the mask is composed of.

Acknowledgements

While conducting this research, Bert Reynvoet was a post-doc researcher supported by the Fund for Scientific Research-Flanders (FSR-F). The contribution of Filip Van Opstal and Tom Verguts was supported by project G.0188.04 from the FSR-F.
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