

Updating a Cautionary Tale of Masked Priming: Reply to Klapp (2005)

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The commentary by S. T. Klapp (2005) on our recent article (A. Lleras & J. T. Enns, 2004) proposes that the empirical finding of negative compatibility in masked priming be attributed to 2 distinct theoretical constructs: (a) perceptual priming through object updating, as described in our article, and (b) nonperceptual priming based on inhibited unconscious response tendencies. The authors argue that this 2nd construct is not supported by either the new data the authors report or the extant literature. Instead, the negative compatibility effect in masked priming is influenced by perceptual interactions among stimuli that appear in the same spatial location, and the authors believe it is this process that deserves further systematic study.

Keywords: masking, priming, unconscious, negative compatibility effect, object updating

Our primary motivation in studying the negative compatibility effect (NCE; Lleras & Enns, 2004) was a concern that research in this area was overlooking an important principle of visual masking. This is the principle that masks are not merely tools of convenience, acting to reduce the visibility of a stimulus so that unconscious influences can be measured, but that the masks themselves alter the perceptual processes that are under investigation (Enns & Di Lollo, 2000). As a result, representations of masked stimuli can in fact be very different than the representations of the same stimuli when unmasked; they are not merely temporally abbreviated, nor attenuated versions of them. In particular, recent research suggests that information from both the to-be-masked and the mask stimulus is often merged together into a single representation during visual backward masking (Lleras & Moore, 2003; Moore & Lleras, 2005).

The commentary by Klapp (2005) indicates to us that these recent advances in the masking literature have yet to be integrated into the research on the negative compatibility effect. Klapp proposes to use masked-priming methodology to study the unconscious processes of response selection (Eimer & Schlaghecken, 2002; Klapp & Hinkley, 2002) without involving any perceptual interactions, an effect he refers to as NCE-NP. Klapp's proposal fails to incorporate the main finding that rapid sequences of visual stimuli, although physically independent and temporally discrete, will not necessarily be treated as such by the human visual system. In particular, rapid sequences of visual stimuli have strong interactive influences, especially when the stimuli in the sequence appear in the same location in space (e.g., Brehaut, Enns, & Di

Lollo, 1999; Breitmeyer, 1984; Giesbrecht & Di Lollo, 1998; Potter, Staub, & O'Connor, 2002; Raymond, 2001, 2003; Raymond, Shapiro, & Arnell, 1992; Sheppard, Duncan, Shapiro, & Hillstrom, 2002; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2004).

It was our interest in the perceptual interactions that occur among rapid stimulus sequences in the same location that prompted us to decouple the spatial locations of the prime–mask stimuli from the target location. Although Klapp and Hinkley (2002) came to their conclusions after presenting all three stimuli (prime, mask, target) at fixation, we opted for the design of Eimer & Schlaghecken (1998, 2002), presenting the prime–mask stimuli a few degrees either above or below fixation and presenting the target at fixation. This permitted us to focus exclusively on possible perceptual interactions between prime and mask stimuli so as to distinguish them from “interactions that might occur over and above the prime–mask interactions” (Lleras & Enns, 2004, p. 478), such as prime–target or mask–target interactions. We found not only that the prime and mask interact in producing priming effects but that these interactions did not require separate theoretical constructs for conscious versus unconscious priming. Moreover, mask type proved critical in predicting the direction of priming, whereas prime visibility seemed to play no role.

Our interpretation was that the priming we observed could be encompassed within a unitary theoretical framework of *object updating*. In brief, rapid sequences of stimuli from the same location are continually being sampled for information relevant to the task of responding as rapidly as possible to the final target stimulus. As all the masks that had been tested up to that point contained target-relevant information (visual composites of the critical features in both targets), they left the visual-motor system at the end of the prime–mask sequence with recently updated information that was in fact opposite to the prime. Thus, what looked like negative priming when indexed with respect to the prime was actually positive priming based on the newly updated features in the mask (Lleras & Enns, 2004).

It is important to clarify two crucial distinctions between the object updating account (Lleras & Enns, 2004) and the unconscious inhibition account of Klapp (2005) and others (Eimer &

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Schlaghecken, 2002; Klapp & Hinkley, 2002). First, whereas the object updating account explains the NCE findings in terms of strictly positive motor priming (elicited by the most recently updated features of the prime–mask bundle), the unconscious inhibition accounts propose that the NCE (or NCE-NP) arises from an unconscious motor-inhibition that suppresses motor preparation elicited by subthreshold stimuli. Thus, whereas in our view internal representations are being activated, leading to positive priming, in Klapp's proposal, some internal representations are suppressed and thus produce a negative priming effect. More specifically, according to Klapp, motor priming is derived solely from the prime stimulus, whereas according to Lleras and Enns (2004), motor priming is derived first from the prime stimulus, but then, when the mask has been processed to some degree, it is based also on the mask stimulus and its perceptual interactions with the prime.

A second important distinction between the two accounts is that only in the unconscious inhibition account is prime visibility held to be critical in determining whether priming is positive or negative. If prime visibility is low, then the prime is processed unconsciously and so priming should be negative. If prime visibility is high, then the prime is also processed consciously and priming should be positive. Prime visibility plays no comparable role in the object-updating account. In fact, we see little evidence linking prime visibility to direction of priming. Although we believe the priming effects arise from largely unconscious processes (i.e., perceptual-motor updating probably takes place automatically and prior to awareness), we see no direct evidence to support the claim that unconscious priming differs from conscious priming (see the Discussion section for a more detailed presentation of this issue).

The most important evidence favoring the object-updating account was the consistent finding that only masks with target-relevant features resulted in an NCE (Lleras & Enns, 2004). Masks with task-irrelevant features always resulted in positive priming (i.e., responses were most rapid and accurate when primes and targets shared relevant features). Because of the consistency of these findings, we were surprised to find out that there are circumstances under which even a mask with task-irrelevant features can produce the NCE. Yet, a closer look at this new result in Klapp's commentary reveals that the results cannot be interpreted unambiguously as “[an]other form of NCE [that] is not due to this type of perceptual interaction because it can arise when the mask is not relevant” (Klapp, 2005, p. 434). The finding is ambiguous because all three stimuli were still presented at the same visual location, namely, at fixation. This leaves open the possibility that perceptual interactions between the stimuli (prime, mask, and target) are still playing a critical role in the NCE-NP. We tested this possibility in the experiment presented below.

To see whether there is indeed any reason to suspect prime–mask–target (PMT) interactions, we compared priming in two conditions. In the PMT-at-fixation condition, we followed Klapp in presenting all three stimuli in the same location. In the PM-only-at-fixation condition, we kept PM in the same location but presented T in one of two locations directly above or below fixation. In both conditions, we compared a task-irrelevant mask and a task-relevant mask, allowing for independent evaluation of target location and mask type. Note that this design also allows for close comparison with the conditions tested previously (Lleras & Enns, 2004), in which the prime–mask stimuli were presented

above or below fixation and the target was presented at fixation. If there are PM-to-T interactions, then the pattern of priming for irrelevant masks should be different in the PMT-at-fixation condition (and Klapp's new data) than it is in the PM-only-at-fixation condition (and our previous data). If, on the other hand, obtaining the NCE with an irrelevant mask is simply a matter of presenting prime and mask at fixation, then the pattern of priming should be similar in both of these new conditions (and similar to Klapp's new data) but different from our previous experiments, where prime and mask always appeared above or below fixation.

Method

Thirty undergraduate students at the University of British Columbia participated for extra credit in psychology courses. Fifteen were randomly assigned to each of the two conditions. Participants completed 640 trials (10 blocks of 64 trials) in a session lasting about 1 hr. All were naïve to the purpose of the study, and all reported vision that was 20/20 or corrected to 20/20.

The participant's task was to discriminate the direction of the arrows in the target as rapidly as possible. The relevant mask consisted of superimposed double arrows; the irrelevant mask consisted of only vertical and horizontal lines (as in Lleras & Enns, 2004, Experiments 1 and 7). The following display sequence was used: One of two prime stimuli was presented at fixation for 15 ms, followed by one of the two masks in the same location for 100 ms, and then a blank interval of either 0 ms, 30 ms, 60 ms, or 100 ms followed before one of two target stimuli was presented for 100 ms. The only difference between conditions was that T appeared at fixation in one condition (PMT at fixation) and either above or below fixation by 1.5° in the other condition (PM only at fixation). If there are stimulus interactions when all stimuli appear at fixation, then the mask target interval should reveal their temporal dynamics.

The participants in the PMT-at-fixation group were also tested in a second session in which they were asked to discriminate the prime in a display sequence consisting only of PM at fixation. In a total of 120 trials (3 blocks of 40 trials), participants were able to detect the prime with 80% accuracy when followed by the irrelevant mask but only 44% accuracy when followed by the relevant mask.

Because 44% is less than the chance level of 50%, and because this level of accuracy was lower than what we had observed in our previous study (Lleras & Enns, 2004), where PM was never presented at fixation, we tested 44% against the chance guessing level of 50%. This difference was significant, $t(14) = 2.91, p < .05, MSE = .012, \eta^2 = .24$, indicating that participants were biased in the relevant mask condition to make a response that was opposite in direction to that of the prime. We interpret this as further evidence that the updated features in the relevant mask are positively biasing responses, in this case even in identifying the prime.

Results

Participants were very accurate (mean > 95%), and mean correct response time (RT) is shown in Figure 1. The most important finding was that RT priming differed, depending on whether T was in the same location as PM. In particular, priming with irrelevant masks differed most between conditions. Whereas priming with the irrelevant mask was positive for the PM-only-at-fixation condition (mean RT difference = 25 ms, $F(1, 15) = 21.81, p < .001; MSE = 831.24, \eta^2 = .61$), just as it was in our previous experiments where the target did not share the same location as the mask (Lleras & Enns, 2004), it interacted with the mask–target interval for PMT at fixation, $F(3, 42) = 4.13, p < .01, MSE = 131.23, \eta^2 = .23$. At a mask–target interval of 0 ms and 30 ms, there was

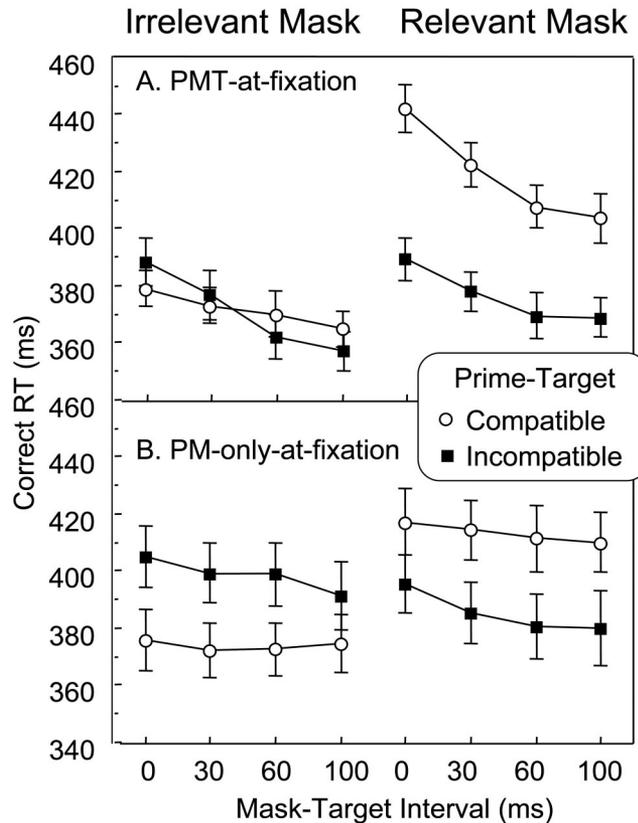


Figure 1. Correct response time (RT) as a function of prime–target compatibility, mask type, mask–target interval, and target location: (A) prime, mask, and target all at fixation; (B) prime and mask at fixation but target 1.5° either above or below fixation. Error bars represent plus and minus one standard error of the mean.

positive priming, $F(1, 42) = 4.73$, $p < .05$, $MSE = 131.23$, $\eta^2 = .10$, but when the mask–target interval was 60 ms and 100 ms, this became negative priming, $F(1, 42) = 6.90$, $p < .05$, $MSE = 131.23$, $\eta^2 = .14$.

For relevant masks, RT priming was negative for both conditions (PMT at fixation = -43 ms, $F(1, 14) = 170.07$, $p < .001$, $MSE = 319.38$, $\eta^2 = .92$; PM only at fixation = -27 ms, $F(1, 14) = 49.54$, $p < .001$, $MSE = 445.27$, $\eta^2 = .78$), and the negative priming was significantly greater in the PMT-at-fixation condition than it was for the PM-only-at-fixation condition, $F(1, 28) = 9.35$, $p < .01$, $MSE = 382.32$, $\eta^2 = .25$. The overall analysis of variance involving the between-participants factor of condition and the within-participant factors of prime–target compatibility (incompatible, compatible), mask type (irrelevant, relevant) and mask–target interval (0 ms, 30 ms, 60 ms, 100 ms) supported these conclusions with a significant four-way interaction, $F(3, 84) = 3.69$, $p < .02$, $MSE = 159.04$, $\eta^2 = .12$.

Discussion

Figure 1 reveals a stark contrast between priming with irrelevant masks (left column) and priming with relevant masks (right column). Whereas priming was negative with relevant masks regard-

less of target location, it was not always negative with irrelevant masks. In agreement with Lleras and Enns (2004), there was positive priming with irrelevant masks when PM and T were presented at different locations (Figure 1B). Recall that in Lleras and Enns (2004), PM was off fixation and T was at fixation—the exact opposite arrangement of stimuli still led to the same result.

This is an important finding because Klapp (2005) argues that Lleras and Enns (2004) failed to observe negative priming with irrelevant masks because PM was in the visual periphery. In direct contradiction to this, Figure 1B shows that strictly positive priming can indeed occur when irrelevant masks are presented at fixation. These data therefore highlight two main points. First, presenting primes and masks in the periphery is not the reason that Lleras and Enns (2004) observed positive priming with irrelevant masks. The present data show that large positive priming with irrelevant masks can occur when the prime and mask are at fixation.

The second noteworthy aspect of these data is the strong interaction between prime–target compatibility and the mask–target interval for irrelevant masks when PMT are all at fixation. Positive priming at short mask–target intervals reversed at longer intervals to become negative priming. Thus we, like Klapp, have obtained a negative priming effect with irrelevant masks but only when targets are also presented at fixation. To interpret this result, one must bear in mind that the only difference between these conditions is the location of T. Thus, the differences in priming cannot be attributed to differences in prime visibility, as Klapp argues. On the contrary, and in accordance with our hypothesis, the presence of PM at the same location as T influenced the speeded response to T. In our view, this points directly to the existence of perceptual interaction between the PM stimuli and the target stimuli.

We hasten to point out that we do not think that such interactions occur only with irrelevant masks; they likely also occur with relevant masks. In fact, it is noteworthy that the priming effects (incompatible RT – compatible RT) appear to be additive with regard to mask type (irrelevant, relevant) and target location relative to that of PM (same, different). Specifically, the presence of a relevant mask moved priming in a negative direction (i.e., faster incompatible trials) by 47 ms, on average, whereas having the target appear in the same location as the prime and mask moved priming in a negative direction by 20 ms, on average. An analysis of variance examining the RT priming effect as the dependent measure indicated that each of these main effects was significant—mask: $F(1, 28) = 125.46$, $MSE = 1047.09$, $\eta^2 = .82$; location: $F(1, 28) = 18.09$, $MSE = 1372.61$, $\eta^2 = .39$ —and that their interaction was not significant, $F(1, 28) = 1.38$, $MSE = 1047.09$, $\eta^2 = .05$.

This pattern of results points to the existence of possibly two independent factors that each contribute to the negative compatibility effect. If the large mask effect in these data (47 ms) is attributable to object updating, as both Klapp and we seem to agree, then the remaining question concerns the explanation of the smaller location effect (20 ms). One possibility is that it reflects an unconscious motor inhibition effect, as suggested by Klapp. However, we believe that it is premature to settle for that account when there are several other well documented phenomena that resemble the same effect and that do not appear to depend on unconscious motor inhibition. These include the more general negative priming effects of Tipper and colleagues (Leek, Reppa, & Tipper, 2003; Milliken, Tipper, Houghton, & Lupianez, 2000), the repetition

blindness effect¹ (Bavelier & Potter, 1992; Kanwisher, 1987; Whittlesea & Masson, 2005), and the rapid adaptation and contrast effects of Suzuki and colleagues (Suzuki, 2001; Suzuki & Cavanagh, 1997, 1998). All three of these effects seem critically dependent on focused visual attention to certain locations and task-relevant visual features. Also, whereas these effects may involve inhibitory effects at the level of perception and attention, they have not yet been shown to be dependent in any way on unconscious motor inhibition. In our view, future research will benefit greatly from attempts to dissociate these effects from the proposed unconscious motor priming of Klapp and colleagues.

Does Visibility Matter?

In conclusion, we would like to address the recurring issue of prime visibility. Whereas Klapp argues that prime visibility is a critical factor in determining the direction of priming, Lleras and Enns (2004) argued that these factors were not causally related. Our first point in this regard can be made with the new data in Figure 1 (Panel A vs. Panel B). Although prime visibility was held constant (PM was always at fixation), entirely different patterns of priming were obtained depending on the location of the target (A). Clearly, visibility differences are not at issue in these results.

We turn next to evidence in the literature on this point. We (Lleras and Enns, 2004) showed that negative priming occurred both at high and low levels of visibility for relevant masks (for high visibility, see Experiments 1–4; for low visibility, see Experiment 7). We also showed that positive priming could occur at both high and low levels of visibility for irrelevant masks (for high visibility, see Experiments 1, 2, and 7; for low visibility, see Experiment 3).

Klapp also cites Eimer and Schlaghecken (2002) as supporting the claim that “the NCE only occurred with low prime visibility” (Klapp, 2005, p. 432) and later adds that “high prime visibility can eliminate the NCE” (p. 433). But we note that this claim is based on a correlation of priming with the stimulus factor of mask density, not with any measured data on prime visibility. A quick glance at Figure 2 (top panel) in Eimer and Schlaghecken (2002) shows that when an NCE has been achieved (mask density larger than 5), NCE magnitude actually increases slightly from density = 10 to density = 15 and then remains quite stable (approximately 20 ms). These results are therefore entirely in keeping with the object-updating hypothesis (Lleras & Enns, 2004): If the mask is composed of intersecting slanted lines, these task-relevant features will likely interact with the prime and produce negative-compatibility priming. Moreover, if these features are present in the mask, density of the mask has little or no effect on priming (Lleras & Enns, 2004, Experiments 2, 3, and 4).

Regarding the evidence Klapp (2005) cites from Klapp & Hinkley (2002; Experiment 1), we note that the analysis of the magnitude of NCE by prime visibility was achieved with a post hoc criterion (55% accuracy) to divide participants into two groups: prime not visible and prime somewhat visible. The difference in NCE magnitude was then tested between these groups on three different testing days. There was a significant difference on one of these days and no difference on the other two days. Clearly, a more appropriate and sensitive analysis would involve a linear regression of individual NCE magnitudes on prime visibility measures. However, this has not been presented in previous reports.

The new data Klapp (2005) reports on this point are in Experiment 2, where irrelevant masks result in negative priming. Yet, mean accuracy in the prime discrimination phase of that experiment is still 69%. This level of accuracy suggests that the prime is still quite visible by the operations of Klapp and Hinkley (2002): Participants correctly identified the prime on more than two thirds of the trials, and yet, they still showed negative priming. It is therefore difficult for us to take this as evidence for a dissociable new form of negative compatibility called NCE-NP, especially for one that should manifest only when prime stimuli are invisible. In short, we are unable to find any evidence clearly linking prime visibility to a negative compatibility effect.

Conclusion

Neither our new data (see Figure 1) nor our consideration of the published literature supports Klapp’s (2005) proposal to distinguish between perceptual versus nonperceptual negative compatibility effects. Indeed, it seems that we agree that this paradigm involves both perceptual and motor priming. Where we disagree most strongly concerns whether there is a need to propose an unconscious inhibition of motor preparation. In our view, the new results point again to the possibility that perceptual interactions among the stimuli may be determining the pattern of response priming and that the motor priming that results from these interactions is positive. Seen in a broader perspective, these results are further evidence that discrete physical events should not be considered as discrete perceptual or psychological events, as seems to have been done by Klapp and others in this area. We look forward to further uses of masking as a tool that can reveal much more about perceptual processing than its role in reducing stimulus visibility.

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¹ Klapp (2005) dismisses the possibility that the NCE-NP could be due to repetition blindness because an NCE was observed in Experiment 2 of Klapp and Hinkley (2002), in which the prime was visual but the target auditory. However, that experiment used arrow stimuli (pointing either up or down) as primes, and the mask was the composite of the two potential prime stimuli. Further, targets were visual on half the trials (auditory on the other half) and the visual target stimuli were the same arrow stimuli used as primes. In other words, the mask was task relevant by Lleras and Enns’s (2004) definition, as it contained visual features associated with a possible motor response. Therefore, in Klapp’s terms, the NCE in that experiment was an NCE-P, as the prime and mask stimuli interacted to create motor preparation opposite to the prime. That the target was auditory is of little consequence because (a) auditory target trials were randomly interspersed with visual target trials, making the visual features of the prime and mask relevant to the task prior to target onset, and (b) the response modality was manual for both visual and auditory targets, and responses between modalities were highly compatible (e.g., high tones and upward-pointing arrows indicated the same response).

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