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No conflict control in the absence of awareness

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Abstract
Introduction In the present study we tested whether control over the impact of potentially conflicting information depends on awareness of that conflicting information.
Method and Results In Experiment 1 participants performed a response-priming task, with either masked or unmasked primes. Prime awareness was assessed on a trial-by-trial basis. A typical conflict control pattern, with reduced priming effects following incongruent rather than congruent primes in the preceding trial was found. Yet, this pattern was obtained only when the prime information was visible and not when it was invisible. With invisible primes the effect did not occur, even when participants accidently judged the prime information correctly. Importantly, this confinement of the conflict adaptation effect to unmasked primes occurred despite identical prime processing times with and without masking—a variable that was confounded with prime awareness in previous studies. In Experiment 2, a similar data pattern was found for judgment times regarding the congruency of prime-target pairs.
Conclusion Altogether, the results support the conclusion that awareness of visual primes is important for controlling conflict in visuo-motor processing.

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No conflict control in the absence of awareness

In human psychology, exerting one’s will is sometimes considered to be conditional on preceding awareness. In line with that assumption, researchers found that aware visual perception was a precondition for subsequent willing modification of processing of visual stimuli (Greenwald, Draine, & Abrams, 1996; Kunde, 2003; van Gaal, Lamme, & Ridderinkhoff, 2010). This conclusion was based on experimental results showing greater response-conflict control after response conflict that was elicited by a visible stimulus of which participants were aware than by an invisible stimulus of which participants remained unaware. In fact, conflict control was completely eliminated in one study, if subliminal conflict-eliciting stimuli were presented below the objective threshold of awareness (Kunde, 2003). The same conclusion is also backed up by the observation that subliminal conflict fails to activate the anterior cingulate cortex (Dehaene et al., 2003), a region involved in the monitoring of conflict (cf. Botvinick, Nystrom, Fisell, Carter, & Cohen, 1999).

This critical role of awareness for conflict control, however, is not certain because of two confounds. First, in prior studies, participants had more time to process visual stimuli in the aware than in the unaware conditions and, second, conflict control was assessed based on a larger ratio of correctly than incorrectly judged conflict-eliciting stimuli in aware than in unaware modes (Frings & Wentura, 2008; Greenwald et al., 1996; Kunde, 2003; van Gaal et al., 2010).

To understand this, we start with a brief description of the evidence for conflict control. Prior research studied conflict control by means of the participants' strategic adjustment of visual sensorimotor processing to a recently seen response-interfering or response-facilitating but task-irrelevant visual stimulus (cf. Gratton, Coles, & Donchin, 1992; Stürmer, Leuthold, Soetens, Schroeter, & Sommer, 2002; Wühr & Ansorge, 2005). In each trial of such an experiment, the participant was presented with two visual stimuli, a task-irrelevant prime (or distractor) and a task-relevant target.

Studies of the role of awareness for conflict control typically used a sequence of an irrelevant prime preceding a relevant target. In conditions of low conflict, the relevant target and the preceding irrelevant prime had the same response meaning. This was called the congruent condition. In conditions of high conflict, the prime and the target had opposite response meanings. This was the incongruent condition. For instance, in Kunde (2003) targets were rightwards or leftwards pointing arrows, and participants had to press the right button for a rightward pointing target arrow and the left button for a leftward pointing target arrow. An irrelevant prime arrow by contrast had to be ignored. In low-conflict or congruent conditions, the target-preceding prime arrow pointed into the same direction as the target arrow. For instance, a rightward pointing arrow as a prime preceded a rightward pointing arrow as a target. In high-conflict or incongruent conditions, the prime arrow pointed to the alternative direction as compared with the target arrow. For instance, a rightward pointing arrow as a prime preceded a leftward pointing arrow as a target.

Although the prime-target sequences were equally likely congruent and incongruent and, thus, participants were well advised to ignore the prime, participants process these primes to some extent. This is reflected in a congruence effect, with better performance in congruent than incongruent conditions. Corroborating prior research (Marcel, 1983), researchers found a congruence effect of visible as well as invisible primes (e.g., Kunde, 2003). In the unaware conditions, the visual primes were backward masked (cf. Breitmeyer & Ogmen, 2006), that is, a visible mask was shown at the prime's position and with so small an interval after the prime that the mask interrupted processing of the prime and made the prime invisible.

The congruence effect of the prime presumably reflected sensorimotor activation (cf. Eimer & Schlaghecken, 1998; Leuthold & Kopp, 1998; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003). In congruent conditions, prime and target had the same response meaning, so that the motor activation by the prime facilitated selection of the required response, whereas in incongruent conditions, the prime had a different response meaning than the target, so that a prime-activated response conflicted with the selection of the required response. In conditions in which participants judged the meaning of target words (cf. Frings & Wentura, 2008; Greenwald et al., 1996) the degree of the semantic fit between the prime meaning and the target meaning could additionally or alternatively account for (part of) the congruence effect, with incongruent prime words interfering with the recognition of the subsequent target word's meaning (in comparison to meaning-congruent prime and target words) (cf. Kiefer & Spitzer, 2000).

In line with prior studies of conflict control, researchers found that participants exerted control over the degree to which they processed the visible prime as a consequence of prime-elicited conflict (e.g., Greenwald et al., 1996; Kunde, 2003): Participants were more reluctant to process the visible prime if they just saw an interfering or incongruent prime in the preceding trial. If a participant had just seen a conflict-eliciting or incongruent prime in a trial *n-1*, the participant suppressed prime processing in the subsequent trial *n*. This conflict-elicited control (henceforth, called 'conflict control') over prime processing was observed in comparison with congruent trials. After congruent trials, no control in the form of a suppression of prime processing took place. This was reflected in an interaction between the two variables prime-target congruence in trials *n-1* and *n*. The congruence effect in trial *n* was larger after a preceding congruent trial *n-1* than after a preceding incongruent trial *n-1*. In the following, we will use the term 'Gratton effect' for this interaction (named after Gratton et al., 1992).

It is believed that the Gratton effect reflects a form of adaptive control of processing of the irrelevant primes based, for example, on an ancillary monitoring mechanism (AMM; see also Carter & van Veen 2007; Gratton, Coles, & Donchin, 1992; Stürmer et al., 2002; for alternative views see van Steenbergen, Band, & Hommel, 2009; Wendt, Kluwe, & Peters, 2006). According to this explanation, if AMM detects an irrelevant stimulus (here: a prime) that leads to conflict because it hinders correct response selection (e.g., in an incongruent trial *n-1*), participants exert control via a gating mechanism that focuses attention more narrowly on the target and better excludes prime processing in a subsequent trial *n*. As a consequence, the congruence effect based on the relation between irrelevant prime and target in trial *n* is small after an incongruent trial *n-1*. By contrast, if AMM detects an irrelevant stimulus that facilitates correct response selection (e.g., in a congruent trial *n-1*), the participant exerts control in the form of an opening of the same attentional gate to distribute attention more broadly and encompass prime and target in trial *n*. As a consequence, the prime-target congruence effect in trial *n* is large after a congruent trial *n-1*.

In line with the assumption that the participants' awareness of the stimulus (or stimulus visibility) of the conflict-eliciting incongruent prime could be crucial for conflict control, van Gaal et al. (2010) found that the Gratton effect was stronger after trials with a visible prime than after trials with an invisible prime, and Kunde (2003) and Greenwald et al. (1996) found the Gratton effect selectively after trials with a visible prime. Kunde (2003) found that with invisible primes, the congruence effect in trial *n* was equally strong after preceding congruent and incongruent trials *n-1*. However, as mentioned above there are two caveats to the conclusion that these findings corroborate the connection between awareness and control.

First, in prior research the prime-target interval (e.g., Kunde, 2003) or the prime duration (e.g., Kunde, 2003; van Gaal et al., 2010) was longer with visible than with invisible primes. As explained, backward masking was used to prevent prime visibility. Backward masking of the prime by a subsequent mask is most efficient with relatively small prime-mask intervals and decreases with longer prime-mask intervals (Alpern, 1953; Breitmeyer & Ogmen, 2006; Vorberg et al., 2003). Therefore, varying the interval between prime and masks and using the target as a mask (cf. Kunde, 2003; van Gaal et al., 2010) or presenting the target always after the mask (cf. Greenwald et al., 1996) rendered primes more or less visible but at the same time confounded influences of visibility with that of prime-target interval. As a consequence of the prime-target interval or prime duration manipulation, participants had more time to process the primes (prior to the targets) in aware than unaware conditions (although the prime-target interval in and by itself seems not to affect the degree of conflict control if visible primes and targets are used, cf. Frings & Wentura, 2008). No wonder that (a) prime discrimination was better in long- than short prime-mask interval conditions and that (b) the prime's Gratton effect was also stronger in visible than invisible conditions.

Moreover, prime-target intervals can have a strong impact on (1) the size of the sensorimotor prime-target congruence effect and (2) the size of inter-trial effects. Concerning influence (1), increasing the prime-target interval has the power to increase (Vorberg et al., 2003) but also to decrease or even reverse the congruence effect (e.g., Eimer & Schlaghecken, 1998; Lingnau & Vorberg, 2005) and, as a consequence, to also (2) modify any inter-trial interaction conditional on the congruence effect (in the preceding trial). This was shown in a study by Vorberg (2009) with masked arrows as primes and visible targets as in Kunde (2003).

In the current study, to rule out that different prime durations or prime-target intervals were responsible for how strong a Gratton effect is, we varied visibility by means of either presenting or not presenting a backward mask after the prime, but by keeping the prime duration and the prime-target interval the same under masked and unmasked conditions. If conflict control in the form of a Gratton effect depends on awareness of the stimulus or stimulus visibility, we should find the Gratton effect in visible (unmasked) but not in invisible (masked) priming conditions. If, however, the prime duration or the prime-target interval is responsible for whether the Gratton effect can be found, the Gratton effect should be the same in visible (unmasked) priming conditions as in invisible (masked) priming conditions (Vorberg, 2009).

In addition, as a consequence of the higher task difficulty in the unaware than in the aware conditions of prior studies (Greenwald et al., 1996; Kunde, 2003; van Gaal et al., 2010), in unaware conditions evidence for conflict control was based on equal amounts of preceding trials, with incorrectly and correctly judged primes, whereas in aware conditions, evidence for conflict control was based on a larger amount of preceding trials, with correctly than incorrectly judged primes. This was reflected in the performance differences between unaware and aware conditions in tasks in which participants judged the identity of either masked or less masked primes, respectively. In these judgment tasks, participants gave a larger ratio of correct prime judgments in the aware (e.g., the long prime-target interval) condition than in the unaware (e.g., the short prime-target interval) condition. Evidently, researchers thought that judgment performance in the masked condition was so low that the correct judgments in the short-interval conditions must have reflected chance performance, too. As a consequence, researchers like Kunde (2003) did not care about different amounts of correctly judged and thus potentially seen primes in unaware (or masked) versus aware (or less masked) preceding trials when assessing the Gratton effect.

However, it is possible that regardless of the participants' awareness of the prime identities, the lack of a Gratton effect in the unaware conditions entirely reflected the participants' beliefs about what they saw in a preceding trial rather than what they actually saw in a preceding trial. Besides blocking of the perception of the prime, a mask creates various subjective visual impressions of a masked stimulus (cf., Polat & Sagi, 2007; for a more general argument, see also Rensink, 2000). Some authors even held the participant's resulting erroneous subjective belief about seeing a particular masked prime responsible for the prime's congruence effect in the first place (cf. Kouider & Dupoux, 2004). According to this logic, a Gratton effect should be found in those trials in which the primes were accurately judged in the preceding trial. However, an opposite Gratton effect would be obtaining in those trials in which the participants inaccurately judged a prime in the preceding trials, because such an incorrect judgment means that the participants believed an objectively realized congruent condition to have been an incongruent condition, and an objectively realized incongruent condition to have been a congruent condition. According to this logic, an equal number of correctly and incorrectly judged primes in the unaware conditions can lead to equal ratios of conflict control after congruent and incongruent trials. By contrast, a higher number of correctly judged primes in the aware conditions will always lead to a larger ratio of conflict control after incongruent trials.

In line with the theoretical possibility that the participants' beliefs rather than their awareness of the stimuli can drive the Gratton effect, van Steenbergen et al. (2009) found that incentives rather than the degree of conflict per se was responsible for Gratton effects. Van Steenbergen et al. (2009) rewarded their participants higher after incongruent trials (with higher conflict) than after congruent trials (with lower conflict) and, as a consequence, reversed the typical Gratton effect into a lower congruence effect after congruent than incongruent preceding trials.

To rule out the possibility that a mixture of correct and false beliefs about the prime-target relation in the preceding trial (corresponding to correct and false prime judgments in the preceding trial) falsely suggested a lower Gratton effect in previous unaware priming conditions, we asked our participants to judge the primes in each trial of our experiments. In this manner we can selectively look at those trials in which participants correctly judge the prime-target sequence in a preceding trial, even in unaware conditions.

If it is true that the participants' low awareness of the conflicting prime in masked conditions reflected chance performance with the correctly judged primes, too, and if the Gratton effect depends on this kind of awareness (or visibility) and not on the participants' beliefs of what they saw, we should find a lower or even no Gratton effect at all in masked conditions, even if we only look at only those trials in which the prime was correctly judged in the preceding trial. However, if it does not matter whether the participants were aware of the prime but rather what they believe they saw, or if the participants' correct judgments about the masked primes reflected residual prime visibility, a Gratton effect should be found in those trials of the masked condition in which participants accurately judged the prime's identity in the preceding trial.

Finally, in Experiment 1, we also tested whether conflict control is domain specific or whether it is domain general. According to domain-general theories of conflict control, conflict in one dimension (or task) can elicit control of conflict in an alternative dimension (or task, cf. Botvinick, Cohen, & Carter, 2004; Kunde & Wühr, 2006; but see, e.g., Davelaar & Stevens, 2009; Kiesel, Kunde & Hoffmann, 2006). Here, we tested whether conflict elicited in one domain by relations between the visible target's meaning and the responses affected the regulation of the conflict in an alternative domain, that is, between invisible prime and target. More or less target-response conflict was elicited by requiring the participants to give spatially corresponding responses to visible targets in one block (i.e., up responses to up targets and down responses to down targets) but spatially non-corresponding responses in another block (i.e., up responses to down targets and down responses to up targets). Prior research showed that responses are faster in corresponding conditions in which the target meaning and the response meaning overlap than in non-corresponding conditions (cf. Lu & Proctor, 1995). This is due to response conflict. The target activates a response based on its long-term meaning (De Jong, Liang, & Lauber, 1994). This response is in accordance with the required response in corresponding blocks, thereby, facilitating the correct response. However, in the non-corresponding conditions, the response elicited by the target word's meaning is in conflict with the finally required response, thereby delaying execution of the correct response.

If a domain-general conflict mechanism is at work and target-response non-correspondence elicits control of the conflict incurred by incongruent primes, too, this should lead to down-regulated prime processing and, hence smaller congruence effects in the non-corresponding than in the corresponding condition. Again, if conflict control depends on stimulus awareness, however, we might find evidence for domain-general conflict control only in the aware but not in the unaware priming condition. In addition to what we already suspect on the basis of the existing studies, a lack of domain-general conflict control in unaware conditions would point to a role of awareness as a necessary precondition not only for eliciting but also for applying conflict control. The reason for this is that domain-general conflict on the basis of target-response correspondence should be always elicited, in unaware (masked) and aware (visible) priming conditions, because participants are always aware of the target. If, however, application of a control setting to down-regulate the prime-target congruence effect in response to target-response non-correspondence requires awareness of prime-target congruence in subsequent trials, conflict control could again be lower in unaware than aware conditions. This should be reflected in a reduced congruence effect in visible and non-corresponding conditions relative to visible and corresponding conditions but similar congruence effects in masked non-corresponding and masked corresponding conditions.

Experiment 1

We used (sandwich-masked) words denoting spatial positions (or directions) on the vertical axis (e.g., the word “up”) as more or less visible primes and as visible targets (cf. Ansorge, Kiefer, Khalid, Grassl, & König, 2010b). Words were used as stimuli for two reasons. Like simple geometrical shapes, such as arrows, words lead to prime-target congruence effects (e.g., Kiefer & Martens, 2010) and to motor activation (e.g., Proctor & Vu, 2002), regardless of their visibility (cf. Kinoshita & Hunt, 2008). In contrast to geometrical shapes, however, words are convenient as masked primes: With words, it is relatively easy (in comparison to masked shapes) to create a large set of different masked primes because virtually any prime word can be rendered invisible if presented with a sandwich mask (Kiefer & Brendel, 2006). Our mask consisted of a few letters that preceded the prime word at prime word position and a few letters that followed the prime word at prime word position. For half of Experiment 1’s participants, a sandwich mask diminished prime word visibility. For the other half of the participants, the prime words were better visible because no letter masks were used.

Importantly, the prime duration and the prime-target interval were the same in masked conditions and in unmasked conditions without a mask. The visible targets were either congruent or incongruent to the prime words, and required a quick response depending on their spatial meaning. If conflict control requires the participants’ awareness of the visual stimulus eliciting the conflict, we expected a higher amount of conflict regulation in unmasked than masked conditions.

We also asked our participants to give a judgment about the perceived prime-target relation in each trial. This was done after the quick response to the target and at leisure. For this task, a visual prompt was shown on the screen indicating the two buttons to be pressed for whether the actual trial contained a congruent or an incongruent prime-target sequence. In this manner, we assessed whether the prime was seen. Note also that we thus used the maximally sensitive task for the present purpose: Only judgments about the congruence or incongruence of the actual prime-target sequence will tap unambiguously into those visual representations that are responsible for the elicitation of conflict control.

We expected better performance in unmasked than masked conditions in this prime visibility test. More importantly, with this procedure, we were also able to restrict our analysis of conflict control of the target responses to only those trials in which the participants correctly judged the primes (here: the prime-target relation). Basing our conclusions about conflict control on only those trials that followed the trials in which our participants correctly judged the primes, we do not only assume but test whether the correct judgments in the masked conditions reflected unawareness of the primes (i.e., chance performance), too.

If the correct judgments in masked trials reflected chance performance and the participants, thus, remained unaware of the prime during these trials, and if conflict control requires awareness of the conflict-eliciting stimulus, Gratton effects or conflict control should be absent in the masked conditions, even if the Gratton effect is estimated solely on the basis of those trials that followed a trial in which participants correctly judged prime-target sequences in the masked condition.

In addition, we also varied the spatial correspondence between the long-term meaning of the words and the required target responses. The target words required a spatially corresponding response in one block and a spatially non-corresponding response in the other block. In the corresponding block, an up target required an upwardly directed key press, and a down target required a downwardly directed key press. In the non-corresponding block, the target-response mapping was reversed: An up target required a downwardly directed key press, and a down target required an upwardly directed key press. In this manner, we tested whether conflict elicited in one domain (non-correspondence between target and response) led to conflict control in a second domain (prime-target congruence) and whether this kind of domain general conflict control was elicited in aware and unaware conditions.

Method

Participants

Forty-eight participants (18 female), mostly students, with a mean age of 25 years participated in exchange for money or course credit. All participants reported normal or corrected-to-normal visual acuity.

Apparatus

Visual stimuli were presented on a 15-inch, color VGA monitor. Its refresh rate was 59.1 Hz. The participants sat at a distance of 57 cm from the screen in a quiet, dimly lit room, with their head resting in a chin rest to ensure a constant viewing distance and a straight-ahead gaze direction. RTs were registered via the numeric keypad of a serial computer keyboard, placed directly in front of the observers. To start a trial, participants pressed the central key (#5) as a home key with the right index finger. They had to release the home key immediately before their target response. Target responses were given by the keys #2 and #8 (labeled “below” and “above”). After reading the instructions, participants started the experiment by pressing the key #8 once, and continued with the next trial by pressing the key #5.

Stimuli and procedure

See also Fig. 1. Prime and target stimuli were German words denoting spatial positions on the vertical axis. The masked prime and the visible target words could either be 'oben' (on top), 'darueber' (above), 'hinauf' (upward), 'hoch' (high), 'unten' (down), 'darunter' (below), 'hinab' (downward), and 'tief' (deep). Each of the eight words was presented as a target and combined with each of the seven remaining words as a prime. Thus, a set of 56 (8 × 7) different prime-target pairs served as stimuli. Prime-target pairs were equally likely congruent or incongruent. In congruent conditions prime and target were of spatially related meaning (e.g., the prime word 'high' preceded the target word 'above') and in incongruent conditions prime and target had spatially opposite meaning (e.g., the prime word 'below' preceded the target word 'on top'). Even in congruent conditions, prime and target were never identical to rule out repetition priming (Forster, 1998; Norris & Kinoshita, 2008).

All stimuli were presented black (<1 cd/m^2) on a gray background (24 cd/m^2). Each trial started with the presentation of a fixation cross centered on the screen for 750 ms. In the masked condition, a forward mask consisting of ten randomly drawn uppercase letters was shown for 200 ms. Immediately after the forward mask, the prime word was shown for 34 ms (equivalent to two screen refreshes at 59.1 Hz) in lowercase letters. It preceded a backward mask also consisting of ten independently drawn random capital letters which were shown for 34 ms. Next, the target word stimulus was shown and remained on the screen until the participant pressed one of the response keys. All stimuli were shown centered on the screen with inter-stimulus intervals (ISIs) of 0 ms. Timing of all stimuli was adapted from a prior study showing low prime visibility (cf. Kiefer & Brendel, 2006). In the unmasked condition, everything was the same with the exception of the masks that were not shown. Masking was realized as a between-participants variable.

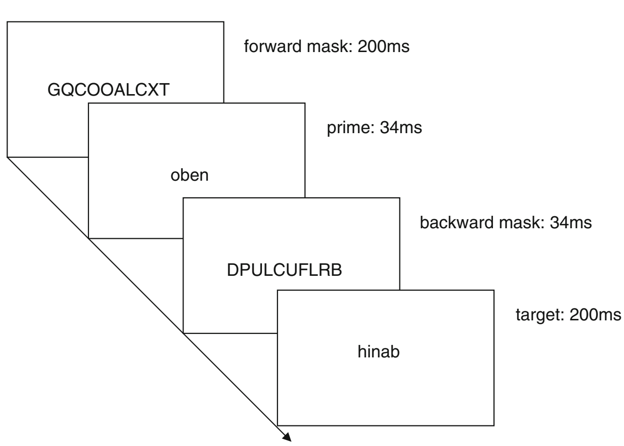

Fig. 1 Depicted is an example of an incongruent trial. The arrow depicts the direction of time. Stimuli are not drawn to scale

The experiment was divided into two blocks, a block with corresponding target-response mapping and a block with non-corresponding target-response mapping. Each block lasted about 45 min. During the corresponding block, participants gave spatially corresponding responses to the meaning of the visible target word. They pressed the upper key for target words denoting elevated positions or directions toward such positions. They pressed the lower key for target words denoting lower positions or directions toward such positions. During the non-corresponding block, participants gave spatially non-corresponding responses to the meaning of the visible target word. They pressed the upper key for target words denoting lower positions or directions toward lower positions, and they pressed the lower key for target words denoting elevated positions or directions toward elevated positions. The second task was a prime visibility task. In each trial, after the quick response to the target had been given, a second display was shown up asking participants to judge whether they had seen a congruent or an incongruent prime-target pair. The stimulus–response mapping for this task changed from trial to trial on a random basis. This was done to prevent action triggering of the correct responses even if the stimuli were perfectly masked (cf. Kunde, Kiesel, & Hoffmann, 2003) and to secure that responses to the prime-target relation had to be based on the participants' awareness about the prime-target relation (cf. Reingold & Merikle, 1988).

Regarding the target responses, after each trial, participants received feedback in case of errors ("Wrong key!") and if their RT exceeded 1,250 ms ("Respond faster!"). Feedback took 750 ms. Thus, keeping a high accuracy and a fast response speed for the targets was mildly rewarded (i.e., saved time). No feedback was given concerning the prime visibility task.

Each block consisted of 320 trials. This corresponds to eighty repetitions of each of the two target types (upward targets; downward targets) × 2 prime types (upward primes; downward primes), with each of the eight targets being equally frequent and prime words being randomly chosen from the set of available prime words for each particular combination of the two possible spatial target meanings and the two possible congruence levels. Within blocks, different conditions were realized in a pseudo-random order. Prior to each block, participants practiced the task for 32 trials.

Results and discussion

Data from one participant per each group were excluded, leaving 23 participants in each group. (The excluded participants had a large rate of congruence judgments of one particular type (>95%), meaning that it was uncertain whether they understood the task at all.) Out of all responses, 4.0% were discarded because correct individual RTs deviated by more than two standard deviations (SDs) from individual mean RTs, or because only one response was given. Degrees of freedom were adjusted by Greenhouse Geisser ε if Mauchly sphericity tests indicated that the assumption of independent variance across steps of the variables was violated.

Prime visibility/prime-target judgments

See Fig. 2 for the results. Visibility of the primes was assessed by prime-target judgments. To assess prime visibility, d' indices of signal detection theory (Green & Swets, 1966; Macmillan & Creelman, 2005) were calculated based on congruent conditions as signals, and incongruent conditions as noise, so that a 'congruent' judgment in the congruent (signal) condition counted as a hit and a 'congruent' judgment in the incongruent (noise) condition counted as a false alarm (FA). Next, the rates of hits and FAs were individually z-transformed and individual d' was calculated as the difference between the z-transformed hit rate minus the z-transformed FA rate. Finally, d' was averaged across

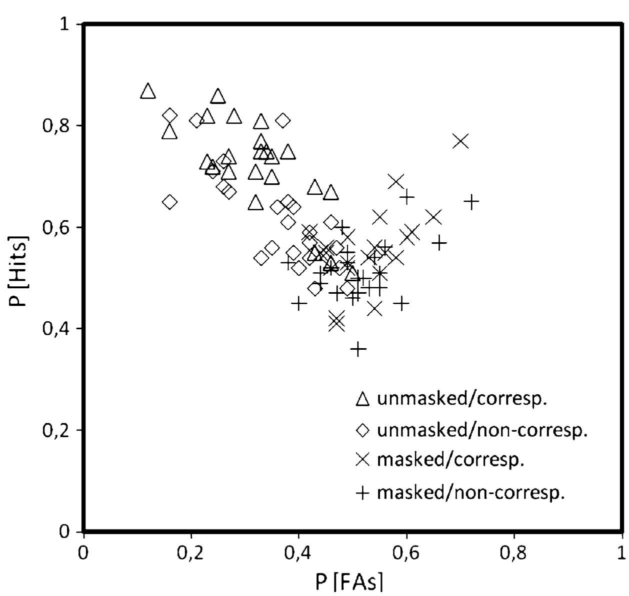

Fig. 2 Depicted are individual hit rates (on the y axis) as a function of individual false alarm (FA) rates (on the x axis), target-response correspondence (corresp. = corresponding vs. non-corresp. = non-corresponding), and masking (masked vs. unmasked). As can be seen, the data from the masked condition roughly align with the diagonal through the origin of the coordinate system. This diagonal corresponds to equal rates of hits and FAs, that is, chance performance. By contrast, in the unmasked condition, hit rates outweigh FA rates. Likewise, hit-to-FA ratios are higher for corresponding than non-corresponding conditions. Data from Experiment 1

participants and compared with zero by t tests, because an average d' of zero corresponds to chance performance, and d' can become ever larger the better the discrimination of the participants. In the unmasked conditions, primes were visible. d' amounted to a significant 1.10, $t(22) = 9.94, p < .01$, in the target-response corresponding block, and to 0.74, $t(22) = 6.94$, $p < .01$, in the target-response non-corresponding block. In the masked conditions, primes were invisible. d' amounted to a non-significant 0.07, $t(22) = 1.76$, $p = .09$, in the target-response corresponding block, and to -0.008, $t(22) < 1.00$, in the target-response non-corresponding block.

A two-way ANOVA of the mean d' indices with the within-participant variable target-response correspondence (target-response corresponding vs. target-response non-corresponding) and the between-participants variable masking (masked primes vs. unmasked primes) led to significant main effects of both variables, masking, $F(1, 44) = 12.61$, $p < .01$, and target-response compatibility, $F(1, 44) = 80.28$, $p < .01$, and a significant two-way interaction between these variables, $F(1, 44) = 5.46$, $p < .05$.

The main effects reflected that judgments were better in unmasked than masked conditions, and in target-response corresponding than in target-response non-corresponding conditions, and a significant two-way interaction demonstrated that this drop of performance from corresponding to non-corresponding blocks was more dramatic in the unmasked blocks than in the masked blocks.

Generally, the performance drop in the target-response non-corresponding blocks relative to the target-response corresponding blocks made it clear that the suspicion of other researchers was right (e.g., Neumann & Klotz 1994) that testing prime visibility and prime congruence effects in the same trials is not the most sensitive procedure for revealing residual prime visibility because this is essentially a dual-task situation in which the demands imposed by the target-response task interfere with optimal performance in the prime visibility task. The likely reason for the two-way interaction was that there was not much to see in the masked blocks in the first place. Therefore, the dual-task interference with the visibility measure could not have been as strong in the masked blocks as it had been in the unmasked blocks.

Target RTs

See also Table 1 for the results. A repeated-measures ANOVA was run based on only those trials in which participants correctly responded to the visible targets within the RT limits (of ± 2 SDs of the individual mean correct RTs) in the just preceding and current trial and in which they correctly judged prime-target congruence relations in the just preceding trial. This ANOVA concerned the

Table 1 Reaction times, error rates, and congruence effects (incongruent–congruent) in Experiment 1

		Pre. con.			Pre. inc.		
		Con.	Inc.	Effect	Con.	Inc.	Effect
Unmasked condition							
Corr.	RT	679	724	45	694	723	29
	ER	1.7	2.7	1.0	2.4	4.4	2.0
Non-cor.	RT	807	828	21	817	818	1
	ER	1.7	4.2	2.5	1.2	2.4	1.2
Masked condition							
Corr.	RT	682	703	21	687	702	15
	ER	2.7	4.1	1.4	2.1	4.0	1.9
Non-cor.	RT	803	818	15	803	828	25
	ER	2.5	3.0	0.5	2.7	3.6	0.9

RT Reaction time (ms), *ER* Error rate (%), *corr.* corresponding, *non-cor.* non-corresponding, *pre. con.* preceding congruent, *pre. inc.* preceding incongruent, *con.* congruent, *inc.* incongruent

medians of the correct responses, with the within-participant variables preceding prime-target congruence in trial *n-1* (preceding congruent; preceding incongruent), current prime-target congruence in trial *n* (congruent; incongruent), and target-response correspondence (corresponding; non-corresponding), and the between-participants variable masking (yes; no).

This ANOVA led to significant main effects of current congruence, $F(1, 44) = 26.97$, $p < .01$, and correspondence, $F(1, 44) = 115.05$, $p < .01$. Responses were faster in current congruent (RT = 746 ms) than in current incongruent trials (RT = 768 ms), and in corresponding (RT = 699 ms) than in non-corresponding conditions (RT = 815 ms). In addition, we found the expected significant three-way interaction of Current Congruence × Preceding Congruence × Masking, $F(1, 44) = 3.90$, $p = .05$, plus a significant three-way interaction of Correspondence × Current Congruence × Masking, $F(1, 44) = 4.24$, $p < .05$.

The first three-way interaction reflected the predicted conflict control only in the visible (unmasked) conditions but not in the invisible (masked) conditions. We found a significant drop of the current trial's congruence effect (incongruent RT–congruent RT) in the visible conditions by 18 ms down from 33 ms after a preceding congruent trial to 15 ms after a preceding incongruent trial, $t(22) = 2.48$, $p < .05$, and the absence of such a drop in the masked conditions in which current congruence effects after a preceding congruent trial (18 ms) and a preceding incongruent trial (20 ms) did not significantly differ from one another, $t < 1.00$. The second three-way interaction was caused by a significant drop of 26 ms, $t(22) = 2.46$, $p < .05$, of the current congruence effect in the visible conditions for blocks in which participants responded non-correspondingly (congruence effect: 11 ms) as compared with blocks that required a corresponding response (congruence effect: 37 ms). This drop was absent in the invisible (masked) conditions in which the current congruence effect was 18 ms in corresponding blocks and, thus, about the same as the 20 ms in non-corresponding blocks.[1]

Additional RT analyses

We ran two additional analyses of only the masked conditions that were not justified by significant interactions in the omnibus ANOVA but interesting nonetheless. The first additional ANOVA was conducted because van Gaal et al. (2010) reported residual conflict control in the masked conditions. These authors used only corresponding target responses. Therefore, we also tested whether in the corresponding blocks the small drop by 5 ms of the masked primes' congruence effect after preceding incongruent trials (congruence effect: 15 ms) as compared with preceding congruent trials (congruence effect: 20 ms) was reliable. However, in a repeated measures ANOVA of only the masked and corresponding conditions, with the two variables preceding congruence and actual congruence the interaction failed to become significant, $F < 1.00$, too.

A second additional ANOVA was conducted to test whether the "reverse conflict control effect" in the non-corresponding masked conditions with a higher congruence effect after preceding incongruent (congruence effect = 25 ms) than preceding congruent conditions (congruence effect = 15 ms) was significant. This repeated measures ANOVA only concerned the masked and non-corresponding trials and was also run with preceding congruence and actual congruence as its variables but again the interaction was not significant, $F < 1.00$.

Errors

A corresponding ANOVA of the arc-sine transformed error rates (ERs) led to a significant main effect of current congruence, $F(1, 44) = 16.58$, $p < .01$, and to a significant three-way interaction of Correspondence × Preceding Congruence × Masking, $F(1, 44) = 5.61$, $p < .05$. The current congruence effect reflected better performance in

[1] A similar ANOVA of the incorrect responses led to only significant main effects of congruence, $F(1, 44) = 19.11$, $p < .01$, with faster congruent RTs (752 ms) than incongruent RTs (767 ms), and of correspondence, $F(1, 44) = 104.33$, $p < .01$, with faster corresponding RTs (702 ms) than non-corresponding RTs (817 ms). The interactions between congruence and preceding congruence, $F(1, 44) = 2.71$, $p = .10$, and between masking, congruence, and preceding congruence failed, $F(1, 44) < 1.00$, suggesting that even in the aware conditions, conflict control depended on the participants' awareness of conflict in the preceding trial.

congruent (ER = 2.1%) than incongruent conditions (ER = 3.5%). The three-way interaction reflected an almost significant reversal of the congruence effect in the preceding trial (preceding congruent RT—preceding incongruent RT) during visible blocks in non-corresponding conditions (0.6%) relative to corresponding conditions (−1.6%), $t(22) = -1.96$, $p = .06$, but if anything a reversal of this pattern in the masked conditions in which the preceding trial's congruence effect was a little stronger for corresponding (0.4%) and non-corresponding blocks (−1.4%), $t(22) = 1.46$, $p = .16$.

Discussion

Experiment 1 nicely confirmed that conflict control was only elicited by visible primes and not by masked primes. Because participants were unaware of the masked primes as demonstrated by chance performance in the discrimination of the present prime-target relations, this observation supported the notion that conflict control is conditional on aware perception of the conflict-eliciting stimulus. Moreover, several alternative explanations that could have accounted for prior instances of reduced conflict control under unawareness conditions were ruled out. Echoing Kunde's (2003) results, we found that conflict control was selectively possible with visible primes but not with masked primes, but this time and in contrast to Kunde (2003), conditions with better visible primes and with masked and with visible primes were exactly matched for the length of the prime-target interval. Thus, an alternative explanation of the difference between aware and unaware priming conditions in terms of prime-target intervals (cf. Vorberg, 2009) was ruled out. Also, the amount of response conflict, as expressed in terms of the size of the congruence effect, was quite comparable in conditions with masking (19 ms) and without masking (24 ms). So differences of conflict that sometimes occur when prime awareness is manipulated are unlikely to explain why conflict adaptation occurred when primes were visible but did not occur when the primes were invisible.

We also found that conflict control was selectively possible with visible primes but not with masked or invisible primes, although the results were based on only correctly judged prime-target sequences in both, visible, and masked conditions. This rules out that the participants' beliefs (rather than what they actually saw) governs the Gratton effect and could have falsely suggested the absence of a Gratton effect in prior masked priming experiments.

This observation also suggests that the Gratton effect cannot be based on the mere intention to reduce interference. Apparently, it does not suffice to believe that a conflicting event had just occurred; instead, this conflicting event must also have left a conscious trace to govern conflict adaptation. However, a correct judgment of masked prime-target congruence need not necessarily reflect much confidence of the observer about this judgment. Therefore, future research seems necessary to clarify to which extent conflict control can be achieved strategically without previous occurrence of conflict.

The conclusion that conflict control was only possible in visible but not in invisible priming conditions was additionally supported by our observation of a second kind of selective conflict control in the visible priming conditions. In prior masked priming studies it had been found that a current trial's congruence effect was larger after a preceding congruent trial than after a preceding incongruent trial, only with visible primes (Greenwald et al., 1996; Kunde, 2003; van Gaal et al., 2010). In the current study, we additionally found that conflict in an alternative dimension elicited control of the prime-target congruence effect only in visible but not in masked conditions. This domain-general conflict-elicited control was based on a non-correspondence between the spatial long-term meaning of a clearly visible target word and the required response. This non-correspondence elicited conflict and led to control of conflict based on the visible primes' incongruence with the targets, too. In line with the assumption that word-response non-correspondence elicited conflict, we found a large significant correspondence effect, with slower responses in non-corresponding than corresponding blocks (cf. Lu & Proctor, 1995). In line with an awareness-dependent and domain-general elicitation of conflict control (cf. Botvinick et al., 2004), we also found only in conditions with a visible prime but not in conditions with an invisible (masked) prime, that conflict induced by word-response non-correspondence reduced the prime-target congruence effect of a visible prime as compared with the prime-target congruence effect in the word-response corresponding condition. No such elicitation of across-domain conflict control of prime-target congruence effects by word-response non-correspondence was found with invisible primes. This result suggests that the application of conflict control elicited in prior trials to a new domain also required awareness.

However, the present finding that masked primes failed to elicit any conflict control is at odds with recent observations by van Gaal et al. (2010). These authors found a weak but significant residual diminution of the congruence effect by 9 ms in masked conditions, if the preceding trial was incongruent in comparison with a preceding trial with a congruent prime-target sequence. It is possible that the slightly weaker overall congruence effect of the masked word primes in the present study (as compared with the stronger overall congruence effect of the masked shape primes in van Gaal et al.'s study) was insufficient to elicit significant residual conflict control here. Another difference to the study by van Gaal et al. (2010) relates to our use of a warning signal (fixation cross) before presentation of the imperative stimuli, and a relatively long inter-trial interval (due to interspersing the judgment task). It might be that weak conflict adaptation effects from masked primes die out more likely with a long inter-trial interval and if a signal tells subjects that a new trial starts. At any rate, the main conclusion of Experiment 1 is barely qualified by this fact because conflict-elicited control was virtually completely dependent on visual awareness here and in van Gaal et al.'s study, and prime-target intervals or different fractions of correct judgments in the preceding trial cannot better account for the difference between visible and invisible priming conditions.

We also observed an unexpected three-way interaction between a preceding trial's congruence effect, word-response correspondence, and visibility. We have no idea what the origin of this three-way interaction might be. We suggest waiting with an explanation until this interaction has been replicated in future experiments.

Experiment 2

The first experiment had a few shortcomings that we wanted to overcome in the second experiment. First, in Experiment 1, our participants had two tasks per each trial. They had to quickly respond to the target and then to judge whether the prime-target sequence was congruent or incongruent at their leisure. This, however, is not optimal because we thereby probably underestimated both effects: prime-target conflict effects (and conflict-elicited control of these effects), as well as prime visibility.

Therefore, in Experiment 2, we skipped the task of quickly responding to the visible targets and only used the prime visibility test. We simply studied the prime-target congruence effect and its control in the judgment times of the prime-target congruence judgments.

Second, in Experiment 1, our conclusion was based on a between-participants variable of masking. It is desirable to realize both conditions, visible and masked priming conditions within participants to rule out that different degrees of conflict control could have reflected (chance) differences between participants. To run both conditions within the same participants we used two blocks per participant, one with masked and one with visible primes and asked for only the prime-target judgment, and skipped manipulation of the variable word-response correspondence. In all other respects the experiment was exactly the same as Experiment 1.

Method

Participants

Twenty-five participants (16 females), mostly students, with a mean age of 24 years participated in exchange for money or course credit. All participants reported normal or corrected-to-normal visual acuity.

Apparatus, stimuli, and procedure

These were the same, except for the following changes. In each trial, participants only had to judge whether the actual trial contained a congruent or an incongruent prime-target sequence. Half of the participants gave an upward response for a congruent trial and a downward response for an incongruent trial, while this mapping rule was reversed for the other half of the participants. All participants received masked and unmasked priming conditions in different blocks, with block order (masked first; unmasked first) balanced across participants.

Results

Prime visibility/prime-target judgments

See Fig. 3 for the results. In the unmasked conditions, primes were visible. d' amounted to a significant 0.82, $t(24) = 7.19$, $p < .01$. In the masked conditions, primes were invisible. d' amounted to a non-significant 0.05, $t(24) = 1.00$, $p = .16$. d' in unmasked conditions was also significantly higher than in masked conditions, $t(24) = 6.42$, $p < .01$.

Judgment times

See also Table 2 for the results. Out of all trials, 4.6% were excluded because RTs differed by more than two standard deviations from individual mean RTs. A repeated-measures ANOVA of the medians of the judgment times was run with only those trials in which participants correctly judged congruence relations in the just preceding trial. This ANOVA had three within-participant variables, preceding prime-target congruence in trial *n-1* (preceding congruent; preceding incongruent), current prime-target congruence (congruent vs. incongruent), and masking (yes vs. no).

This ANOVA led to significant main effects of masking, $F(1, 14) = 24.21$, $p < .01$, and preceding congruence, $F(1, 24) = 8.18$, $p < .01$. Responses were faster in masked (RT = 896 ms) than unmasked (RT = 1,383 ms) conditions and after a preceding congruent trial (RT = 1,115 ms) than after a preceding incongruent (RT = 1,164 ms) trial. Most importantly, there was a significant three-way

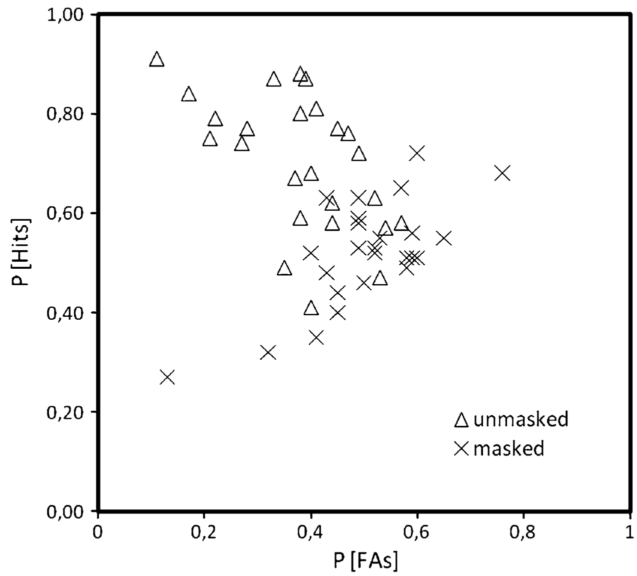

Fig. 3 Depicted are individual hit rates (on the *y* axis) as a function of individual false alarm (FA) rates (on the *x* axis) and masking (masked vs. unmasked). As can be seen, the data from the masked condition roughly align with the diagonal through the origin of the coordinate system. This diagonal corresponds to equal rates of hits and FAs, that is, chance performance. By contrast, in the unmasked condition, hit rates outweigh FA rates. Likewise, hit-to-FA ratios are higher for corresponding than non-corresponding conditions. Data from Experiment 2

Table 2 Reaction times, error rates, and congruence effects (incongruent–congruent) in Experiment 2

	Pre. con.			Pre. inc.		
	Con.	Inc.	Effect	Con.	Inc.	Effect
Unmasked condition						
RT	1,301	1,385	84	1,428	1,416	−12
ER	30.6	34.0	3.4	28.8	42.9	14.1
Masked condition						
RT	881	893	12	894	916	22
ER	54.4	45.9	−8.5	42.2	55.7	13.5

RT Reaction time (ms), *ER* Error rate (%), *pre. con.* preceding congruent, *pre. inc.* preceding incongruent, *con.* congruent, *inc.* incongruent

interaction of Masking × Preceding Congruence × Current Congruence, $F(1, 24) = 5.02, p < .05$, that reflected a current congruence effect, with faster responses in current congruent (RT = 1,301 ms) than incongruent (RT = 1,385 ms) trials, only for visible prime trials that followed a preceding congruent trial, $t(24) = 2.33$, $p < .05$. The current trial's congruence effect was absent after a preceding visible incongruent trial (current congruent RT = 1,428 ms; current incongruent RT = 1,416 ms, $t < 1.00$), and in the masked conditions, after a preceding congruent trial (current congruent RT = 881 ms; current incongruent RT = 893 ms; $t < 1.00$) and after a preceding incongruent trial (current congruent RT = 894 ms; current incongruent RT = 916 ms; $t(24) = 1.02, p = .31$).

In addition, we observed trends towards significant main effects of current congruence, $F(1, 24) = 3.11$, $p = .09$, and towards a significant two-way interaction of Preceding Congruence × Masking, $F(1, 24) = 3.44$, $p = .08$. The trend towards current congruence mirrored the typical better performance in current congruent (RT = 1,126 ms) than current incongruent (RT = 1,153 ms) conditions. The two-way interaction reflected that a larger cost was incurred by a visible preceding incongruent (RT = 1,422 ms) as compared to a preceding congruent (RT = 1,343 ms) trial than by a preceding masked incongruent (RT = 905 ms) as compared to a preceding masked congruent (RT = 887 ms) trial.

A corresponding ANOVA of the arc-sine transformed ERs led to a significant main effect of masking, $F(1, 24) = 64.07$, $p < .01$, and to significant two-way interactions of Masking × Preceding Congruence, $F(1, 24) = 7.17$, $p < .05$, and of Preceding Congruence × Current Congruence, $F(1, 24) = 7.02$, $p < .05$. The main effect of masking was trivial and reflected a higher percentage of errors in masked (ER = 49.6%) than in unmasked (ER = 34.1%) conditions. The two-way interaction of masking and preceding congruence reflected an almost significant selective cost incurred by a visible preceding incongruent (ER = 35.8%) as compared with a visible preceding congruent (ER = 32.3%) condition in visible trials, $t(24) = 1.90, p = .07$, that was numerically reversed in masked conditions (preceding congruent ER = 50.1%; preceding incongruent ER = 49.0%; $t[24] < 1.00$). The two-way interaction of preceding congruence and current congruence was due to a selective congruence effect after preceding incongruent conditions (current congruent ER = 35.5%; current incongruent ER = 49.3%; $t[24] = 3.47$, $p < .01$) that was absent after preceding congruent conditions (current congruent ER = 42.5%; current incongruent ER = 40.0%; $t < .100$). The three-way interaction was not significant, $F(1, 24) = 2.47, p = .13$: Current congruence effects (incongruent ER–congruent ER) were observed after both masked (current congruence effect = 13.5%) and visible preceding incongruent (current congruence effect = 14.0%) trials, both $ts(24) > 2.27$, both $ps < .05$. In the ANOVA of the ERs, the main effect of preceding congruence, $F < 1.00$, and the remaining two-way interaction, $F(1, 24) = 1.74, p = .20$, were not significant.

Discussion

In Experiment 2, we confirmed the exclusive presence of conflict control in the aware conditions, with visible priming trials. With visible primes, the Gratton effect was weak though. It was only present in the judgment times. In the ERs, by contrast, for the visible and for the masked primes, there was a stronger congruence effect after preceding incongruent trials. However, the difference between the Gratton effects in RTs under aware and unaware priming conditions made it quite clear that selective conflict control in aware conditions but absence of conflict control in unaware conditions persisted. Not even the weak RT evidence for a Gratton effect that we observed in aware or visible conditions was found in the unaware or masked conditions. This difference in conflict control was found with masked and visible priming conditions realized within the same participants.

We also observed a significant main effect of masking on RTs and (obviously and trivially) on ERs. Concerning the ER effect, because we asked our participants to judge prime-target congruence relations and because primes were barely visible in the masked condition, the ER in the masked condition had to be higher than in the visible condition. This is in contrast to the results of Experiment 1 because in Experiment 1 the corresponding ER effects were not measured as prime-target congruence influences on judgment times but (as in standard masked priming experiments) as prime-target congruence influences on RTs to clearly visible targets.

By comparison with the ER effect, the effect of the variable masking on judgment times is more interesting. Faster judgments in masked than unmasked conditions indicated that participants took less time for their judgments of prime-target relations in masked than in unmasked conditions. Thus, it is possible that part of the lower rate of correct judgments in the masked condition as compared with the unmasked condition reflected a speed-accuracy trade-off. On a more fundamental level, however, one has to ask for the probable reason of this ER effect. We think that it is plausible that participants simply took little time for judging of masked prime-target relations because this was impossible—that is, the masked primes were hardly seen.

One final aspect of Experiment 2 is noteworthy. The fact that a congruence effect was observed at all suggested that this congruence effect reflected a kind of semantic interference between the prime and target meaning in incongruent trials (cf. Kiefer and Spitzer, 2000). This is so because, there was no response conflict between prime and mask neither in the congruent condition, nor in the incongruent condition, because all congruent prime-target relations required one and the same response, and all incongruent prime-target relations required one and the same alternative response. Therefore, a response could not be activated on the basis of the prime alone, and hence there was no prime-target response conflict in any of the conditions.

General discussion

In the present study, we ran two experiments to test the hypothesis that awareness about (here: the visibility of) a conflict-eliciting stimulus is necessary for subsequent conflict control (Kunde, 2003). We confirmed this hypothesis and found that conflict control depended on the participants' awareness about the conflict-eliciting stimulus.

In Experiment 1, we wanted to rule out that the time for the processing of a conflict-eliciting stimulus—a variable fully confounded with the participants' awareness of a conflict-eliciting stimulus (or its visibility) in prior experiments (cf. Greenwald et al., 1996; Kunde, 2003; van Gaal et al., 2010)—provided a better explanation for lower degrees of conflict control in masked than unmasked conditions. We therefore kept the time for the processing of the conflict-eliciting stimulus exactly the same in aware (visible) and unaware (invisible) priming conditions. Yet, conflict control was only elicited by the visible stimulus of which participants were aware (Experiments 1 and 2). In addition, in line with a domain-general conflict control principle (cf. Botvinick et al., 2004), we found that a visible stimulus that elicited conflict in one domain (here: target–response conflict) also triggered conflict control in an alternative domain (here: prime–target congruence), but again only if participants were aware of the primes—that is, in visible priming conditions. Again, the same kind of conflict failed to trigger conflict control if participants were unaware of the primes because the primes were masked and thus invisible. Evidently nothing prevented conflict by target-response non-correspondence, even in the masked priming conditions because this conflict depended on the fit between the visible target's spatial long-term meaning and the response directions, and because the participants were thus aware of the conflict-eliciting stimulus even in the masked priming conditions. This was confirmed by a large RT cost that was incurred in non-corresponding relative to corresponding conditions, in both masked and unmasked priming conditions. The failure of domain-general conflict control in the masked priming conditions therefore indicated that the application of a control setting to down regulate the prime processing as a consequence of conflict in another domain also required that the participants were aware of the stimulus to which the control setting was to be applied.

Another aspect that we criticized in prior research on the control of conflict with unaware stimuli concerned the implications of the low measured visibility of the conflict-eliciting stimulus for the correct interpretation in this research. In former research, authors used about equal numbers of incorrectly and correctly judged visual conflict-eliciting stimuli in a preceding trial for a test of conflict control in unaware conditions (e.g., Kunde, 2003). However, in the aware conditions of the same studies, the number of correctly judged visual conflict-eliciting stimuli by far exceeded the number of incorrectly judged visual stimuli. Therefore, former studies of awareness and conflict control based their comparison of conflict control under aware versus unaware conditions on unequal numbers of correctly judged stimuli in aware versus unaware conditions. If the correct judgment about a visual stimulus reflected the participants' belief in whether they saw a conflicting stimulus and if the participants' belief about whether they saw a conflicting stimulus was necessary for conflict-elicited control, then it is no wonder that basing conclusions on a larger number of incorrectly judged stimuli in unaware conditions, researchers (e.g., Greenwald et al., 1996; Kunde, 2003) found less evidence for conflict control if participants more often believed that factually conflict-eliciting stimuli were not conflicting and that factually non-conflicting stimuli were conflicting.

In the present study, however, this was not a concern because we asked our participants to judge the conflict-eliciting stimulus in each and every trial. As a consequence, we were able to base even our analysis of conflict control in unaware conditions, solely on those trials, which followed a correctly judged conflicting stimulus. Although this is a very conservative measure, we still found the expected difference in conflict control between aware and unaware conditions: no conflict control in the unaware condition at all, but conflict control in the aware condition. The reason for this finding is probably that even the correct judgments in the unaware condition reflected chance performance, an assumption that so far was rarely tested but was confirmed by implication of the results of the present study.

One caveat of the conclusions from the present Experiment 1, however, was that we collected the data in a dual-task condition, with one quick response for the measurement of conflict and conflict control and one slower judgment about the visual stimulus for the test of awareness of the conflict-eliciting stimulus. This dual-task procedure must have led to an underestimation of the participants' awareness of the conflict-eliciting stimuli, as well as to an underestimation of conflict and conflict control. To overcome this problem, we switched to a simpler judgment-only task in Experiment 2—that is, we skipped the quick responses to the visible targets. Instead, we tested the conditions for conflict control by way of the judgment times. The judgment times had a much larger variance than the quick target responses in Experiment 1. Therefore, overall conflict effects were weak in Experiment 2 and so was conflict control. This shortcoming notwithstanding, we were able to again confirm selective conflict control if participants were aware of the conflict-eliciting stimuli.

The current study thus confirmed that particular forms of top-down control, namely conflict control in response to visual conflict-eliciting stimuli (cf. Gratton et al., 1992), are dependent on the participants' awareness of the conflict-eliciting stimulus. This, however, does not mean that each form of top-down control requires awareness about the stimulus to be processed. Kunde, Kiesel and Hoffmann (2003), for example, showed that top-down control over the processing of a visual stimulus' meaning can be exerted even in the absence of the participants' awareness for the stimulus. There are numerous other instances in which top-down control was exerted even with stimuli remaining below the threshold of aware perception (cf. Ansorge & Neumann, 2005; Held, Ansorge & Müller, 2010, in press; Schlaghecken & Eimer, 2004).

This brings us to a final question: What is the decisive difference between the situations in which top-down control can be exerted over the processing of stimuli of which observers remain unaware (cf. Ansorge, Horstmann, & Worschech, 2010a; Ansorge, Kiss, & Eimer, 2009; Kiefer & Martens, 2010; Kunde, Kiesel, & Hoffmann, 2003; Lau & Passingham, 2007; Mattler, 2005), and the conditions in which top-down control fails because participants remain unaware of the stimuli (cf. Cheesman & Merikle, 1985; Greenwald et al., 1996; Held, Ansorge, & Müller, 2010, in press; Kunde, 2003; McCormick, 1997)? The difference seems to be whether a top-down control setting that fits to the subliminal stimuli can be set up in advance of the stimuli. If a top-down set is already in place, even a stimulus that is presented below the threshold of aware perception can be processed if it fits to the task set. For example, if participants know in advance that they need to press a key in response to a number below five, presenting a visual number four outside the participants' awareness, the number four will nonetheless activate its response (cf. Dehaene et al., 1998; Kunde et al., 2003).

One might wonder, how this could explain the lack of conflict control after target-elicited conflict in the non-corresponding conditions of the present Experiment 1's masked priming conditions. One possibility is that top-down control settings for conflict control were set up for the control of the responses to the visible targets in the non-corresponding blocks, but that these could not be applied to the masked primes because conflict elicited by the masked primes reflected interference between the semantic processing of incongruent primes and targets rather than response activation effects of the masked primes. In line with this, semantic conflict alone produced a prime-target congruence effect in Experiment 2 when response conflict was ruled out. According to this explanation, the fact that different processes are involved in conflict in non-corresponding conditions versus conflict in incongruent conditions (i.e., sensorimotor processes in the case of non-correspondence and semantic processes in the case of incongruence), means that the two types of conflict could in principle be solved by different forms of conflict control. Hence, conflict control to down-regulate motor activation by visible targets in non-corresponding blocks could be without consequence for the masked prime's semantic interference effect in incongruent conditions. This is so at least unless the participants' awareness of the primes suggested that control over the processing of the semantic meaning of the targets and the primes could be a way to take care of both sources of inference at one and the same time. In this respect, our results might not generalize to other forms of stimulus-elicited conflict control, like conflict control after incongruent geometrical shapes such as squares and diamonds (e.g., Neumann & Klotz 1994), because these geometrical stimuli might not necessarily activate strong semantic representations and instead might only activate motor responses. Hence, it will be interesting to directly compare masked priming with words and with geometrical stimuli with respect to its vulnerability to domain-general conflict control in future studies.

To make the argument complete, however, on a more general note, we need to understand why conflict control as it was reflected in the Gratton effect cannot be applied to unaware stimuli. The crucial difference seems to be the fact that conflict control of the Gratton type requires changing rather than keeping the advance top-down settings. For the Gratton effect, top-down settings must be revised on the basis of recent evidence. This kind of control cannot be solved beforehand by a fix control setting. It seems to be much less likely that a top-down control setting is revised in response to the information delivered by a stimulus that remains outside the participants' awareness as suggested by results beyond the scope of the present research. For example, if a conflict-eliciting condition with a masked and therefore invisible word plus a visible target word (e.g., a girl's name as a prime preceding a boy's name as a target) is so probable in the context of an experiment that participants would be well advised to prepare for an alternative response (e.g., prepare pressing the key for boy's name when the prime is a girl's name) than the one that would be indicated by the invisible prime word (e.g., the key for a girl's name when the prime is a girl's name), participants fail to develop this alternative strategy if the incongruent word is also invisible (cf. Ansorge, Heumann, & Scharlau, 2002; Cheesman & Merikle, 1985; McCormick, 1997). It is exactly this kind of reactive and changing rather than advance and fix top-down control that would also be necessary to control the processing of the next visual stimulus after a conflict-eliciting visual stimulus in a just preceding trial. This sort of reactive control seems to require awareness about the stimulus, as has been confirmed in the present study, too, but further investigations are certainly desirable to confirm this conclusion and exactly map out the limits of reactive top-down control (cf. Jaśkowski, Skalska, & Verleger, 2003).

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