

The Influence of Subliminally Presented Primes on Response Preparation

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Summary: In a RT study the influence of masked prime stimuli on behavioral performance was investigated under different presentation conditions. Results suggested that primes that are not consciously perceived nevertheless trigger a response preparation that is later inhibited. Masked primes were presented prior to target stimuli. Primes were either identical to the target (compatible trials), or identical to a target mapped to the opposite response (incompatible trials). Mask-target SOA was varied in steps of 32 ms, ranging from 0 ms to 128 ms. Additionally,

stimuli were presented either at the center of fixation or peripherally. With short mask-target SOAs as well as with peripherally presented primes, RTs were slower on incompatible than on compatible trials. With longer mask-target SOAs and centrally presented primes, the reversed pattern of results was obtained. It is argued that the effects of the masked primes on motor activation reflect the activity of a visuomotor control system that utilizes stimulus information independent of conscious perception in order to prepare the appropriate response.

1. Introduction

1.1 Perception without awareness

Our conscious experience of the external world is based upon sensory impressions. We perceive integrated objects and coherent events on the basis of sensory information, that is, on the basis of sensory input sufficiently processed by various sensory systems. Thus the main task of these systems seems to be the continuous transformation of sensory input into a conscious experience of our surroundings. Moreover, we tend to regard this conscious experience as a prerequisite for any controlled action: If, for example, one wants to pick up a certain object, one has to identify it correctly, determine its position, orientation, and shape, prepare the appropriate hand movement, and so on. Thus it seems quite natural to regard conscious experience as a necessary outcome of sensory processing, indispensable for the planning and execution of controlled action.

However, there is some evidence that this view may not be entirely correct. The simplest examples are cases of automaticity, where complex actions are performed accurately without conscious awareness of the objects involved (e.g., driving a car while being engaged in a conversation). Of course in cases like these it is generally assumed that the surrounding was consciously perceived but unattended, not that it was unconsciously perceived. However, there are other examples indicating a true dissociation

between conscious perception and visually guided performance. Probably the most famous of these is the phenomenon of "blindsight": Some patients suffering from cortical blindness are able to perform correct pointing gestures toward a visual target in their blind area - but consistently report to be absolutely unaware of the existence of any visual stimulus in this region at all (cf., Weiskrantz, Warrington, Sanders, & Marshall, 1974).

Blindsight and other cases of deficient visual perception coupled with intact visuomotor performance observed in brain-damaged patients (e.g., Milner, Perrett, Johnston, Benson, Jordan, Heeley, Bettucci, Mortara, Mutani, Terazzi, & Davidson, 1991) indicate that visually guided behaviour is not necessarily dependent on conscious visual perception. Although these phenomena might also be interpreted in terms of specific attention deficits due to cortical lesions, this interpretation becomes increasingly problematic if one takes into account evidence for the same dissociation in normal subjects. For example, there are conditions where pointing gestures toward a stationary visual target are not influenced by experimental manipulations that affect the perceived position of the target (Brigdeman, Kirch, & Sperling, 1981), and grasping movements toward an object are very little influenced by manipulations that affect the perceived size of the object (Agliotti, DeSouza, & Goodale, 1995). Similarly, Goodale, Pellison, & Prablanc (1986) demonstrated adequate correction of an

aiming movement toward a target light that was displaced during saccadic eye movement, although participants did not detect the displacement. Finally, Fehrer & Raab (1962) found that the activation of a motor response does not depend upon conscious perception of the target at all, since simple RT in situations where the target was effectively masked turned out to be as fast as simple RT to an unmasked test stimulus. Recently, Neumann & Klotz (1994) have demonstrated analogous effects for choice RT: When visual targets appearing at the left or right were preceded by a subliminally presented prime occurring at the same position, RTs were found to be significantly faster than if they were preceded by a prime occurring at the opposite position.

1.2 The "two visual systems" approach

Taken together, these findings indicate that at least some kind of object-directed behaviour is possible without conscious awareness of (the relevant aspects of) the object in question. This notion seems quite puzzling, though: If the critical feature is not yet available to conscious perception, how can it guide the appropriate movements? And if, on the other hand, object-directed behaviour is prepared prior to and independently of conscious awareness, why do we have conscious visual perception at all? A possible explanation of this seemingly paradoxical situation is formulated in the "two visual systems" hypothesis of Milner & Goodale (1995), based on a distinction originally employed by Ungerleider & Mishkin (1982). The authors argue that there are two separate functions of vision: One is the construction of integrated representations necessary for object recognition ("visual perception"), the other one is the preparation and control of object-directed actions ("visuomotor control"). They propose that visual perception is mediated by a ventral processing stream that connects the primary visual projection areas with regions of the inferotemporal cortex, while a dorsal stream that projects from the primary visual cortex to the posterior parietal cortex is responsible for visuomotor control.

In terms of the model advocated by Milner & Goodale (1995), the findings reported above seem to be less puzzling. A direct link between sensory information and response parameters that is not mediated by conscious perception (termed "direct

parameter specification" by Neumann & Klotz, 1994) could be interpreted as a function of the visuomotor control system: Due to fast processing within the dorsal stream, information relevant for response preparation is already available to the motor system, even though within the ventral stream it has not been processed sufficiently to be available to consciousness. Consequently, the appropriate response can at least partly be activated prior to (and independently of) the conscious perception of the respective stimulus.

Following this line of reasoning, one may ask what kind of "information relevant for response selection" can be processed within the dorsal stream. Milner & Goodale (1995) propose that the visuomotor control system responds to all visual features relevant for object-directed behaviour, like location, size, and form. For stimulus location and stimulus size, the studies reported above gave some evidence in favour of this proposal. In a series of experiments (Eimer & Schlaghecken, in press), we were able to show that the form of a subliminally presented stimulus can also influence performance, as the identity of a efficiently masked stimulus systematically influences RTs and error rates in a choice RT task. These experiments will be shortly described in the next two sections: In section 2, the basic effect will be described, in section 3, some additional findings are presented. In section 4, an experiment is reported where the nature and more specifically the time course of this influence of masked primes on motor behaviour is further studied.

2. The inverse compatibility effect

In the experiments of Eimer & Schlaghecken (in press), masked primes and targets were presented successively at fixation, and responses were assigned to stimulus identity. For example, a right-hand reaction had to be given in response to an arrow pointing to the right, while an arrow pointing to the left required a left-hand response. Moreover, a specifically designed masking stimulus (see below) was added to prevent the conscious perception of the prime. Thus each trial consisted of three stimuli: First, the prime, consisting of either of the two target stimuli (" \ll " and " \gg ") or of a neutral (not response-related) stimulus (" \diamond " or " $>\ll$ "), was presented for 16 ms. The prime was then masked for 100 ms by a pattern mask (a superimposition of left-

and right-pointing double arrows). The mask was in turn immediately followed by a 100 ms presentation of the target. If prime and target were identical stimuli, the trial was termed "compatible", if the prime was mapped onto the opposite response, it was termed "incompatible". If a non-target stimulus was presented as prime, the trial was termed "neutral". In addition to the behavioural data, the Lateralized Readiness Potential (LRP), a continuous electrophysiological measure of motor activation, was recorded (for details of LRP measurement see Coles, Gratton, & Donchin, 1988; Coles, 1989; Eimer, in press). In order to test whether prime stimuli were in fact presented subliminally, Forced Choice (FC) performance blocks, where participants were asked to indicate the identity of the masked primes, were run at the end of the experiment. Effects of prime stimuli on visuomotor control were expected to be reflected in performance benefits for compatible trials (faster RTs and fewer errors as compared to the neutral condition), whereas performance costs (slower RTs and more errors) should arise in incompatible trials. Moreover, a specific pattern of LRP data was expected: An early activation of the correct response on compatible trials, an initial activation of the incorrect response on incompatible trials, and no such effects on neutral trials.

As predicted, prime-target compatibility had a strong influence on RTs and error rates in this experiment, although the result of the FC test, where discrimination performance was at chance level, confirmed that the direction of the prime was efficiently concealed. However, the direction of this influence was exactly opposite to what had been expected: Compared to neutral trials, RTs were about 35 ms slower and significantly more errors were made on compatible trials, while on incompatible trials, RTs were about 20 ms faster and significantly less errors were made (see Fig. 1, top panel).

In accordance with these behavioural data, the LRP waveforms show that the target-related lateralization starts very early on incompatible trials, late on compatible trials, and with an intermediate latency on neutral trials (see Fig. 1, bottom panel). Although these results were surprising, a closer inspection of the LRP waveforms reveals a possible mechanism underlying the observed effects: During a very early phase - starting around 200 ms after prime onset - the LRPs for compatible and incompatible trials show a small but significant latera-

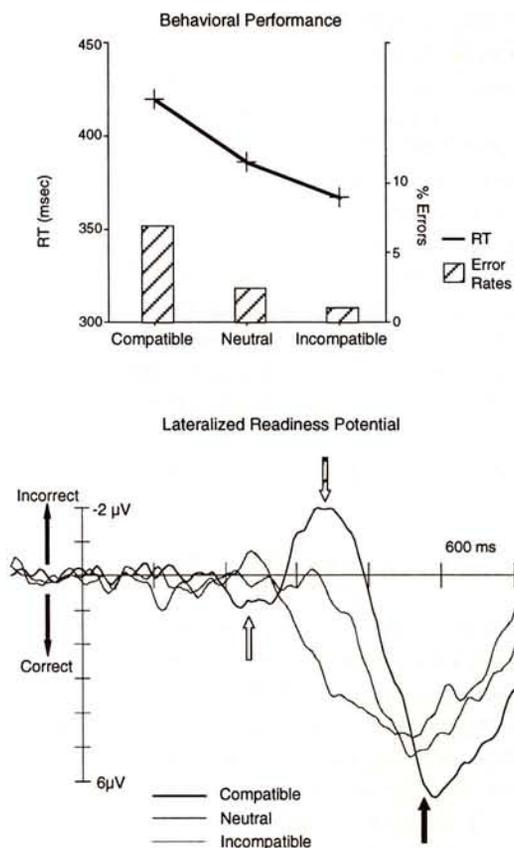


Figure 1: Behavioral data and LRP waveforms measured in an experiment (Eimer & Schlaghecken, in press, Experiment 1a) where left-pointing or right-pointing target arrows were preceded by compatible, neutral, or incompatible masked primes (see text for details). Top panel: Mean response times (line graphs) and error rates (bar graphs) obtained in compatible, neutral, and incompatible trials. Bottom panel: Grand mean lateralized readiness potential waveforms recorded in the interval between prime onset and 600 msec after prime onset for compatible, neutral, and incompatible trials. Downward-going deflections indicate the activation of the correct response (the response assigned to the target stimulus), upward-going deflections indicate the activation of the incorrect response. Arrows indicate the three activation phases visible in the LRP obtained for compatible trials: Initial activation of a prime-related response (white arrow), reversal phase, resulting in an activation of a response opposite to the prime direction (hatched arrow), and target related response activation (black arrow).

lization in the direction of the prime-related response (that is, a correct lateralization on compatible trials, and an incorrect one on incompatible trials). Shortly thereafter, this lateralization is replaced by an pre-activation of the opposite re-

sponse. On compatible trials, this second lateralization has to be reversed again in order to activate the correct target-related response. On incompatible trials, on the other hand, the second lateralization is already in the direction of the correct target-related response. Thus while on compatible trials the target-related activation is delayed due to the reversal phase, on incompatible trials, the target-related activation benefits from this phase. In a series of follow-up experiments (Eimer & Schlaghecken, in press) described briefly below, we tried to address some of the questions arising from this rather unexpected pattern of results.

3. More details about the incompatibility effect

3.1 Automatic vs. instruction dependent activation

In order to test whether the initial prime-related activation occurs automatically in response to arrow stimuli or only when primes are associated with a response, an experiment was conducted where letter pairs "LL" and "RR" served as targets and required a left-hand or right-hand response, respectively. In all other respects, the design was identical to the basic experiment. If the effects described above were due to the specific S-R pairings as determined by the instruction, no RT effects of prime-target compatibility should be present at all. If, in contrast, left-pointing and right-pointing arrows activated their corresponding responses automatically, essentially the same results as before should be obtained. As it turned out, the evidence is in favour of the former hypothesis: RTs were identical in all three conditions (compatible, incompatible, and neutral), and no differential influence of the prime on the LRP waveforms was observed. Thus it can be concluded that the early activation phase observed before was due to the specific S-R pairings as determined by the instruction.

3.2 Mask-induced activation vs. response suppression

Of course the most puzzling effect observed in the basic experiment is the reversal of the initial response activation visible in the LRP waveform for compatible trials. There are several possible explanations for this phenomenon. For example, the

reversal may occur because of induced motion: Replacing, for example, a left-pointing arrow with a superimposition of a left- and a right-pointing arrow may result in the perception of a movement to the right, which in turn may activate a right-hand response. However, the incompatibility effect was replicated in an experiment where symmetrical stimuli (" \diamond ", "<math>>") were used as primes and targets, thus ruling out the induced motion hypothesis. A related assumption was that the prime acts as a forward mask for the masking stimulus, rendering those parts of the mask that correspond to the prime less visible. As a result, participants may confuse mask and target stimulus, responding to that part of the mask which is not affected by the prime. This explanation, too, was ruled out: Under conditions where the mask did not bear any similarity to prime and target stimuli ("oo" and "++" as primes and targets, and letters "SS" and "ZZ" superimposed upon one another as mask) the incompatibility effect nevertheless remained.

3.3 Selective activation vs. selective inhibition

From these results it was concluded that the reversal phase has to be regarded as the result of a specific mechanism involved in suppressing a previously pre-activated movement. However, the question remains whether this suppression is performed via an activation of the alternative response or via an inhibition of the previously activated one. Since the LRP only indicates the relative strength of lateral activation, on the basis of the data reported so far one cannot decide between the possibilities that the reversal is due (i) to a selective inhibition of the initial response activation, (ii) to a selective activation of the opposite response, or (iii) to a combination of both due to a specific coupling of the left and right hand. If assumption (iii) is correct, the incompatibility effect should not occur under conditions where the responses are mapped to two fingers of the same hand (Single Hand condition). If assumption (ii) is correct, the Single Hand condition should yield the same results as the basic experiment, but under conditions where only one target requires a response while the other one acts as Nogo stimulus (Single Finger condition), no incompatibility effect should occur. If, finally, assumption (i) is correct, the incompatibility effect should be observed in both experimental conditions. A RT ex-

periment testing these assumptions revealed that the incompatibility effect remained regardless of these experimental manipulations (Eimer & Schlaghecken, in press). Thus the data obtained so far are clearly in favour of the hypothesis that the reversal phase results from specific inhibition of a previous response preparation.

3.4 Prime detection performance

In order to test whether participants were unable to consciously perceive the prime stimulus, different FC procedures were adopted in the experiments reported above. Under present/absent instructions, participants had to decide whether there was a prime preceding the masking stimulus at all, while under identification instructions there was always a prime, and participants had to respond to its identity. Only primes and masks were delivered in order to facilitate prime detection / identification. However, in all experiments reported above FC performance was at chance level, indicating that the prime-related response preparation occurs without any conscious awareness of the the prime.

4. The time course of the incompatibility effect

4.1 Introduction

From the pattern of alternating lateralizations observed in the LRP waveforms it seems quite suggestive to explain the incompatibility effect as resulting from an initially activated and later inhibited prime-related response. However, the data reported so far give only indirect evidence for this assumption, since the LRP, as noted above, is an index only for the relative strength of an unimanual response activation. Thus it has yet to be demonstrated that the lateralization starting around 200 ms after prime onset really represents the activation of a response to a prime that has not even been consciously perceived.

One way to test the activation/inhibition hypothesis more directly is to investigate the time course of the incompatibility effect. If the early lateralization phase is due to prime-related response activation, a target-related response activation starting during this period should be influenced in the following way: On compatible trials (prime and target

mapped onto the same response), target-related response activation should benefit from the already initiated response activation, while on incompatible trials (prime and target mapped onto opposite responses), target-related response activation should be delayed. In short, with target-related response activation starting during the initial lateralization phase, a "normal" compatibility effect should occur, leading to shorter RTs on compatible and on longer RTs on incompatible trials. If, on the other hand, the initial phase does not represent prime-related response activation, no such influence of target-related response onset on RT is to be expected. In principle, there are two ways to manipulate the target-related response onset relative to the prime: Either the response onset is "moved back" towards the initial phase of response activation by shortening the prime-target SOA, or the initial response activation phase is delayed by rendering perceptual analysis of the prime more difficult. Both methods were employed in the experiment reported below. On the one hand, prime-target SOA was varied in 32ms-steps from 0 ms to 128 ms. It was expected that with short SOAs (0 ms, 32 ms), a compatibility effect should be obtained, while with long SOAs (96 ms, 128 ms), an incompatibility effect should occur. On the other hand, the difficulty of perceptual analysis of the prime was manipulated by presenting the masked prime either at the center of fixation or peripherally, 2.8° above or below fixation. If the duration of the perceptual analysis of the prime was affected by this manipulation, with peripheral primes compatibility effects should occur even for longer prime-target SOAs.

However, with this manipulation the problem of how to compare both conditions arises: If primes and targets were both presented at the same location, perceptual analysis of the targets, too, may be delayed in the peripheral presentation condition, and this may obscure any systematic influence of prime position. If, on the other hand, targets were always presented centrally, the spatial separation of primes and targets may influence the perceptual processing of the prime. To circumvent this problem, all four possible combinations of prime-target locations were employed in the present experiment: In the "central-central" ("cc") condition, prime and target stimuli both appeared at fixation, in the "peripheral-peripheral" ("pp") condition, prime and target stimuli both appeared 2.8° above or below the center of fixation. In the "central-peripheral" ("cp")

condition, primes appeared at fixation, while targets appeared 2.8° above or below the center, whereas in the “peripheral-central” (“pc”) condition, primes appeared 2.8° above and below the center, while targets appeared at fixation. Prime and target location, prime-target SOA and prime-target compatibility were varied independently of one another. In order to allow for the variation of prime-target SOA without changing the overall properties of the stimuli, each target stimulus consisted of two double arrows, one shifted slightly to the left, the other one shifted slightly to the right side, leaving a gap between them which was filled exactly by the prime and mask stimuli. This manipulation made it possible to present mask and target independently of one another, varying the SOA without changing the critical prime / mask relation.

Additionally, a FC procedure was employed in the present experiment that was slightly different from the procedures described above. Previously, no target stimuli were presented in the FC blocks because it was assumed that participants may get confused when confronted with a clearly visible stimulus while required to respond to a less visible one, resulting in a FC performance that is lower than the actual prime detection performance. Thus omitting the target stimulus was thought of as enhancing FC performance. However, this procedure may have had quite the opposite effect: It seems possible that during the experimental blocks the target stimulus acted as a mask for the masking stimulus, thus rendering the prime more visible, while during the FC blocks, the now unmasked masking stimulus effectively prohibited prime detection. In order to test more directly whether the effects described above can be attributed to the influence of a prime that has not been consciously perceived, in the FC blocks employed in the present experiment, a target stimulus was delivered on each trial, rendering the FC presentation conditions as similar to the experimental presentation conditions as possible.

4.2 Method

Participants

10 paid volunteers (5 male), aged 20 - 37 years (mean age: 24.9 years) participated in the experiment. All participants were right-handed and had normal or corrected-to-normal vision.

Stimuli and apparatus

As in the basic experiment, left- and right-pointing double arrows (“<<” and “>>”) served as prime stimuli, and the mask was constructed via superimposing these stimuli upon one another. The target consisted of two pairs of left- and right-pointing double arrows (“<< <<” and “>> >>”), spaced appropriately to allow prime and mask to fit exactly into the central gap. All stimuli were presented in black on a white background on a 17” computer screen. Stimuli subtended a visual angle of approximately 1.15° x 0.4°. For the target stimuli, each pair of double arrows was horizontally displaced 1.15° to the left or right, respectively. In the “pp” condition, an additional fixation cross was delivered, subtending a visual angle of approximately 0.4° x 0.4°. Stimuli appeared either at fixation or 2.8° above or below fixation.

Procedure

Participants were seated in a dimly lit, electrically shielded and sound attenuated chamber, with response buttons under their left and right index fingers. A computer screen was placed 100 cm in front of the participants’ eyes, carefully positioned so that the screen center was in the center of the participants’ horizontal straightahead line of sight. Participants were instructed to maintain central eye fixation and to respond as fast and accurate as possible. Regular experimental blocks consisted of 80 trials, each consisting of the presentation of a prime stimulus (16 ms duration), followed by a mask (100 ms duration) and the target stimulus (100 ms duration). Left-pointing target arrows required a left button press, right-pointing target arrows required a right button press. Trials were termed “compatible” if prime and target consisted of arrows pointing to the same direction, and “incompatible” otherwise. Both conditions were equiprobable and completely randomized. Mask-target SOAs were blocked and were either 0 ms, 32 ms, 64 ms, 96 ms, or 128 ms. The intertrial interval was 1 s.

Different prime-target location combinations “cc”, “pp”, “cp”, and “pc”) were also blocked. Since each of the 5 SOAs was combined with each of the 4 prime-target location combinations, there was a total of 20 different location/SOA-combinations, each of which was delivered in a separate block.

Each block was presented twice, resulting in a total of 40 regular experimental blocks. The order in which these blocks were delivered was determined as follows: First, all 20 blocks with identical location of prime and target ("cc" and "pp") were grouped together (group "i"), as were all 20 blocks with different location of prime and target ("cp" and "pc"; group "d"). Second, groups were divided into halves of 10 blocks each, such that within each half there was exactly one block of any given location/SOA-combination (resulting in experimental parts i1, i2, d1, and d2). Within each experimental part, the order of delivering the 10 different location/SOA-combination blocks was randomized for each subject individually. Finally, half of the subjects were given the experimental parts in the order "i1"- "d1"- "i2"- "d2", for the other half, the order was "d1"- "i1"- "d2"- "i2".

At the end of the experiment, four FC blocks were added, resulting in a total of 44 experimental blocks. In each of the FC blocks, half of the trials consisted of prime, mask, and target ("present" condition), while the other half consisted of mask and target only ("absent" condition). Participants were informed about the existence of the masked prime and were told that on 50% of the trials no prime occurred. They were instructed to press the right response button in case they thought they noticed a prime and to press the left response button otherwise. In order to investigate whether the different location/SOA-combinations may have had a differential influence on prime detectability, in one of the FC blocks "present" trials were identical to the cc-0 condition (prime, mask, and target presented centrally, mask-target SOA 0 ms), in another one they were identical to the cc-128 condition (prime, mask, and target presented centrally, mask-target SOA 128 ms), in a third one "present" trials were identical to the pp-0 condition (prime, mask, and target presented peripherally, mask-target SOA 0 ms), and in the last one they were identical to the pp-128 condition (prime, mask, and target presented peripherally, mask-target SOA 128 ms).

Data Analysis

For each of the two prime positions (central, peripheral), a separate repeated measures ANOVA was performed for the factors SOA (0 ms, 32 ms, 64 ms, 96 ms, and 128 ms), TARGET LOCATION (cen-

tral, peripheral), and prime-target COMPATIBILITY (compatible, incompatible). Where appropriate, Greenhouse-Geisser adjustments to the degrees of freedom were performed (indicated in the result section by ϵ). Pairwise comparisons between the RTs for compatible and incompatible trials were conducted with paired t-tests. For the FC blocks, paired t-tests were employed to test whether the participants' detection performance was significantly different from chance. Additionally, a repeated measures ANOVA with the factors PRESENCE (present, absent), prime-target COMPATIBILITY (compatible, incompatible), LOCATION (central, peripheral), and SOA (0 ms, 128 ms) was performed in order to test whether there was any systematic influence of the target stimulus on prime detection performance.

4.3 Results

Central Primes

As can be seen from Fig. 2 (top panel), RTs were faster on compatible than on incompatible trials with short SOAs, while with long SOAs, this relation was reversed. This was reflected in a significant interaction of COMPATIBILITY \times SOA ($F(4,36) = 17.96, p < .001, \epsilon = .678$), while neither the main effect of COMPATIBILITY nor the main effect of SOA approached significance. There was, however, a main effect of TARGET LOCATION ($F(1,9) = 176.39, p < .001$), as RTs were generally much faster in blocks where targets appeared at fixation. Additionally, there was a three-way interaction of COMPATIBILITY \times SOA \times TARGET LOCATION ($F(4,36) = 12.65, p < .001, \epsilon = .661$), probably due to the fact that the rather large effects observed in the "cc" condition were almost absent in the "cp" condition. Paired t-tests confirmed these findings: With central targets, there were significant compatibility effects for short SOAs (0 ms: $t(9) = -4.42, p < .002$; 32 ms: $t(9) = -5.33, p < .001$) as well as significant incompatibility effects for long SOAs (96 ms: $t(9) = 5.30, p < .001$; 128 ms: $t(9) = 6.41, p < .001$). With peripheral targets, on the other hand, no comparison approached significance (all $t < 2$).

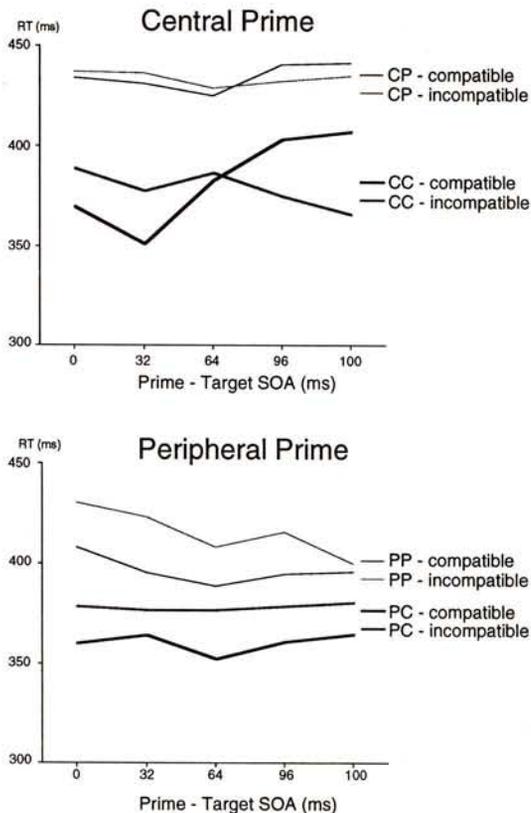


Figure 2: Top panel: Response times obtained in compatible and incompatible trials in response to arrow targets following a centrally presented masked prime. Thick lines represent central target condition, thin lines peripheral target conditions. Bottom panel: Response times obtained in compatible and incompatible trials in response to arrow targets following a peripherally presented masked prime. Again, thick lines represent central target conditions, thin lines peripheral target conditions.

Peripheral Primes

Contrary to the central prime condition, there was a significant main effect of COMPATIBILITY ($F(1,9) = 30.15, p < .001$), as with both presentation conditions and all five SOAs, RTs to compatible trials were faster than RTs to incompatible trials. Additionally, there was also a main effect of TARGET LOCATION ($F(1,9) = 30.06, p < .001$), since RTs were again faster in blocks where targets appeared at fixation. Moreover, the two-way interaction COMPATIBILITY \times SOA reached significance ($F(4,36) = 3.65, p < .032, \epsilon = .649$), as compatibility effects tended to become smaller with longer SOAs. Finally, there was a three-way interaction of COMPATIBILITY \times SOA \times TARGET

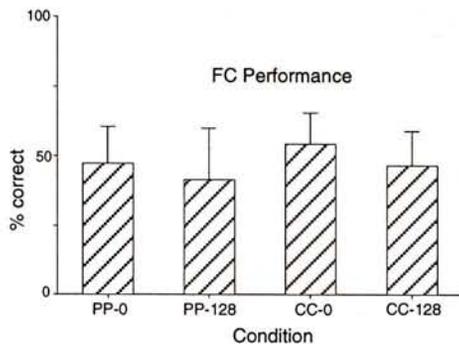


Figure 3: Percentage of correct prime detections in the Forced Choice performance blocks for the four different location / SOA conditions (peripheral presentation, 0 ms SOA; peripheral presentation, 128 ms SOA; central presentation, 0 ms SOA; and central presentation, 128 ms SOA). Lines indicate standard deviation.

LOCATION ($F(4,36) = 3.54, p < .034, \epsilon = .661$). Paired t-tests revealed that with central targets there was a significant compatibility effect at each SOA (all $t > 2.6$, all $p < .029$), while with peripheral targets, there was no effect at the 128 ms SOA ($t < 0.6$).

Forced Choice

As can be concluded from Fig. 3, prime detection performance was at chance level for all four conditions (all $t < 1.45$).

The repeated measures ANOVA revealed no main effect of COMPATIBILITY, LOCATION, or SOA on FC detection performance, and no interaction between these factors. However, there was an almost significant effect of PRESENCE ($F(1,9) = 5.08, p < .051$), as participants were more often correct on "absent" than on "present" trials (that is, there was a slight tendency towards "absent" responses).

4.4 Discussion

The aim of the present experiment was to investigate the time course of the incompatibility effect observed in previous studies. It was assumed that this effect is due to a tri-phasic pattern of alternating response activations: First, a response to the prime is initiated, second, this lateralization is reversed,

reflecting an inhibition of the initial activation, and third, the final target-related response is activated. In order to test the response activation/inhibition hypothesis more directly, the influence of the initial activation on behavioral performance was investigated. It was hypothesized that if the target-related response is activated within the time interval where the response triggered by the prime is still partially active, this should lead to faster RTs in compatible and to slower RTs in incompatible conditions. This pattern was indeed observed: When target-related response activation started early because of short prime-target SOAs, a significant compatibility effect occurred at least for centrally presented targets, while with long SOAs, the incompatibility effect described above was obtained again. With an intermediate SOA, no RT difference between compatible and incompatible conditions occurred. Additionally, when prime-related activation was manipulated by rendering the perceptual analysis of the prime more difficult (peripheral conditions), again the incompatibility effect was replaced by a compatibility effect.

However, under these latter conditions the observed pattern of results did not quite turn out as expected. It was assumed that rendering perceptual analysis of the prime more difficult would lead to delayed prime-related activation. Consequently, it was expected that in the peripheral prime / central target / short SOA condition target identification should precede prime identification. Under these conditions no RT effect whatsoever should occur, since target-related response activation should start prior to or simultaneously with prime-related response activation. Thus the finding of a significant compatibility effect for the short SOA condition may indicate that shortening the prime-target SOA on the one hand, and rendering the prime more difficult to identify on the other, are not equivalent manipulations, but rather influence different processes. One could assume, for example, that with peripheral presentation the effect of the prime stimulus is not so much on motor but mainly on sensory processing stages, facilitating the identification of similar (i.e., compatible) targets and/or rendering the identification of dissimilar (incompatible) targets more difficult. However, the FC performance gave no evidence that stimulus location or mask-target SOA had any influence on prime detectability, since prime detection was at chance level in all four FC conditions. Thus one has to

assume that if there was any influence of peripherally presented masked primes on sensory processing stages, those effects would also be independent of the conscious awareness of the prime stimuli. Of course, on the basis of the present data this reasoning has to remain highly speculative.

5. Concluding remarks

In this paper we discussed the influence of subliminally presented primes on response preparation. Numerous studies have shown that at least to some degree a successfully controlled object-directed behaviour is possible without conscious awareness of the critical features of the objects involved. These findings challenge the view of conscious perception as a prerequisite for appropriate and successful response selection. Instead, Milner & Goodale (1995) have proposed the existence of a specific stream of visual processing responsible for visuo-motor control that is independent of conscious visual awareness.

In a series of experiments designed to test whether the Milner & Goodale (1995) model applies to situations where response selection has to be performed on the basis of stimulus identity (Eimer & Schlaghecken, *in press*), it was found that efficiently masked primes caused RTs to be slower on trials where prime and target were compatible (mapped onto the same response), and faster on trials where they were incompatible. A tentative explanation of this rather unexpected finding was given on the basis of LRP data, showing a tri-phasic pattern of alternating lateralizations. It was presumed that these lateralizations reflect a sequence of prime-related response activation, inhibition of the initial preparation, and finally target-related response activation.

The experiment described above was designed to test this assumption more directly. We were especially interested in whether the initial lateralization phase really represents prime-related response activation: If there is a prime-related activation, starting the target-related response during this phase (i.e., prior to the reversal phase) should result in a "normal" compatibility effect, because on compatible trials prime-related activation and correct target-related activation both require the same direction of lateralization. This hypothesis was confirmed by the results: When target-related activa-

tion began during the initial lateralization phase (due to short prime-target SOAs), the subliminal prime caused a compatibility effect, while in situations where target-related activation started substantially after the first lateralization phase, again the incompatibility effect was observed. Moreover, with an intermediate SOA (causing the target-related activation to begin after the initial lateralization, but prior to the reversed lateralization), no compatibility effect of the masked prime on RT occurred. Together with the finding that participants were not able to perceive the prime stimulus consciously, as evidenced by the FC performance, it can be concluded that the present experiment supports the notion of a visuomotor control system (Milner & Goodale, 1996) that utilizes stimulus information rather quickly in order to prepare the appropriate response - independent of and in fact prior to the conscious perception of the stimuli in question.

Finally, it should be noted, that this kind of unconscious information processing is different from cases of automaticity: In the example given in section 1.1, the lack of conscious awareness is due to a lack of attention towards the objects in question. In the experiments described here, on the other hand, the masked prime was not consciously perceived even under conditions where participants attended to the prime location. However, although FC performance revealed that no conscious perception of the prime stimulus was possible, the finding that prime-target compatibility had an influence on RT even under conditions where target-related response activation was supposed to start prior to prime-related response activation ("peripheral prime, central target, short SOA" condition) may indicate that not only motor preparation processes, but also sensory processes are involved in producing the observed effects. Thus the influence of subliminally presented primes on sensory processing stages as

well as the the role of attention in this type of information processing require further investigation.

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