

# Control of Attention by Nonconscious Information: Do Intentions Play a Role?

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**Abstract.** The present study explores the deployment of attention towards non-conscious information. It is both theoretically and empirically likely that the deployment of attention can be controlled by information which is not consciously registered (attentional priming), similar to the control of sensorimotor responses by nonconscious information (response priming). However, not much is known about the functional basis of attentional priming. The present experiment explore whether and how strongly intentions (current action plans) determine whether attention is allocated towards invisible information (so called direct parameter specification). The results demonstrate that intention-mediated control is possible, but it seems to break down easily, that is to provide a weak and non-robust type of control .

**Keywords:** visuo-spatial attention, metacontrast, masking, intention, direct parameter specification, perceptual latency, priming

## 1 Introduction

The assumption that a precondition of conscious perception of a stimulus is that this same stimulus has been attended to is common in theories of visual awareness. It allows an interesting prediction: It should be possible to control the deployment of visuo-spatial attention by information which itself is not consciously perceived.

This possibility has been tested in several recent studies and yielded interesting results. For example, McCormick (1997) studied costs and benefits of a peripheral cue on response times. Peripheral cues—abruptly onsetting, mostly visual stimuli—are commonly assumed to capture attention towards their location. This leads to benefits in discrimination of or responding to a stimulus which appears at this location. On the other hand attention produces costs if the relevant stimulus appears at another location (e.g., Posner, 1980). McCormick observed that such costs and benefits were independent of whether the participants were aware of the peripheral cue. In an ‘unaware’ condition, the peripheral cue was of low contrast and the observers could not reliably report its presence. Nevertheless, it speeded response times if it correctly predicted the location of the target, and increased response times if it appeared at a different location. Such costs and benefits are typically ascribed to visuo-spatial attention.

Jaśkowski, van der Lubbe, Schlotterbeck, and Verleger (2002) used a more powerful means of excluding a stimulus from conscious perception, namely *metacontrast*



*masking*. Metacontrast is a type of visual backward masking in which the mask laterally adjoins the masked stimulus (Breitmeyer, 1984). For example, a disk could be masked by a ring, or a bar by two flanking bars. With onset intervals of about 40 to 80 ms, the masked stimulus often is perfectly invisible. In the study of Jaśkowski and coworkers, conscious perception of the masked stimulus was at chance level. As dependent variable, the authors measured event-related potentials. Although there was no clear evidence for deployment of attention to the masked stimulus, they found that the posterior contralateral negativity—a lateralized difference in the event-related potentials that indicates selection of a contralateral target—lacked if the masked stimulus correctly predicted the location of the target in the mask. By contrast, attentional selection as indicated by the posterior contralateral negativity was necessary if the target in the masked and in the masking stimulus were on opposite sides. Thus, the masked stimulus left a ‘trace’ on visual selective attention.

As Jaśkowski and coworkers, Scharlau and Neumann (2003a) used metacontrast masking for preventing perceptual awareness of a visual stimulus. They assessed the influence of attention with a perceptual measure, perceptual latency priming. This method relies on the finding that attending to a stimulus or its location speeds up its processing and thus shortens its latency. This “prior entry” of an attended stimulus has been studied extensively in the 19<sup>th</sup> and early 20<sup>th</sup> century (e.g., Titchener, 1908; Wundt, 1887) and has recently again gained interest (e.g., Rorden, Mattingley, Karnath, & Driver, 2002; Shore, Spence, & Klein, 2001; Stelmach & Herdman, 1991).

In the paradigm used by Scharlau and Neumann (2003), attention is drawn to a location by a peripheral visual stimulus, the so-called *prime*. This prime is after a short interval masked via metacontrast by a target appearing at its location. The perceptual latency of this target is compared with that of an unprimed target appearing at a different location. The authors found a robust facilitation of the primed target’s latency. Yet, the observers were unable to discriminate the features of the prime and could barely detect its presence. This phenomenon is called *perceptual latency priming*.

Attentional processing of masked or nonconscious information is a new paradigm, and much of its functional basis remains to be understood. At present, insights might be gained from related fields, such as sensorimotor processing of masked information (response priming). Such an attempt seems to be justified by a wealth of findings showing that the control of attention might be mandatorily coupled to the control of responses, especially saccades (e.g., Bekkering & Neggers, 2002; Deubel & Schneider, 1996), that is, it might rest on a similar functional basis.

One exciting finding with respect to sensorimotor processing of masked visual information is that it depends on *current intentions* of the observer. Ansorge and Neumann (2005) found that appropriate intentions were necessary to produce sensorimotor priming effects. They demonstrated that primes whose colour was different from those of the targets—that is, which were not expected or intended by the observers—did not affect the responses to the targets. Similarly, Klotz and Neumann (1999) observed that the effect of a masked prime shape to responses to visible targets was largely reduced and indeed statistically not reliable if the participants continually and randomly had to change the stimulus-response-mapping, that is, their intentions.

Such findings can be explained by the model of *direct parameter specification* (Neumann, 1990). This model combines three important assumptions. First, information can be processed in the visuo-motor system without being consciously perceived.

This processing route leads directly from sensory input to motor output and bypasses conscious control ('direct specification'). Possible motor parameters which can be specified include pointing direction (Schmidt, 2002), button presses (Klotz & Neumann, 1999), or pronouncing words (Ansorge, Klotz & Neumann, 1998). Second, this specification is not automatic. The responses studied in this domain are artificial behaviours depending on specific instructions to the human observers.

Third, such "direct specification" of response parameters is possible only under specific conditions. Most importantly, the sensory information has to meet a pre-established action plan which identifies how to respond to this information. For example, masked primes may activate left-hand or right-hand responses in a given experimental setting. Yet, they do so only under the condition that they match the current intentions of the observer. For example, if the observer has to respond to a red target with a left-hand response and to a green target with a right-hand response, a masked red prime will activate and eventually trigger a left-hand movement and a green prime will activate or trigger a response with the right hand. A yellow or blue prime, however, will trigger neither response, because it is not part of the action plan.

In sum, direct parameter specification predicts a specific pattern of empirical results. First, masking must not damage the impact of a stimulus on sensorimotor processing. Second, only information which matches current criteria specified in the action plan elicits priming. The present paper is concerned with the second prediction. Will any abrupt-onset prime capture attention, as earlier results (e.g., Scharlau & Neumann, 2003) suggest? Or will primes capture attention only if they match the action plan or intentions, as the model of direct parameter specification suggests?

Indeed, in a recent study, Scharlau and Ansorge (2003) reported that attentional allocation towards nonconscious primes was mediated by the current intentions. In their experiments, the observers judged the temporal order of two targets defined by colour, for example red and blue, while ignoring further distractor stimuli of, for instance, yellow colour. Blue and red primes elicited latency facilitation, which indicates that they attracted attention. Yellow primes, however, entailed only a small latency benefit which was not statistically different from zero. Unfortunately, there was a confound in the study of Scharlau and Ansorge: Matching primes had the same colour as the primed target (e.g., blue prime and blue target), distractor primes always had a different colour (e.g., yellow prime and blue target). Thus, the DPS-like pattern in the results might also be explained by a further factor, speeded processing of repeated information or perceptual priming. The present study attempts to remove this confound and explore direct specification of attention shifts further.

## 2 Experiment 1

The present experiments explore whether attention is controlled by non-conscious information depending on and in accordance with current intentions of the observer. Attention is assessed via its facilitating influence on the perceived latency of an attended stimulus (as compared to an unattended stimulus). In advance of one target, a prime is presented which—if it captures attention to its location—should shorten the perceptual latency of the later target trailing at this location (perceptual latency prim-



ing). The match of the prime to the current intention is varied. It either corresponds to the target set (*intention-matching prime*) or it resembles a distractor set (*non-matching prime*). In order to study whether perceptual similarity influences the amount of priming, the matching prime is either *similar* (feature of the target at the same location) or *dissimilar* (feature of the other target). If, for example, the participants have to judge red and blue targets and ignore yellow distractors, in the matching/similar condition, a red target is preceded by a red prime, and a blue target by a blue prime, in the matching/dissimilar condition, a red target is preceded by a blue prime and a blue target by a red prime, and in the non-matching condition, the red target as well as the blue target is preceded by a yellow (distractor-coloured) prime.

The most powerful proof of DPS would be a large effect of the intended prime, irrespective of similarity, combined with no effect of the non-matching prime. Quantitatively, the size of perceptual latency priming by a matching prime should be approximately half of the onset interval between prime and primed target (Scharlau & Neumann, 2003). The DPS account would be most strongly supported if the non-matching prime had no influence at all, but it suffices if the non-matching prime elicited reliably less perceptual latency priming than matching primes.

## 2.1 Participants, Apparatus, Stimuli, and Procedure

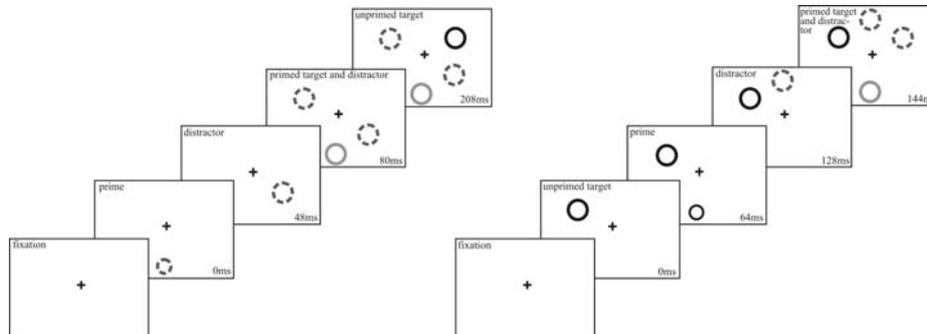
Fourteen voluntary naïve participants with normal or corrected-to-normal visual acuity (9 female; mean age 28 years) gave their informed consent and received € 4 or course credits.

Participants sat in a dimly lit room. Their head rested on a chin rest, their line of gaze was straight ahead, and viewing distance was fixed at 60 cm. Stimuli were presented on a 17 in. colour monitor with a refresh rate of 60 Hz. The participants responded by pressing either the left or the right key of a mouse.

Targets were rings with a diameter of  $1.9^\circ$  of visual angle. Primes were smaller rings which fitted into the inner contours of the targets ( $1.3^\circ$ ). The stimuli were presented in three colours: yellow, red, and blue. For each participant, one of the colours was chosen as the distractor colour and had to be ignored. Distractor and target colours were balanced across participants. The stimuli were presented on 6 positions on an imaginary circle presented around fixation ( $11^\circ$  diameter). In each trial, 4 stimuli were shown, two distractors and two targets of different colour. In three quarters of the trials, a masked prime was shown in advance of one of the targets at the same location. It was either matching/similar, matching/dissimilar, or non-matching. In the remaining quarter of the trials, there was no prime.

Target intervals (onset asynchronies between the two targets) were  $-128$ ,  $-64$ ,  $+64$ , and  $+128$  ms. Negative numbers indicate that the primed target was presented in advance of the unprimed targets, and positive that the unprimed target appeared first. The prime, if presented, led the primed target by 80 ms. Two distractors were presented, one leading the primed target by 16 or 48 ms, the other one simultaneously with the primed target. This temporal proximity should ensure that the observers really had to *disregard* the distractor in order to find the target. For two example trials, see Figure 1.





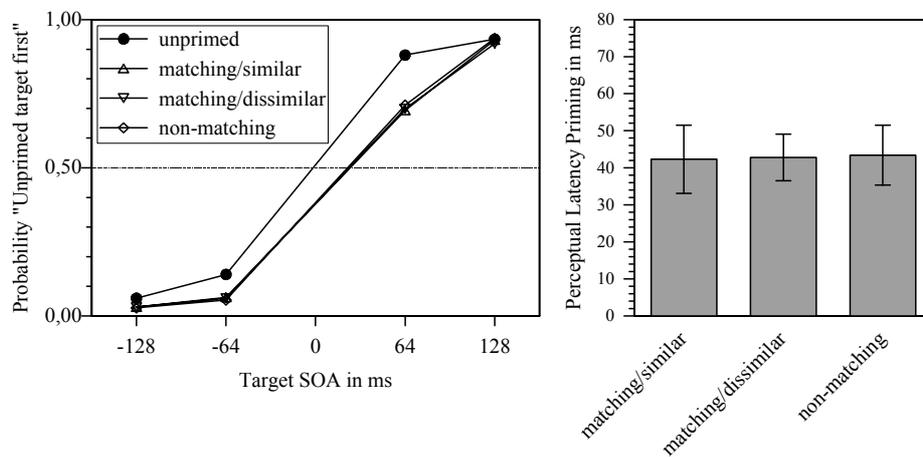
**Fig. 1.** Examples of two trials. Each trial begins in with a fixation cross (bottom screen). Primes, targets and distractors appear in various sequences. The prime might be the first stimulus (left trial) or the second one (right trial), and the primed target might lead the unprimed target (left trial) or vice versa. One of the distractors is presented simultaneously with the primed target, the other one shortly before it. Exemplary time values are given in the lower right corner of the screens.—Stimulus colours are given by grey shades and line types. Stimuli are not drawn to scale.

Targets and distractors were visible until the participants pressed the response button; the prime was deleted after 32 ms. There were 16 experimental conditions (4 target intervals  $\times$  4 priming conditions, unprimed, matching/similar, matching/dissimilar, non-matching). Each condition was presented 24 times in a random order resulting in a total of 384 trials.

The participants fixated on a central cross throughout each trial. They judged the temporal order of the targets, indicating with the mouse buttons which of the two targets had appeared first. The instruction emphasized accuracy; there was no time pressure. Every 64 trials, a break was inserted automatically.

## 2.2 Results and Discussion

From the judgment data, psychometric functions were constructed for each experimental condition (Figure 2, left part). The individual psychometric functions were approximated by logistic functions. Logit analysis (Finney, 1971) was used to estimate the Point of Subjective Simultaneity (*PSS*) for each participant. The *PSS* is the point on the fitted logistic function at which the observer cannot discriminate the temporal order (subjective simultaneity;  $p = 0.5$ ). In unprimed trials, *PSS* is usually zero. A positive (rightward) shift of *PSS* in primed trials indicates perceptual latency priming: Simultaneity is perceived when the unprimed stimulus appears in advance of the primed one. Perceptual latency priming was assessed by subtracting the *PSS* in unprimed trials from each of the *PSS*' in the primed conditions.



**Fig. 2.** Left: Psychometric distributions of Experiment 1. Perceptual latency priming is indicated by a rightwards shift of the distribution. It is evident for all primed conditions. The PSS can be inferred from the intersection of distribution and the horizontal line at the .5 probability. The right part of the Figure gives the PLP values in relation to the priming interval (80 ms, y-axis).

Figure 2 (right part) depicts the amount of perceptual latency priming. As can be seen, latency priming is present in all of the conditions. Its size does not change with intention. Individual latency priming values were submitted to a one-way repeated-measures analysis of variance and to separate t-tests against zero. The t-tests showed that priming was present in all of the conditions (all  $t_s(19) \geq 3.27$ , all  $p_s < .01$ ). Perceptual latency priming values were 42, 43, and 43 ms, that is, in the expected range of half to two thirds of the priming interval (80 ms). Yet, a main effect of priming condition was not found in the analysis of variance ( $F(2, 26) = .02, p = .98$ ).

That is, there was no evidence for intention-mediated control of attention shifts in Experiment 1. This may be due to at least four reasons. First, Experiment 1 might not have enough power to reveal the effect of intention-match. This argument is not very convincing, because the latency priming values are highly similar. Second, direct specification of attention shifts might be impossible and the earlier positive finding an artefact of the sensory confound (Scharlau & Ansorge, 2003). Third, the non-matching primes do, in fact and unfortunately, match the intentions partly, because they have an abrupt onset, and this onset is important for the intention to judge temporal order. Thus, it is conceivable that the effect of onset-match is so strong (or so quickly arising) that it does not leave enough room for the (smaller) effect of colour-match to operate. Fourth, the conditions used in the present experiment might not favour intention-mediated control. DPS-type control of sensorimotor priming effects seems to rely on the number of target stimuli (Kiesel, Kunde, Pohl, & Hoffmann, 2006). The number of visible target stimuli is very small in the present experiment (two plus one distractor). Thus, it should be tested whether direct specification of an attention shift emerges with a simpler action plan. Experiment 2 tests the two last conjectures.

### 3 Experiment 2

Experiment 2 was similar to Experiment 1. Only the matching/similar condition was abandoned in order to simplify the action plan. This measure forecloses to test whether a similarity confound was responsible for the DPS-like findings of Scharlau and Ansorge (2003). However, this was not the central aim of the present study. The main question—whether intentions guide attentional processing of nonconscious information—remains unaffected by this measure.

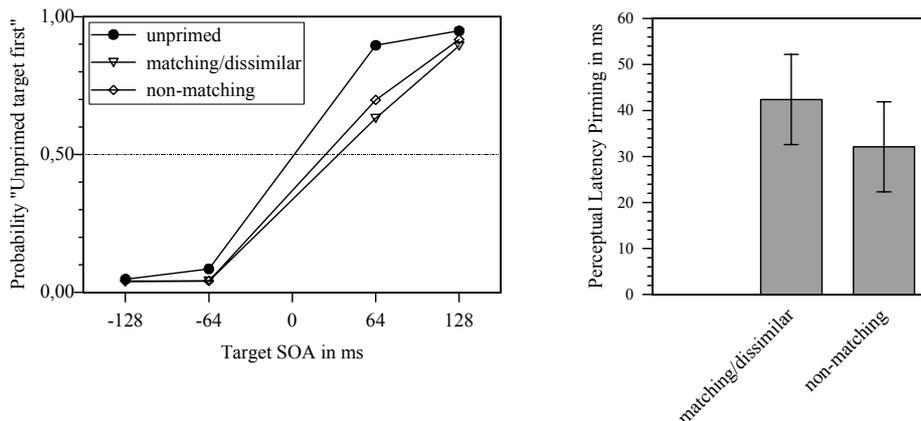
#### 3.1 Participants, Apparatus, Stimuli, and Procedure

Twenty voluntary naïve participants with normal or corrected-to-normal visual acuity (11 female; mean age 26 years) gave their informed consent and received € 3 or course credits. Apparatus, stimuli, and procedure were the same as in Experiment 1. The matching/similar condition was omitted. Trials were thus reduced to 288.

#### 3.2 Results and Discussion

Data were treated as above. Perceptual latency priming was found in both conditions, as indicated by *t*-tests (matching/dissimilar: 43 ms,  $t(19) = 4.32$ ,  $p < .001$ ; non-matching: 32 ms,  $t(19) = 3.27$ ,  $p < .01$ ). The difference was statistically significant ( $t(19) = 2.25$ ,  $p < .05$ ).

In contrast to Experiment 1, the present experiment revealed that intentions mediate the deployment of attention towards non-conscious visual information. The non-matching prime captured attention less effectively or less often than the matching prime. The experiment also confirmed that the non-matching prime is also an effective attentional signal: Its effect is by 10 ms smaller than the effect of a matching prime, but it is still quite large (32 ms).



**Fig. 3.** Left: Psychometric distributions of Experiment 2. Perceptual latency priming is indicated by a rightwards shift of the distribution. It is evident for all primed

conditions. The PSS can be inferred from the intersection of distribution and the horizontal line at the .5 probability. The right part of the Figure gives the PLP values in relation to the priming interval (80 ms, y-axis).

## 4 General Discussion

The experimental results reported above support recent evidence on the role of intentions in the processing of nonconscious information. Yet, they do so only partly. In sum, intention-matching nonconscious primes *can* capture attention more effectively than primes which match distractor information. However, they do *not necessarily* do so. Supposedly, intention-mediated capture by nonconscious primes might even be an exception rather than the rule. On the level of processes: Current intentions *might* mediate whether attention is deployed towards nonconscious information, but they do *not necessarily* and maybe *only exceptionally* do so.

The experiments indicate heavy limits of direct specification of attention shifts that will be analysed in the following. First, non-matching primes captured attention in both experiments, and they did so to a reasonable degree, that is, resulted in latency facilitation of 43 ms in the first, and 32 ms in the second experiment. These values are similar to those reported by Scharlau and Ansorge (2003), and they are in the lower range of facilitation values reported for matching primes (Scharlau & Neumann, 2003).

Yet, the interpretation of this finding is not clear. As mentioned above, it is difficult to relate it to the operation of direct specification (intention-mediated control) of attention shifts because of the following reason: In a temporal order judgment task, observers are likely “set for” onsets as well as specific features (colour in our case). This is so, because they are required to judge temporal order which presupposes that onsets are registered. Thus, the perceptual latency priming effect of a distractor-like, non-matching prime can be due to automatic attentional capture and thus reflect a breakdown of direct specification, but it may also be a direct specification mode in which any onset captures attention. Which of these explanations holds requires further data, though outside the temporal-order judgment domain.

As a second cutback, in Experiment 1, there was no direct specification at all. How might this be explained? It should not be regarded as an experimental artefact, because the data were neat and the variance was not unusually high. Further, a replication with another sample of participants showed exactly the same absence of direct specification. One might thus speculate that direct specification by nonconscious information is a fragile control mode and might collapse easily and even under weakly unfavourable conditions.

Which were these unfavourable conditions? Experiments 1 and 2 differed in the number of conditions (and, consequently, trials). There are some hints that stimulus set size affects whether direct specification is present or not (Kiesel, Kunde, Pohl, & Hoffmann, 2006), but this finding refers to speeded responses in a semantic classification task, and stimulus set was much larger than in the present experiments. Interestingly also, it is not the *instructional set* which differs between Experiments 1 and 2: The observers had exactly the same instruction. The only difference was that among



the sequences of an invisible and a visible stimulus in Experiment 1, there was a very simple one in which the two stimuli had the same colour, whereas in Experiment 2, the stimuli always differed in colour. Why this overloads the direct specification mechanism remains obscure.

Note also that the present experiments imply a marked contrast between direct specification of an attention shift and direct specification of motor responses. The latter has been reported for a variety of stimuli, including colour stimuli, and is a robust finding (Ansorge & Neumann, 2005; Schmidt, 2002). This difference indicates that sensorimotor specification is a more powerful mode of processing nonconscious information than direct specification of an attention shift.

As a final open question, the precise mechanism by which the intention-mediated deployment of attention is realised remains to be specified. Less capture by non-matching primes might be due to one or several of the following reasons. Non-matching primes might capture attention in a smaller proportion of trials than matching ones, capture attention more slowly than matching ones, or capture attention initially, but result in a disengagement of attention after the error is detected. If the latter holds, the question why including the matching/similar condition abolished the intention-mediated effect might find an easy answer: In the matching/similar condition, no colour change between prime and target can be detected, and if the attentional filter system can be reset easily and quickly (as, for example, DiLollo, Kawahara, Zuvic, & Visser, 2002, suggest), this absence of a detectable error might bias the attentional control system towards orienting to any onset, including the non-matching primes.

To sum up, the present experiments reveal a robust and strong deployment of attention towards non-consciously registered information. They also demonstrated some control of this deployment by the current intentions. Yet, although theoretically interesting, it seems too weak or unreliable for practical applications.

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