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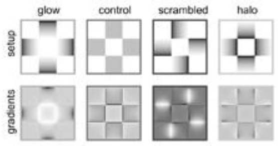

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Comparing sensitivity across different processing measures under metacontrast masking conditions ☆

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Abstract

In the so-called metacontrast dissociation, masked primes with a target-congruent shape facilitate responses to visible targets, whereas masked shape-incongruent primes interfere with them, even if participants cannot successfully discriminate between masked imperative primes (comprising congruent *and* incongruent shape primes) and non-imperative primes (with a shape different from that of all targets). Previous research suggests that visual motion perception can be spared from metacontrast masking [Kolers, P. (1963). *Vision Research*, *3*, 191–206]. Here, we confirmed that detection of visual rotation is spared to a larger degree than detection of visual shape (Experiment 1) and that even shapes of masked stimuli can be detected if the shape-detection task is easier (Experiment 2). Implications of our findings for the conclusion that performance in masked priming studies depends on processing of non-conscious inputs are discussed.

Keywords: Vision; Masking; Motor control; Priming; Motion perception

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1. Introduction

Metacontrast masking is a form of visual backward masking of a test stimulus by a spatially adjacent, temporally trailing masking stimulus, with the latter often simply being called a "mask" (Stigler, 1910). In this context, masking denotes a decreased likelihood that a test stimulus feature can be reported. The extent to which a particular feature can or cannot be consciously seen under metacontrast masking conditions differs depending on the feature under investigation. Whereas a metacontrast mask strongly diminishes the perception of shape and brightness (for overviews see Breitmeyer, 1984; Breitmeyer & Ogmen, 2006), it impacts much less on motion (Kolers, 1963).

In early studies of metacontrast masking, investigators had a major interest in detailing the mask-induced changes of the phenomenally perceived test stimulus features. Werner (1935), for example, found that strokes protruding from a test stimulus disk were falsely perceived as being part of the trailing ring-shaped mask. Although studies of such feature misattributions prevail today (cf. Otto, Ogmen, & Herzog, 2006; Scharlau, Ansorge, & Horstmann, 2006), recent metacontrast masking studies have been used to block the conscious perception of visual stimuli. Thus, metacontrast masking provides a method for investigating the subliminal processing of visual stimuli (cf. Breitmeyer, Ro, & Singhal, 2004; Klotz & Wolff, 1995; Leuthold & Kopp, 1998; Neumann & Klotz, 1994; Schmidt, Niehaus, & Nagel, 2006; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003; Wolff, 1989). In particular, metacontrast masking has been applied to detection dissociations: the mask renders a visual stimulus,

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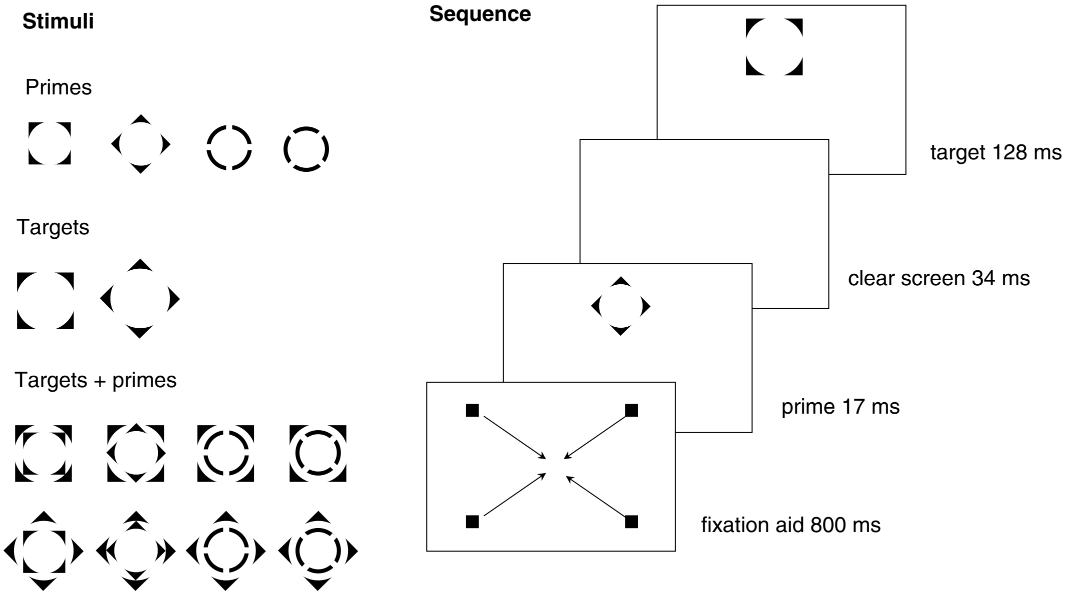

Fig. 1. Depicted are the different stimuli on the left, and an example of the stimulus sequence within a trial on the right. Left: In Experiments 1 and 2, targets were either squares or diamonds. In Experiment 1, incongruent conditions (i.e., conditions with a square-shaped prime and a diamond-shaped target or with a diamond-shaped prime and a square-shaped target) and neutral conditions were used. In neutral conditions, primes were circular. Note that two sorts of circular primes were used, one circle prime with its constituting line segments aligned with that of the square-shaped figure (the left depicted circular prime), the other one with its line segments aligned with that of the diamond-shaped figure (the right depicted circular prime). In Experiment 2, congruent conditions (i.e., conditions with a square-shaped prime and a square-shaped target or with a diamond-shaped prime and a diamond-shaped target) were used instead of the neutral conditions. Right: Depicted is the sequence of stimuli (starting from the bottom) in an incongruent trial, with prime and target above fixation. Note that the stimuli in the frames are not drawn to scale.

the so-called "prime" (see below), invisible, as determined by a *direct measure* of conscious stimulus perception, whereas processing of the invisible prime on consciousness-dissociated functional levels is spared, as testified in an *indirect measure* (Klotz & Neumann, 1999). In the following, we will use the term "prime detection" for the direct measure and the term "masked priming" for the indirect measure.

For their masked priming effect Klotz and Wolff (1995) presented a clearly visible shape as a target in each trial. This visible target was either a square or a diamond and participants pressed one button for the square and another button for the diamond. Unknown to the participants, a smaller invisible prime preceded the visible target. This prime either had the same shape as one of the two targets and, therefore, was response-relevant, or it had a circular shape of one of two kinds (with each of these circular shapes being equally probable) and, thus, was neutral with respect to the response alternatives (see also Fig. 1 for the procedure). Square- and diamond-shaped primes were equally likely to precede a target of the same shape ("congruent" trials) or of the other shape ("incongruent" trials).

Due to the small but positive stimulus onset asynchrony (SOA) between prime and target, the prime's visibility was suppressed by the trailing target. In other words, besides determining the requested responses the target also served as a metacontrast mask for the prime. Masking was demonstrated in a prime detection task, in which participants had to detect trials with a target-shaped prime (congruent and incongruent trials) and tell them from trials without such a prime (neutral trials). Participants performed on a chance level in this prime detection task (cf. Ansorge, 2003; Klotz & Wolff, 1995).[1]

Yet, in line with the assumption that even an invisible prime can activate responses (cf. Neumann, 1989, 1990), reaction times (RTs) to the visible targets were increased with an incongruent prime and decreased with a congruent one, when compared to the neutral prime, although the prime's shape was not available to conscious report (Ansorge, 2003; Klotz & Wolff, 1995). In summary, metacontrast completely masked the primes' shapes reflected in prime detection performance but allowed for consciousness-dissociated processing of the subliminal prime shapes reflected in masked priming effects.

However, the metacontrast dissociation as implemented by Ansorge (2003) and Klotz and Wolff (1995) can still be

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[1] Differences between Experiment 3 of Ansorge (2003) and the study of Klotz and Wolff (1995) concerned the exact timing, screen positions, and luminance of the stimuli, as well as the number of trials devoted to the prime detection and masked priming tasks. Ansorge used 160 trials per task, with primes and targets of durations of 17 and 34 ms, respectively, and a prime–target SOA of 64 ms. Stimuli were dark (<1 cd/m^2) on a bright background (48 cd/m^2), and shown vertically centred, 5.7° left or right of screen centre. Klotz and Wolff (1995) used 320 trials per block, with primes and targets of durations of 30 and 90 ms, respectively, and an SOA of 75 ms. Stimuli were 0.4 cd/m^2 on a 108 cd/m^2 background, and shown horizontally centred, 3.4° above or below screen centre.

criticized for its prime detection task. First, these authors concluded from the failure of the participants to detect primes that were squares or diamonds, and to tell them from trials with a circular prime, that there was no residual conscious perception of the prime. However, the authors did not test whether the participants were able to detect different types of motion produced by the prime and the trailing mask, despite the fact that motion perception can escape the detrimental metacontrast masking effect (Kolers, 1963). Indeed, we recently found in a variant of the metacontrast dissociation procedure (Klotz & Neumann, 1999) that participants detected visual rotation if a prime shape (e.g., square shape) preceded an incongruent target shape (e.g., a diamond shape) (Ansorge, Becker, & Breitmeyer, submitted for publication). This implies that conscious prime perception when using a motion detection criterion could have been better than when using a prime detection criterion: some residual capacity to consciously see the prime shape was reflected by the better-than-chance performance in a rotation detection task. Thus, the prime detection task used by Klotz and Wolff (1995) and Ansorge (2003) might not have been an exhaustive measure of conscious prime perception (cf. Reingold & Merikle, 1988).

With respect to the perception of rotation, however, it should be noted that this sort of prime perception can hardly account for the masked priming effect. Thus, even if we find that participants are capable of detecting rotation under incongruent conditions, this does not call into question that the masked priming effect depended on subliminal input. The reason is that rotation can only be perceived after presentation of the target; thus, perception of motion is too late to explain the initial response activation induced solely by the masked prime which was picked up electrophysiologically (cf. Leuthold & Kopp, 1998; Vath & Schmidt, 2007).

Moreover and more telling, it can also be objected that in their prime detection tasks Ansorge (2003) and Klotz and Wolff (1995) asked their participants to tell imperative (target-like) prime shapes from neutral prime shapes. This means that participants had to classify congruent *and* incongruent conditions as belonging to the same category (of imperative primes). By contrast, in the masked priming task these two different imperative conditions led to the largest performance difference: RT differences were most pronounced between the congruent and the incongruent conditions. Moreover, the S–R mapping rule was thus more complex in the prime detection task than in the masked priming tasks: in the masked priming task, with different button presses for diamonds vs. squares, two stimuli mapped on two responses, but in the prime detection task one button was pressed for squares *and* diamonds and another button for the circles (cf. Schmidt & Vorberg, 2006). These two objections concern the measurement of the visibility of the prime shape and are thus potentially detrimental to the conclusion that the masked priming effect draws on the processing of subliminal inputs.

2. Purpose of the present study

The current study addressed both of the concerns mentioned above. In Experiments 1 and 2, stimuli and procedures of Ansorge (2003) were used, except for the following important changes. First, to check whether rotation detection is more sensitive for prime-contained information than prime detection four tasks were used in separate blocks: a masked priming task (a) in which speeded responses to visible targets were given and a congruence effect of the masked primes was expected; a prime-shape detection task (b) in which participants had to detect a response-relevant angular prime used in incongruent trials in the context of neutral trials with a circular prime (Experiment 1) or in which participants had to detect a particular shape prime (i.e., diamonds) in congruent vs. incongruent trials (Experiment 2); a rotation detection task (c) based upon prime *and* target detection, in which participants had to detect rotation resulting from the combination of prime and mask; and a localization-of-rotation task (d). In this latter task, also drawing upon both prime and target detection, we used two prime–target sequences, one above, the other one below fixation, one of them incongruent, the other one neutral (Experiment 1), or one of them incongruent, the other one congruent (Experiment 2). In this task (d), participants had to locate the rotating prime–target sequence (i.e., the incongruent sequence) as being either above or below fixation. If it is true that motion perception escapes the detrimental influence of metacontrast masking, we expected to find better than chance performance at least in the rotation detection task (c) and the localization-of-rotation task (d), whereas shape detection (b) might still turn out to be insensitive for the prime-contained shape information (cf. Ansorge et al., submitted for publication; but see below).

Second, to test whether a greater task difficulty in the prime-shape detection than in the masked priming task has been responsible for the poor performance in the prime detection task in Ansorge (2003), we also used either only incongruent and neutral conditions (Experiment 1), or only incongruent and congruent conditions (Experiment 2), and asked our participants to detect angular incongruent primes (Experiment 1) or diamond-shaped primes (Experiment 2) in the prime-shape detection task (b). If it is true that a higher task difficulty in the prime-shape detection task than in the masked priming task of Ansorge (2003) accounted for the poor performance in the prime detection task, we expected to find similar sensitivities to prime-shape information in the currently used prime-shape detection task (b) and the masked priming task (a) in Experiment 1: Experiment 1's prime-shape detection task eliminated responses based on shape classification across congruent and incongruent conditions, and thus tested whether this sort of decreased difficulty of the shape detection task suffices to eliminate the dissociation between prime-shape detection performance and masked priming effect. Note, however, that Experiment 1's prime-shape detection task still required participants to classify two kinds of angular prime shapes (squares and diamonds) by one response and two kinds of neutral primes (those with their segments aligned with the trailing targets and those with their segments not aligned with the trailing targets; see Fig. 1) by an alternative response. This prime-shape detection task was still slightly more demanding than the masked priming task and thus possibly leads to a dissociation.

3. Experiment 1

In Experiment 1, we compared the ability to process and perceive a masked prime under incongruent conditions with that under neutral conditions in four tasks, a masked priming task (a), a prime-shape detection task (b), a rotation detection task (c), and a localization-of-rotation task (d). The latter task necessitated that two prime–target sequences were presented in each trial. Also, as in the study of Klotz and Wolff (1995), primes and targets were horizontally centred and presented above or below fixation. With the exception of these changes, the procedure was similar to that used by Ansorge (2003).

We used three-alternative criteria for our testing of the metacontrast dissociation. First, most straightforward and very sensitive, we tested whether detection performance in tasks (b) to (d) and masked priming effects in task (a) were significantly different from chance level influences of the masked prime. This dissociation criterion is fulfilled if performance in the prime detection task is not significantly different from chance-level accuracy, whereas the masked priming effect indicates an above-chance-level influence of the masked prime shape (cf. Reingold & Merikle, 1988). Second, when the first dissociation criterion failed, we also directly compared effect sizes based on prime detection performance with those based on masked priming. This second dissociation criterion is less conservative than the first one, and can thus be met even under conditions where the first criterion fails and conscious perception of the primes (or the test stimuli) is possible in some extent (cf. Reingold & Merikle, 1988). Third, if the first dissociation criterion was not fulfilled, we additionally tested whether detection performance and masked priming effect were significantly correlated with one another. This should be the case, if conscious detection of the masked prime is possible and is also a crucial prerequisite for the masked priming effect. According to this logic, non-significant (''zero'') correlations between detection performance and masked priming effect are diagnostic of dissociations between the two measures (cf. Breitmeyer, Ogmen, Ramon, & Chen, 2005; Naccache & Dehaene, 2001; see also Schmidt & Vorberg, 2006, for a generalization of the principle). This is probably the least conservative and most easily fulfilled dissociation criterion.

Irrespective of the dissociation criterion that is used, if it is true that an increased task difficulty in the prime-shape detection task relative to the masked priming task accounted for the metacontrast dissociation of Ansorge (2003), we might find no dissociation in Experiment 1 at all. The reason for this expectation is that participants no longer had to classify congruent *and* incongruent conditions as belonging to the same class of imperative shapes in the prime-shape detection task (b) of the present experiment: only incongruent but not congruent conditions were used and had to be told from neutral conditions without a target-like shape prime. Thus, task difficulty, being more similar in the prime-shape detection task and in the masked priming task, might eliminate dissociations.

Also regardless of the dissociation criterion that is used, if it is true that under metacontrast masking conditions, motion perception is spared to a larger extent than shape perception, we might find better performance in a rotation detection task (c) and in a localization-of-rotation task (d) than in a prime-shape detection task (b).

3.1. Methods

3.1.1. Participants

Twenty-four volunteers (14 female, 10 male) with a mean age of 26 years participated. Here and in the following experiment, participants were students at Bielefeld University, had normal or fully corrected vision, and were paid for their participation.

3.1.2. Apparatus

The experiment was controlled by a computer that also registered responses. Stimuli were presented on a color monitor. A serial mouse was used for the responses. Participants pressed left and right mouse buttons with the index fingers of the corresponding hands. Latencies were measured from the beginning of the target to the nearest millisecond. The participants were seated in a dimly lit room, in front of the screen, with their line of gaze straight ahead, head supported by a chin rest.

3.1.3. Stimuli and procedure

See also Fig. 1. The stimuli were displayed dark (<1 cd/m^2) on a bright background (48 cd/m^2). To draw the attention of the participants to the center of the screen, four small filled dark squares (each with a side length of 0.4°) were presented at the start of each trial in the corners of the screen that moved on diagonal trajectories towards the center where they merged and disappeared. This fixation aid took 800 ms. In each trial of (a) the masked priming task, (b) the prime-shape detection task, and (c) the rotation detection task, immediately after the fixation aid, a prime was presented for 17 ms. The prime was equally likely one of two small circles, one with its segments aligned with that of the square, the other with its segments aligned with that of the diamond shape (these were the neutral primes), or one of two angular stimuli, a small diamond or a small square (these were the incongruent primes). After a blank interval of 32 ms, a target was shown for 128 ms. In each trial, the target was either a square or a diamond. Both of these targets had a side length of 1.6°, and each had inner contour boundaries that fitted exactly around the outer contour boundaries of the preceding prime. In the neutral conditions, both types of circular primes were presented with equal likelihood prior to both types of angular target shapes. In the following, the neutral condition in which the circular prime had its segments aligned with that of the temporally trailing angular target in the same trial will be called neutral/aligned, whereas the neutral condition in which the circular prime had its segments arranged in a manner different from that of the temporally trailing angular target in the same trial, will be called neutral/unaligned. In the incongruent conditions, if the prime was a small diamond, the target was a square, and if the prime was a small square the target was a diamond. Each prime–target sequence appeared 3.4° above or below the screen centre. Squares and diamonds were presented as targets with equal probabilities and they were equally likely above or below fixation. Different conditions were equally likely and the order of conditions was pseudo-randomized within each block.

In each trial of the localization-of-rotation task (d), two prime–mask sequences were presented simultaneously, one above, the other one below the centre. In each trial of task (d), both of these sequences contained the same target/mask, say the square, but one of these targets was preceded by a circular prime (neutral prime–target sequence), the other one was preceded by an angular prime of the type of the alternative target (incongruent prime–target sequence). Otherwise the procedure was exactly the same as in the other task conditions described above.

Participants worked through four blocks. The first block was always the masked priming task (a), in which participants either pressed the left mouse key with their left index finger in response to a visible square target, and the right mouse key with their right index finger in response to a visible diamond target, or vice versa (with S–R mappings balanced across participants). The second to fourth blocks were the different detection tasks (b) to (d), with the order of the detection tasks being balanced across participants. In each trial of the prime-shape detection task (b), participants had to judge whether the actual masked prime was angular or not. To classify a response as correct, this task required a "yes" response in incongruent conditions and a "no" response in neutral conditions. In each trial of the rotation detection task (c), participants had to judge whether or not they perceived any rotation in the prime–target sequence. Here, to classify a response as correct, the task required a "yes" response in incongruent conditions and a "no" response in neutral conditions. Finally, in each trial of the localization-of-rotation task (d), participants had to judge whether the perceived rotation was above or below fixation. To classify a response as correct, this task required an "above" response if an incongruent prime–mask sequence was shown above fixation (and a neutral prime–mask sequence was shown below fixation) and a "below" response if an incongruent prime–mask sequence was shown below fixation (and a neutral prime–mask sequence was shown above fixation).

To meet the exclusiveness criterion (Reingold & Merikle, 1988, 1990)—that is, to make performance in the tasks (b) to (d) insensitive for influences of subliminal or unconscious visual input of the motor activation type, participants were informed about the pertinent mapping of yes versus no responses to the left versus right index fingers only *after* the presentation of the prime–mask sequence. Prior research has shown that an action plan must be completed prior to the masked prime for a motor activation effect of an unconscious prime to occur (cf. Ansorge, 2004; Ansorge & Heumann, 2006; Ansorge & Neumann, 2005; Klotz & Neumann, 1999; see also Ansorge, Neumann, Becker, Kälberer, & Cruse, 2007, for a more general explanation). For instance, presenting information about the currently pertinent S–R mapping with an interval of only 250 ms prior to the masked prime already reduces the masked priming effect (cf. Experiment 4 of Neumann & Klotz, 1994). Hence, the presentation of instructions after the stimulus sequence prevented influences of unconscious visual input via prime-induced motor activation in the detection tasks (b) to (d). In the current study, the instructions informing participants about the S–R mappings in the detection tasks (b) to (d) stayed on the screen for maximally 10 s or until a judgment was given for the actual trial.

In the masked priming task (a), participants had to respond as fast and as accurately as possible, and in the other tasks (b) to (d) as accurately as possible. Participants were informed about the presence of the primes prior to the first of the three detection tasks (b) to (d) but not prior to the masked priming task (a). In the instructions of the detection tasks (b) to (d), it was explained to the participants that the prime shape or the rotation might be hard to perceive but participants were encouraged to give a judgment in each trial: they were told to make their best guesses about the presence of the prime shape or the presence of rotation if they thought they did not see anything because prior research indicated that guessing performance can be better than chance under very similar conditions (cf. Marcel, 1993).

The inter-trial-interval was 2 s. In the masked priming task (a), an error message was presented for 700 ms if an incorrect response was given, and a feedback was presented for 700 ms that instructed participants to respond faster if their RT had exceeded 750 ms. Otherwise no feedback was given (in the detection tasks [b] to [d]).

In the blocks of the masked priming task (a), and the detection tasks (b) and (c), each of the combinations that resulted from a complete crossing of two target shapes (square vs. diamond) × three prime shapes (circular/aligned vs. circular/unaligned vs. angular/incongruent) × two positions (above vs. below fixation) was repeated 32 times, leading to altogether 384 trials. In the location-of-rotation task (d), each of the combinations that resulted from a complete crossing of two target shapes (square vs. diamond) × two neutral circular prime shapes (neutral/aligned vs. neutral/unaligned) × two positions of the incongruent prime–mask sequence (above vs. below fixation) was repeated 48 times, leading to 384 trials, too. Together with practice trials, prior to each block, participants took 3–4 h to complete all four tasks during three to four separate sessions.

3.2. Analysis

For the computation of the detection task measures (b) to (d), each participant's hit rates were z-transformed (Macmillan & Creelman, 2005). For tasks (b) and (c), the hit rates were defined as the rates of yes responses in incongruent trials and the rates of false alarms were defined as rates of yes responses in neutral/aligned trials and neutral/unaligned trials. For task (d), the hit rates were defined as rates of above responses in trials with the incongruent prime–mask sequence presented above fixation and the rates of false alarms were defined as rates of above responses with the incongruent prime–mask sequence presented below fixation. For the masked priming effect in task (a), separately for each participant, the median of all correct RTs below 1000 ms was computed. Next, rates of incongruent responses above the overall median RT across all correct responses above 100 ms and below 1000 ms and rates of neutral trials above the same median RT were computed as analogues of hit rates and false alarm rates, respectively (the RT exclusion criterion was also used in the former studies by Ansorge (2003) and Klotz and Wolff (1995)). This procedure yields intuitively, although not formally tested and fully analogous measures for the hit rates in the tasks (b) to (d): the underlying assumption here is that processing of the incongruent shape prime but not that of the neutral shape prime activates the alternative response and can thus interfere with the correct response to the target. Thus, an intuitive analogue of shape detection corresponds to the delay of the correct target response by the incongruent shape prime but not by the neutral shape prime, so that the incongruent shape prime should yield a correct RT above the median RT with a higher probability than the neutral shape prime (note that this procedure yields positive d' values under incongruent conditions, for which Klotz and Neumann (1999) reported negative d' values because they used RTs < median RT as hits. The different procedures are inconsequential for the power of the resulting indices to illuminate the participants' prime shape processing abilities). Besides, average correct RTs as well as average error rates from task (a) were analyzed by standard ANOVAs.

Separately for each participant and each of the four tasks, z-transformed false alarm rates were subtracted from z-transformed hit rates to get four d' indices per participant and task (Green & Swets, 1966): d' for diamond targets, with performance under incongruent conditions pitted against performance in neutral/aligned conditions, d' for diamond targets, with performance under incongruent conditions pitted against performance in neutral/unaligned conditions, d' for square targets, with performance under incongruent conditions pitted against performance in neutral/aligned conditions, and d' for square targets, with performance under incongruent conditions pitted against performance in neutral/unaligned conditions.

Average d' values across participants were tested against zero by t tests, with an average d' that is not significantly different from zero indicating chance performance in the respective detection measure—that is, no evidence for an ability to consciously see the feature in question. Average d' values from any of the detection measures (b) to (d) that exceeded zero were directly tested for significant differences to average d' values derived from the respective masked priming task by within-participant t tests (cf. Reingold & Merikle, 1988). This test was conducted as the second, more liberal dissociation criterion—that is, a direct comparison of the effect sizes (cf. Reingold & Merikle, 1988, 1990). Additionally, average d' values from any of the detection measures (b) to (d) that exceeded zero were also tested for significant correlations with average d' values derived from the RTs of the respective masked priming tasks (cf. Naccache & Dehaene, 2001). This test provided a third dissociation criterion.

3.3. Results

Table 1 shows the main results. Between one participant's data (for the masked priming effect [a]) and four participants' data (for detection measure [d]) were lost for the computation and analyses of performance due to technical error, not showing up of individual participants to all experimental sessions, and misunderstanding of task instructions in (some of) the measures (a) to (d) (misunderstandings of the task were indicated by more than 50% errors in the masked priming task [a], and by rates of hits or false alarms of less than 5%).

In the masked priming task (a), out of all trials, 0.7% were excluded from the analyses because responses were faster than 100 ms or slower than 1000 ms. A repeated-measures ANOVA of individual means of correct responses, with the two within-participant variables of *target type* (square vs. diamond) and *prime type* (neutral/aligned vs. neutral/unaligned vs. incongruent), led to a significant main effect of prime type, $F(2,44) = 8.12$, $p < .01$. The main effect of target type, $F < 1.00$, and the interaction of Target type × Prime type, $F(2,44) = 2.83$, $p = .07$, were non-significant. Post-hoc t tests confirmed that RT was significantly increased in incongruent conditions (469 ms) compared to neutral/aligned (460 ms; $t[22] = 2.31$, $p < .05$) and neutral/unaligned (457 ms; $t[22] = 4.79$, $p < .01$) conditions. Although these RT differences were small, they were reflected in significant masked priming effects in d' analyses of the masked priming effect, too (see Table 1). Moreover, there was no indication of a speed–accuracy trade-off. A repeated-measures ANOVA of arc-sine transformed error rates, with the same variables

Table 1
Results of Experiment 1

Task	Target	Incongruent vs.	Mean d'	d' range	t	n	p (one tailed)
(a) Masked priming	Diamond	Neutral/aligned	0.16	−0.27 to 0.54	3.21	23	<.01
		Neutral/unaligned	0.16	−0.39 to 0.58	2.93	23	<.01
	Square	Neutral/aligned	0.29	−0.07 to 0.73	5.70	23	<.01
		Neutral/unaligned	0.21	−0.36 to 0.80	3.47	23	<.01
(b) Shape detection	Diamond	Neutral/aligned	−0.02	−0.57 to 0.44	−0.29	23	=.39
		Neutral/unaligned	−0.08	−0.80 to 0.43	−1.50	23	=.07
	Square	Neutral/aligned	−0.05	−0.94 to 0.59	−0.74	23	=.23
		Neutral/unaligned	−0.10	−1.02 to 0.43	−1.57	23	=.07
(c) Rotation detection	Diamond	Neutral/aligned	0.14	−0.30 to 0.86	1.97	21	<.05
		Neutral/unaligned	0.13	−0.51 to 0.94	1.80	21	<.05
	Square	Neutral/aligned	0.13	−0.67 to 1.69	1.10	21	=.14
		Neutral/unaligned	0.05	−0.47 to 1.15	0.62	21	=.27
(d) Localization of rotation	Diamond	Neutral/aligned	−0.05	−0.45 to 0.30	−0.96	20	=.25
		Neutral/unaligned	−0.06	−0.53 to 0.40	−1.05	20	=.15
	Square	Neutral/aligned	0.23	−0.15 to 0.99	3.51	20	<.01
		Neutral/unaligned	0.09	−0.38 to 0.75	1.37	20	=.09

as were used for the analysis of RTs, led to a significant main effect of prime type, $F(2,44) = 11.31$, $p < .01$, and to a significant interaction of Target type × Prime type, $F(2,44) = 3.60$, $p < .05$. Follow-up t tests confirmed significantly elevated error rates in square target trials under incongruent conditions (5.3%) as compared with neutral/aligned (2.4%; $t[22] = 3.53$, $p < .01$) and neutral/unaligned (2.1%; $t[22] = 3.87$, $p < .01$) conditions, but not in diamond target trials (incongruent: error rate = 3.5%; neutral/aligned: error rate = 3.5%; neutral/unaligned: error rate = 2.7%), both non-significant $ts(22) < 1.10$, both $ps > .31$.

Detection performance measures (b) to (d) reflected different sensitivities for information contained in the masked primes or the prime–mask sequences. First, in line with prior findings, the prime-shape detection task (b) was insensitive for shape information contained in the masked prime (see Table 1). Note that the tendency toward significant differences between average d' values and zero under conditions in which circular/unaligned primes were presented prior to a mask was in the opposite direction of the expected effect: d' values were negative. Therefore, the one-tailed t test that we have used was in fact simply rendering the wrong result.

Second, in line with a spared motion perception capacity of the participants under metacontrast masking conditions (Ansorge et al., submitted for publication; Kolers, 1963), performance in the motion detection task (c) reflected the participants' capacity to report information delivered by different prime–target sequences. At least with a diamond-shaped target as a mask, participants were able to detect rotation under incongruent conditions and, thus, discriminated incongruent prime–target sequences (with a angular square-shaped prime) from neutral prime–target ones (with a circular prime): as expected, the former conditions more frequently led to the impression of visual rotation than the latter conditions (see Table 1). Although the corresponding capacity was not evident in task (c) when a square-shaped target was used as a mask, a related perceptual capacity was reflected in the participants' ability to locate an incongruent prime–target sequence with such a square-shaped target as a mask, as being the one sequence that leads to stronger rotation perception than the concomitantly presented neutral prime–target sequence using the same target as a mask (and a circular/aligned prime) in the localization-of-rotation task (d).

Third, comparisons conducted separately for those combinations of prime shape and target shape that allowed for better than chance performance in one of the measures (c) (i.e., for diamond-shaped targets), or (d) (for square-shaped targets) between the respective masked priming effect (a) and either the significant rotation detection performance (c) or the significant localization of rotation performance (d) revealed that sensitivity for information contained in the masked prime was about equal in the masked priming task (a) and in the respective detection task (task [c] for diamond-shaped targets and task [d] for square-shaped targets): this was indicated by non-significant differences between average d' values, all four $ts(20) < 1.20$, all four $ps > .27$.

Additionally, for each prime–target sequence that was detected with better than chance likelihood in one of the detection tasks (c) or (d) correlations between average d' based on the masked priming effect (a) and average d' based on detection performance in tasks (c) or (d) revealed no significant correlations, with coefficients ranging from $r = -.01$ to $r = .37$, $N = 20$, all four $ps > .10$. See also Fig. 2.

3.4. Discussion

Experiment 1 yielded a number of noteworthy results. First, we replicated part of the metacontrast dissociation (cf. Ansorge, 2003; Klotz & Wolff, 1995) using only neutral

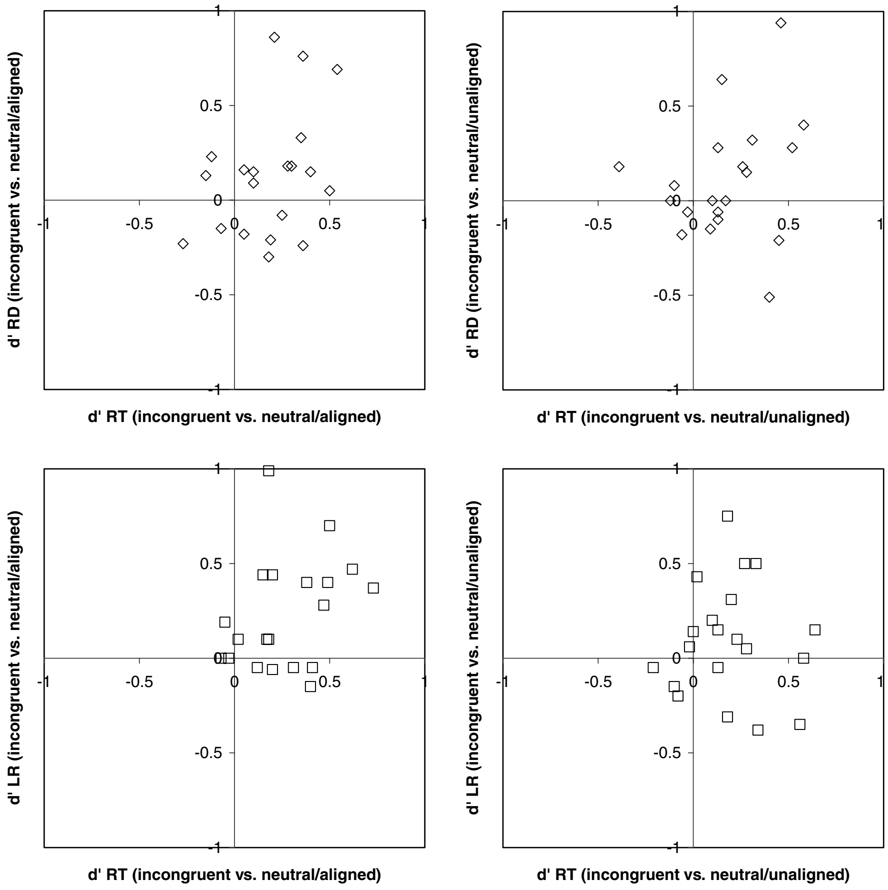

Fig. 2. Data from Experiment 1. Participants' individual masked priming reaction time effects in task (a) on the ordinates—in terms of individual *d*′ values (*d*′ RT)—as a function of the participants' performance in the prime detection tasks on the abscissas—also in terms of individual *d*′ values (*d*′ RD, *d*′ LR). Upper panels: *d*′ values for diamond-shaped targets from the rotation detection task (*d*′ RD); lower panels: *d*′ values for square-shaped targets from the localization-of-rotation task (*d*′ LR). RT, reaction time; RD, rotation detection; LR, localization of rotation. For details refer to Sections 3.1 and 3.4.

and incongruent conditions and a prime-shape detection task. This result goes beyond what is known because the dissociation between the processing of the "unconscious" or subliminal masked prime shape reflected in the significant and reliable masked priming effect (a) and the apparent "invisibility" of the prime shape reflected in the chance performance during the prime-shape detection task (b) were found with both tasks being more alike in terms of task difficulty and complexities of S–R mappings used (cf. Schmidt & Vorberg, 2006). Thus, it seems unlikely that a higher task difficulty in the detection task than in the masked priming task is the sole or major factor responsible for the metacontrast dissociation.

However, it should be noted that the prime-shape detection task (b) of Experiment 1 still could have been slightly more demanding than the masked priming task (a) because the former but not the latter task required classifying two stimulus alternatives as belonging to the same class of events (e.g., two different circular primes, one with aligned, the other with unaligned inner segments). Hence, an even more straightforward levelling of task difficulties in shape-detection and masking priming tasks would be to map only one stimulus on one of two responses in both of these tasks. This further going levelling of task difficulties will be realized in Experiment 2 below.

A second interesting finding was that participants in Experiment 1 were able to perceive motion: in the current case rotation as resulting more frequently from incongruent than neutral prime–target sequences. This finding is in line with former observations (Ansorge et al., submitted for publication; Kolers, 1963). Importantly, for two reasons we are relatively certain that the detection performance in the rotation detection tasks (c) and (d) indeed reflected conscious perception of information contained in the masked primes and the targets rather than unconscious motor processing of the masked primes. One reason is that in Experiment 1 rotation detection abilities were evident under instructions that emphasized accuracy over speed, and asked participants to take their time for their judgments. These are standard procedures in psychophysical tasks securing that performance is based on conscious perception. A second reason is that the instructions about the S–R mappings pertaining in an actual trial were provided only after the prime–mask sequence. Therefore, participants were not able to set up an action plan, mapping alternative responses to different visual motion stimuli in advance of the displays. The completion of an action plan in advance of the visual input has been found to be a necessary prerequisite for processing of unconscious visual input (cf. Ansorge, 2004; Ansorge & Neumann, 2005; Ansorge et al., submitted for publication; Kunde, Kiesel, & Hoffmann, 2003; Neumann & Klotz, 1994; Scharlau & Ansorge, 2003). Hence, the current detection tasks were very likely insensitive to influences by a processing of unconscious masked primes, making it in reverse likely that conscious perception of the prime–mask sequences was exclusively reflected in the detection performance measures (b) to (d). Finally, the insensitivity of measure (b) for prime-contained shape information also supports this interpretation.

A third finding of interest in Experiment 1 is that the capacity to detect rotation created by different incongruent prime–mask sequences was reflected in either rotation detection (c) or localization of rotation performance (d). With diamond-shaped masks, the ability was evident in task (c) but not in task (d), whereas with square-shaped masks, we found the opposite pattern of results. Thus, neither of the tasks (c) and (d) was the most sensitive one. Instead, the two tasks (c) and (d) appeared to be differentially sensitive for particular stimulus features creating the motion percept. These somewhat inconsistent results were unexpected, and we do not have an explanation for them.

A fourth result of Experiment 1 concerns the contributions of (a) line segments and (b) outer contours to the detection ability reflected in the rotation detection and localization-of-rotation tasks. With the diamond-shaped targets as masks, detection of rotation in task (c) was equally good, regardless of whether detection performance under incongruent conditions was compared to detection performance under neutral conditions with a circular/aligned prime or with a circular/unaligned prime. Thus, what seemingly matters for the detection of rotation has been the change of the outer contours from prime to mask and not simply the change between the line segments of the prime relative to those of the mask.

This interpretation was supported by performance in the localization-of-rotation task (d) with square-shaped targets as masks. In measure (d), the strongest ability to locate an incongruent prime–mask sequence as rotating was obtained in comparison with a concomitant neutral prime–target sequence consisting of a circular/aligned prime and a square target as a mask—that is, in comparison to a sequence of two consecutive stimuli that had their line segments spatially arranged in a similar manner. Thus, it seems as if the similarity of prime and target in terms of their line segments facilitated the localization of rotation. By contrast, in neutral conditions with a circular/unaligned prime preceding a square-shaped target as a mask, a change of the line segments from prime to target compromised the localization of rotation, possibly by increasing perceptual noise levels.

A final noteworthy finding in Experiment 1 is that although the detection tasks (c) or (d) were approximately as sensitive to information contained in the masked prime as the masked priming task (a), detection performance and masked priming effect were still not significantly correlated with one another. This corroborates the view that indeed the third dissociation criterion of a zero correlation between prime detection and masked priming effect can be most easily met.

In conclusion, Experiment 1 demonstrates that motion detection escapes the detrimental effects of a metacontrast mask under conditions where shape detection does not. However, this finding does not call into question the dissociation between the capacity to consciously perceive a visual stimulus and the capacity to process the very same stimulus. The reason is that motion perception drawing on prime *and* target occurs too late to account for prime-locked response activation (cf. Vath & Schmidt, 2007). Moreover, the dissociation was reflected in a comparison between the significant masked priming effect and the chance performance in the prime-shape detection task although the prime-shape detection task no longer required classification across congruent *and* incongruent conditions.

And yet, the prime-shape detection task in Experiment 1 could have been more difficult than the task used for deriving of the masked priming effect, because the former task but not the latter required a classification across two types of neutral (circular) and across two types of imperative (angular) primes. Therefore, Experiment 2 addressed the question whether a further levelling of the difficulties of prime-shape detection task and masked priming task eliminated the dissociation.

4. Experiment 2

In Experiment 2, we compared the ability to process and perceive a masked prime under incongruent conditions with that under congruent conditions. Otherwise, the procedure was the same as in Experiment 1.

4.1. Methods

4.1.1. Participants

Twenty-four volunteers (15 female, nine male) with a mean age of 25 years participated in Experiment 2.

4.1.2. Apparatus, stimuli, and procedure

These were the same as those in Experiment 1, except as noted. Congruent instead of neutral conditions were used. In congruent conditions, prime and subsequent target/mask had the same shape. Correspondingly, in the prime-shape detection task (b), participants had to decide whether the actual masked prime was a diamond or not. In all blocks of the indirect measure task (a), and the measures (b), (c), and (d), each of the combinations that resulted from a complete crossing of two target shapes (square vs. diamond) × two prime shapes (square vs. diamond) × two positions (above vs. below fixation) was repeated 48 times, leading to 384 trials.

Table 2
Results of Experiment 2

Task	Target	Incongruent vs.	Mean d'	d' range	t	n	p (one tailed)
(a) Masked priming	Diamond	Congruent	0.31	−0.28 to 0.93	4.71	22	<.01
	Square	Congruent	0.37	−0.15 to 0.86	6.53	22	<.01
(b) Shape Detection	Diamond	Congruent	0.17	−0.30 to 1.48	1.76	21	<.05
	Square	Congruent	−0.26	−2.27 to 0.33	−1.97	21	<.05
(c) Rotation detection	Diamond	Congruent	0.28	−0.33 to 1.65	2.50	20	<.05
	Square	Congruent	0.12	−0.53 to 0.88	1.70	20	=.05
(d) Localization of rotation	Diamond	Congruent	0.09	−0.24 to 0.44	2.29	24	<.05
	Square	Congruent	0.20	−0.32 to 0.94	2.96	24	<.01

4.2. Results

Table 2 shows the main results. Due to technical error, not showing up of individual participants to all experimental sessions, and misunderstanding of task instructions (indicated by the same criteria as in Experiment 1), out of the 24 participants, between zero participant's data (in the localization-of-rotation task [d]) and four participants' data (in the rotation detection task [c]) were lost for the computation and analyses of performance scores in the different tasks.

For the masked priming effect, out of all trials, 1.5% were excluded from the analyses because responses were slower than 1000 ms. A repeated-measures ANOVA of individual means of correct responses, with the two within-participant variables of *target type* (square vs. diamond) and *prime type* (congruent vs. incongruent) led to a significant main effect of prime type, $F(1,21) = 43.21$, $p < .01$. The main effect of target type, and the interaction of Target type × Prime type, were non-significant, both Fs < 1.00. RT was higher in incongruent (469 ms) than in congruent (448 ms) conditions. Again the RT differences were also reflected in significant priming effects in d' analyses of the masked priming effect (see Table 2). Moreover, there was no indication of a speed–accuracy trade-off. A repeated measures ANOVA of arc-sine transformed error rates with the same variables as were used for the analysis of RTs led to a significant main effect of prime type, $F(1,21) = 26.63$, $p < .01$. Error rate was higher under incongruent conditions (6.4%) than under congruent conditions (4.1%). The main effect of target type, $F(1,21) = 1.96$, $p = .18$, and the interaction of Target type × Prime type, $F(1,21) = 1.20$, $p = .29$, were non-significant.

Performance in tasks (b) to (d) indicated sensitivity to information contained in the masked primes as well as in the prime–mask sequences. First, in contrast to prior findings (Ansorge, 2003) and Experiment 1 of the present study, the prime-shape detection task (b) reflected sensitivity to information about different prime shapes contained in incongruent versus congruent conditions (see Table 2). A positive average d' with a diamond-shaped target as a mask and a negative average d' with a square-shaped target as a mask were to be expected because we used the diamond-shaped prime as a signal (being present in the congruent conditions with the diamond-shaped target as a mask and in the incongruent conditions with a square-shaped target as a mask) for the computation of d' with both types of target/mask shapes.

Second, again a spared motion perception capability under metacontrast masking conditions (Kolers, 1963) was also demonstrated, both in the rotation detection task (c) and in the localization-of-rotation task (d). Rotation was detected more reliably in incongruent than in congruent conditions.

Next, we first compared average d' based on the masked priming effect (a) to that from the prime-shape detection task (b) separately for each of the two target types, and found no significant differences, $t(18) < 1.00$.[2] In contrast to that finding, comparing average d' based on the masked priming effect (a) to that from the rotation detection task (c) confirmed a significantly higher masked priming effect than rotation detection performance for square-shaped targets, $t(17) = 2.74$, $p < .05$, but not for diamond-shaped targets, $t(17) < 1.00$.[3] Third, average d' based on the masked priming effect (a) was significantly higher than that in the localization-of-rotation task (d) for both target types, both ts$(22) > 1.88$, both ps $< .10$ (one tailed). Finally, there were no significant correlations between average d' based on the masked priming effect (a) and that in any of the detection tasks (b) to (d), with coefficients ranging from $r = -.16$ to $r = .13$, all six ps $> .50$. See also Figs. 3 and 4.

4.3. Discussion

Experiment 2 showed no dissociation between the masked priming effect (a) and performance in the prime-

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[2] Square-shaped target d' values in the shape detection task (b) were originally negative because diamonds were used as signals for the computation of d'. Therefore, with the square-shaped targets, inverse d' values from the shape discrimination task were used for the within-participant comparison of the performance in that task to the masked priming effect of task (a).

[3] The different degrees of freedom used in the within-participant comparisons of the masked priming effect with that in alternative detection measures were due to the variable and selective missing of particular masked priming or detection performance data sets of individual participants.

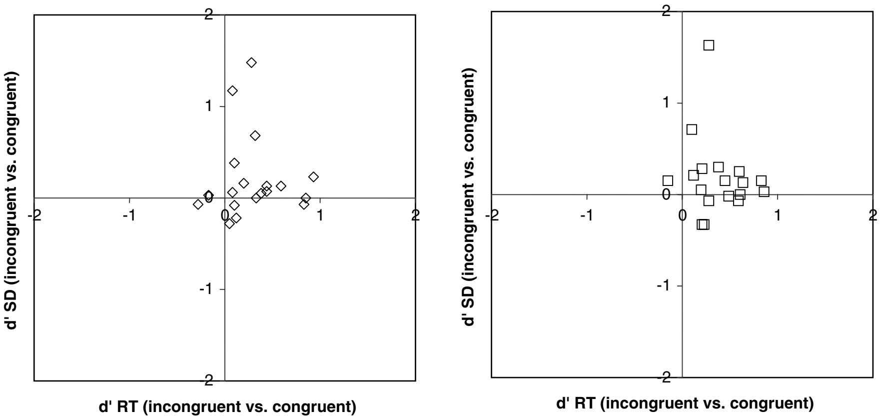

Fig. 3. Data from Experiment 2. Participants' individual masked priming reaction time effects from task (a) on the ordinates—in terms of individual d' values (d' RT)—as a function of the participants' performance in the prime-shape detection tasks (b) on the abscissas. Left panel: d' values for diamond-shaped targets; right panel: d' values for square-shaped targets. RT, reaction time; SD, shape detection. For details refer to Sections 4.1 and 4.2.

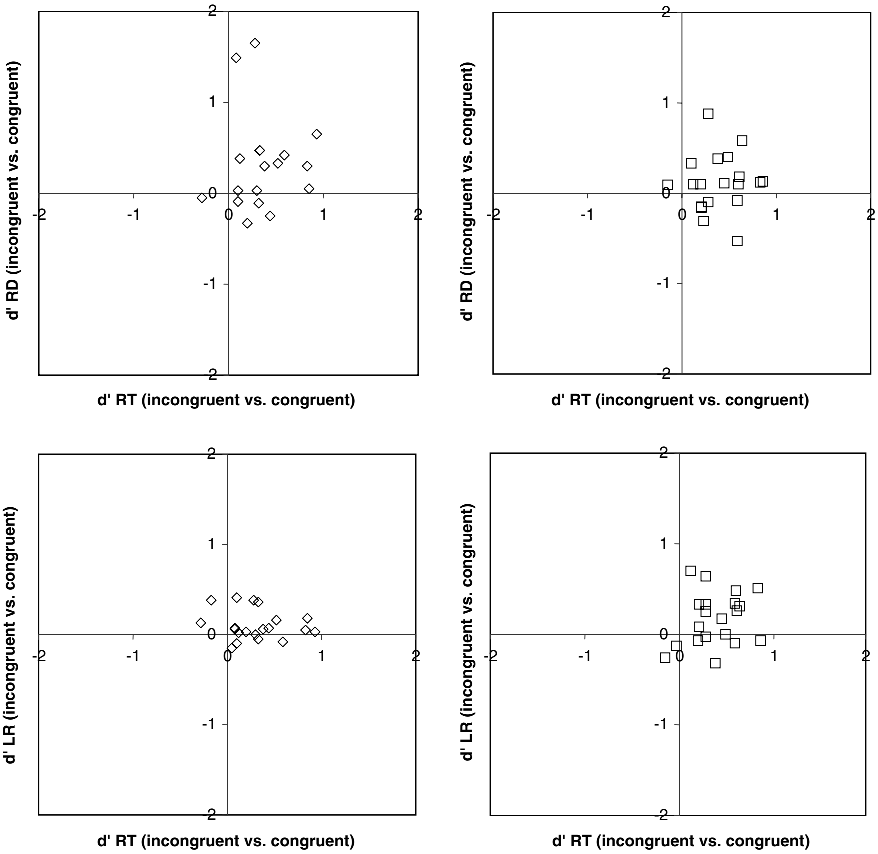

Fig. 4. Data from Experiment 2. Participants' individual masked priming reaction time effects in task (a) on the ordinates—in terms of individual d' values (d' RT)—as a function of the participants' performance in the detection tasks (c) and (d) on the abscissas, also in terms of individual d' values (d' RD, d' LR). Upper panels: d' values from the rotation detection task (d' RD); lower panels: d' values from the localization-of-rotation task (d' LR); right panels: d' values for diamond-shaped targets; left panels: d' values for square-shaped targets. RT, reaction time; RD, rotation detection; LR, localization of rotation. For details refer to Sections 4.1 and 4.2.

shape detection task (b): as in former studies (cf. Klotz & Neumann, 1999; Klotz & Wolff, 1995), processing of the masked primes was reflected in masked priming effects in task (a). However, in contrast to previous reports, participants were also able to tell trials with a masked diamond-shaped prime from trials with a masked square-shaped prime in a prime-shape detection task (b).

Two explanations are conceivable to account for the difference between the present finding of an ability to detect the shape of the masked prime and the previous studies' failures to find evidence for the same ability. According to the first explanation, participants could have used the more frequently perceived rotation in incongruent than in congruent conditions for inferring the shape of the prime in the present prime-shape detection task but not in former studies: in the current study, participants could have used stronger perceived rotation under incongruent conditions to infer that the actually presented masked prime's shape differed from that of the actually trailing target's shape. Likewise, they could have used less perceived rotation under congruent conditions to infer that the actually presented masked prime's shape was the same as that of the actually trailing target. By contrast, in prime-shape detection tasks of previous studies, the participants' use of the absence of perceived rotation, for example, to consistently infer that the masked prime had a target-like shape and to give a yes response, but the use of the presence of rotation to consistently infer that the masked prime did not have a target-like shape and to give a no response would have artificially brought performance to chance. Yes-responses (hits) would have been as probable as no responses (false rejections) under conditions with a signal (i.e., under conditions with a target-like shape prime) (the same logic applies with a reverse but consistent mapping of perceived rotation vs. not perceived rotation to yes and no responses, respectively).

At least two arguments speak against this explanation. If it were true that participants based their prime shape judgments on their rotation perception, one would have expected at least a similarly high sensitivity in the rotation detection task (c) or in the localization-of-rotation task (d) as in the prime-shape detection task (b) of Experiment 2. However, contrary to this expectation, the prime-shape detection task (b) of the present experiment was as sensitive as the masked priming task (a) (indicated by a non-significant difference between the corresponding d' measures), whereas sensitivity in the rotation detection task (c) and the localization-of-rotation task (c) of the present experiment were significantly lower than that in the masked priming task (a) (reflected in significantly higher average d' values in task [a] than tasks [c] and [d]).

Second, suppose it is true that participants based their shape judgments in the present prime-shape detection task on perceived rotation: Why did they not use the same strategy in Experiment 1? In Experiment 1, rotation detection (c) and localization of rotation (d) were also significantly better than chance, but this left chance performance in the prime-shape detection task (b) unaffected.

Given these inconsistencies in the first explanation, a second and more detrimental explanation is plausible According to this explanation previous studies (e.g., Ansorge, 2003; Klotz & Wolff, 1995; Neumann & Klotz, 1994) used a more difficult and demanding prime-shape detection task than masked priming task (cf. Schmidt & Vorberg, 2006). In previous studies, only in the prime-shape detection task but not in the masked priming task, participants had to discriminate between neutral trials without a target-like prime shape and trials with primes and targets of similar shapes (congruent trials) *and* trials with primes and target of different shapes (incongruent trials) (in the masked priming task, participants only had to discriminate between two target shapes or between two target positions by a two-alternative choice response). Thus, only the prime-shape detection task but not the masked priming task required classification of different stimulus conditions as belonging to the same category of responses. Therefore, the former was more difficult than the latter (cf. Schmidt & Vorberg, 2006).

This explanation is also in line with the dissociation in the present Experiment 1. The present Experiment 1's dissociation was found with a prime-shape detection task that was still slightly more difficult than the masked priming task. In the present Experiment 1 but not in Experiment 2 the prime-shape detection task required categorization across different angular shape primes (squares and diamonds) and across different neutral shape primes (circular/aligned and circular/unaligned). Thus, an explanation in terms of task difficulty differences accounts for dissociations in previous studies and in the current Experiment 1, as well as for the absent dissociation in the current Experiment 2.

Moreover, as in Experiment 1, we found that the zero correlation between masked priming effect and detection performance in any of the other tasks was the most easily fulfilled dissociation criterion and was also met in the current experiment.

In summary, across Experiments 1 and 2 motion perception indeed turned out to be more robust than shape perception under metacontrast masking conditions in the following sense: in contrast to shape detection, detection of motion from prime–target sequences was possible, regardless of whether prime and target segments aligned or not. This finding is in line with previous observations that motion perception escapes detrimental backward masking effects (Kolers, 1963) under conditions where shape perception is subject to masking (e.g., Ansorge et al., submitted for publication).

However, we also found that under metacontrast masking conditions prime-shape detection performance can be at least as accurate as motion detection performance and that it can be even better than the prime discrimination ability which is implied in a masked priming effect. A crucial prerequisite for this significant prime-shape detection performance is that the procedure in the prime-shape detection task is sensitive enough—that is, its difficulty has to match that of the other tasks. This finding corroborates the suspicion raised by Schmidt and Vorberg (2006) that a greater task difficulty of the prime-shape detection task than in the masked priming task can sometimes erroneously suggest the existence of dissociations. By implication, our results also indicate that rotation perception and shape perception are not based on exactly the same prime-contained information: segmental prime structure heterogeneity was an obstacle for accurate prime-shape detection performance but not for correct rotation detection performance.

5. General discussion

Detection dissociation procedures are one popular way to test and demonstrate processing of subliminal or unconscious visual inputs in normal human subjects. In the domain of visual processing, demonstrating detection dissociations requires that a visual input stimulus (1) cannot be consciously perceived—here reflected in a prime detection task—, and (2) is processed nonetheless—here reflected in a masked priming effect (cf. Jaśkowski & Ślósarek, 2007; Jaśkowski, van der Lubbe, Schlotterbeck, & Verleger, 2002; Klotz & Neumann, 1999; Schmidt, 2002; Vorberg et al., 2003). Importantly, however, the successful demonstration of detection dissociations necessitates the use of an exhaustive direct measure of conscious stimulus perception. Providing an exhaustive direct measure is sufficiently difficult that some researchers were sceptical about the possibility of ever demonstrating detection dissociations (cf. Eriksen, 1960; Holender, 1986; Reingold & Merikle, 1988, 1990).

5.1. Task difficulty influences in the metacontrast dissociation

In response to this scepticism, in the current study, we tested an objection that was being made against a particular variant of the detection dissociation, the so-called metacontrast dissociation (cf. Schmidt & Vorberg, 2006). We tested whether higher task difficulties in the prime-shape detection task than in the masked priming task could have provided a less than exhaustive measure of residual conscious prime shape perception (cf. Ansorge, 2003; see also Klotz & Wolff, 1995). Specifically, Schmidt and Vorberg noted that only the prime-shape detection task required classification of congruent and incongruent prime–target sequences as belonging to the same class of yes-response conditions, whereas no such classification across stimuli was required in the masked priming tasks of studies such as that of Klotz and Neumann (1999), and likewise of Ansorge (2003) and Klotz and Wolff (1995). To test this contention, in the present study, we only used neutral and incongruent conditions (Experiment 1), or only used congruent and incongruent conditions (Experiment 2). These manipulations reduced the complexities of the S–R mapping rules for the prime-shape detection task and, thus, levelled difficulties of the shape detection task and the masked priming task.

In line with the objection of Schmidt and Vorberg, we indeed found a better capacity to tell the shapes of the masked primes from one another in the prime-shape detection task of Experiment 2. In contrast, in Experiment 1, we successfully replicated the previously found dissociation—that is, chance performance in the prime-shape detection task but a significant masked priming effect. One likely reason for this replication of the previous results is that the prime-shape detection task of Experiment 1 was still more difficult than the masked priming task and the prime-shape detection task of Experiment 2, because only in Experiment 1's but not in Experiment 2's prime-shape detection task two-alternative neutral stimulus conditions (i.e., aligned and unaligned primes) had to be classified as requiring the same judgment and two-alternative imperative stimulus conditions (i.e., diamond and square primes) had to be classified as requiring the same judgment. In conclusion, the present findings support the concern of Schmidt and Vorberg (2006) that evidence for detection dissociations could be an artefact of the different task difficulties of prime-shape detection and masked priming tasks.

5.2. Motion perception under metacontrast conditions

Also, following up on experiments demonstrating that the visibility of visual motion can escape the detrimental effects of a metacontrast mask (Ansorge et al., submitted for publication; Kolers, 1963), we tested whether in an incongruent prime–target sequence (consisting of either a square prime preceding a diamond target or of a diamond prime preceding a square target; both in Experiments 1 and 2), participants could have perceived more visual rotation than if presented with a neutral prime–target sequence (consisting of a circular prime preceding either a diamond or a square target; Experiment 1) and with a congruent prime–target sequence (consisting of a square prime preceding a square target or consisting of a diamond prime preceding a diamond target; Experiment 2).

The results of the present experiments demonstrate that participants are indeed able to detect rotation under the incongruent conditions to some extent. Motion perception was found to be less affected by metacontrast masking than shape perception in the sense that shape detection performance crucially depended on task difficulty, whereas motion perception did not: prime-shape detection performance was above chance only with the easier task in Experiment 2 but not with the more demanding task in Experiment 1, whereas participants detected rotation in both experiments. Importantly, the detection of rotation was also likely due to conscious perception of visual motion: instructions mapping perceived rotation to a particular keypress were given only *after* a prime–target sequence. Thus, response-activation effects of rotation presented at subliminal or unconscious levels could not contribute to the rotation detection performance measures in tasks (c) and (d): prior research showed that such effects of subliminal inputs depend on the existence of a corresponding specific intention in advance of the presentation of the subliminal stimuli (cf. Ansorge, 2004; Ansorge & Neumann, 2005; Ansorge et al., submitted for publication; Kunde et al., 2003; Neumann & Klotz, 1994).

The finding that perception of motion was possible sheds light on the mechanisms underlying metacontrast masking's function under ecological conditions outside the laboratory. Seeing motion under metacontrast masking conditions is at variance with the assumption that metacontrast primarily prevents perception of "impossible motion": Kahneman (1968) proposed that by masking the test stimulus, metacontrast prevents that one and the same object (the test stimulus) is perceived as moving into several different directions simultaneously, which Kahneman called "impossible motion". However, seeing one and the same object moving in different directions at one and the same time is not only possible but even quite common: approaching stimuli, for example, are exactly based on such simultaneous motion perception of one object expanding in several directions at the same time.

In contrast, concomitantly allowing for motion perception but suppressing shape perception, metacontrast would ideally serve the purpose of de-blurring moving objects. As was noted by Ogmen (1993) motion of visual stimuli across the retina would blur shape images due to inert photoreceptor activity and the resultant smeared spatial signal, much as it can be seen on a photography taken of a sufficiently fast moving object. Under these very common ecological conditions, however, metacontrast decreases visual blur by suppressing the stimulus' shape perception from the no-longer occupied positions of the moving stimulus along its motion trajectory (cf. Otto et al., 2006).

5.3. Motion perception and its relation to masked priming effects

It might be tempting to attribute the general masked priming effect (Ansorge, Klotz, & Neumann, 1998; Eimer, 1999; Klotz & Wolff, 1995) or at least the particular masked priming effect of Ansorge (2003) to residual conscious perception of motion. However, there are at least two reasons that rule out such an interpretation. First, the metacontrast dissociation could be demonstrated in a variety of experimental paradigms, including some in which perception of more or less visual rotation (or motion) could not have contributed to the masked priming effect in the indirect measure (Ansorge, 2004; Ansorge & Neumann, 2005; Breitmeyer et al., 2004; Schmidt, 2002; Schmidt et al., 2006; Vorberg et al., 2003). Schmidt (2002), for example, used red and green rings as masks and targets and red and green disks as primes. Under these conditions, congruent trials (e.g., a green disk preceding a green ring) and incongruent trials (e.g., a red disk preceding a green ring) did not obviously differ with respect to their perceived motion features.

Second, even the metacontrast dissociation based on a masked shape priming effect cannot be attributed to motion perception: the masked shape prime activated the lateralized readiness potential (LRP) of the EEG (cf. Eimer & Schlaghecken, 1998; Leuthold & Kopp, 1998; Vath & Schmidt, 2007) whose onset was prior to the presentation of the target. Because perception of motion between prime and target can occur only *after* processing of the target, the corresponding motion percept comes too late to account for the prime-induced, target-preceding LRP effect.

In summary, it is more likely that the residual perception reflected in the rotation detection task (c) and the localization-of-rotation task (d) reflected another *indirect* effect of the prime on perception of the target, much as the masked priming effect does. This is theoretically plausible because the kind of motion that was being perceived by our participants was possible only after prime and target were shown. Moreover, in line with the possibility that perceived motion reflects an indirect effect of the prime on perception of the target, prior research indicates that features of the prime are sometimes misperceived as belonging to the trailing target (cf. Herzog & Koch, 2001; Scharlau & Neumann, 2003; Werner, 1935). Future research, however, should be aimed at investigating these matters with greater scrutiny.

5.4. Dissociation criteria

In addition, even in the present research, the results at least met one dissociation criterion: no significant correlation between the better-than-chance detection performances and the masked priming effects was observed, although one might have expected such a correlation if conscious detection were indeed responsible for the masked priming effect (cf. Naccache & Dehaene, 2001). Admittedly, however, this general finding should be better considered as an argument against the use of this very liberal dissociation criterion: finding no dissociation evidence in all criteria except the zero-correlation criterion points in the direction of a lack of validity of the latter.

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