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Masked Emotional Priming: A Double Dissociation between Direct and Indirect Effects Reveals Non-conscious Processing of Emotional Information beyond Valence

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---------- Consciousness and Cognition, in press ----------

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Abstract

We demonstrate non-conscious processing beyond valence by employing the masked emotional priming paradigm (Rohr, Degner, & Wentura, 2012) with a stimulus-onset asynchrony (SOA) variation. Emotional faces were briefly presented and directly masked, followed by the target face, using a SOA of either 43ms or 143ms. Targets were categorized as happy, angry, fearful, or sad. With short SOA, we replicated the differentiated priming effect within the negative domain (i.e., angry differentiate from fearful/sad). A direct test of prime awareness indicated that primes could not be discriminated consciously in this condition. With long SOA, however, we did not observe the priming effect whereas the direct test indicated some degree of conscious processing. Thus, indirect effects dissociated from direct effects in our study, an indication for non-conscious processing. Thereby, the present study provides evidence for non-conscious processing of emotional information beyond a simple positive-negative differentiation.

Keywords: affective priming; emotion perception; non-conscious; facial expression; automatic processing

WORD COUNT: 7480 (main text incl. footnotes)

1. Introduction

There is a long and sometimes heated debate about how to demonstrate non-conscious processing of stimuli or stimulus features in sequential priming paradigms (e.g., Holender, 1986; Merikle & Reingold, 1988; Schmidt & Vorberg, 2006). A standard procedure to establish evidence for non-conscious processing is to combine an indirect test and a direct test of prime processing (for alternatives see Lähteenmäki, Hyönä, Koivisto, & Nummenmaa, 2015; Schmidt, 2015): In the indirect test, participants respond to clearly visible target stimuli, preceded by a sequence of a briefly presented prime and a masking stimulus. In the direct test, identical trials are presented but participants respond to the primes instead of the targets. Typically we infer non-conscious processing from observed priming effects in the indirect test with the absence of priming effects in the direct test (i.e., indicating no conscious prime awareness; e.g., Dehaene et al., 1998; Klauer, Eder, Greenwald, & Abrams, 2007). This route has, however, some caveats. For example, besides the notorious null hypothesis testing problem (here: for the direct test), the zero awareness criterion is often not perfectly met (e.g., Draine & Greenwald, 1998; Reingold & Merikle, 1988; Schmidt, 2007; Schmidt & Vorberg, 2006).

Greenwald, Klinger, and Schuh (1995) addressed this problem by suggesting a regression method, regressing the individual priming differences between incongruent and congruent conditions on the individual prime detection indices. They argue that a significant intercept might be interpreted as the existence of a priming effect in the absence of prime awareness (given the adequate regression procedure, Klauer, Draine, & Greenwald, 1998; Klauer, Greenwald, & Draine, 1998, and some boundary conditions, see Klauer & Greenwald, 2000). However, there is a considerable and challenging debate about the regression method (see, Dosher, 1998; Klauer, Draine, et al., 1998; Klauer & Greenwald, 2000; Merikle & Reingold, 1998; Miller, 2000;

Schmidt & Vorberg, 2006) that focuses on the question whether the intercept dominantly reflects error variance if no strong relationship between priming differences and prime detection indices is given (which is typically the case). Thus, alternative solutions are highly desirable.

As an alternative route, Schmidt and Vorberg (2006; see also Kouider & Dehaene, 2007; Schmidt, 2007; 2015) proposed demonstrating experimental dissociations: If a certain experimental manipulation (e.g., SOA, prime duration, variations of attention) influences direct and indirect tests in opposite directions, these can be more straightforwardly explained by different – that is, conscious versus non-conscious – underlying processes. The authors contrast a general model which assumes that conscious and non-conscious perceptual information both influence the direct and the indirect measure with a null model which denies the non-conscious influences. This null model is falsified (given some rather mild assumptions) by observing such a double dissociation. The prime example given by Schmidt and Vorberg (2006) is the variation of the prime-target stimulus-onset asynchrony (SOA): In their response priming paradigm with meta-contrast masking (see Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003) they observed (given specific conditions) *increasing* priming effects with increasing SOA, but *decreasing* performance in the direct measure. Consequently, the priming effects must result from non-conscious processes; otherwise, they should have increased with increasing awareness. The approach from Schmidt and Vorberg (2006) thus possess the advantage that alternative explanations (i.e., error variance, conscious processes) for the observed effects are more easily excluded.

In the present study, we applied this approach to the masked emotional priming paradigm, a variant of the evaluative priming paradigm (Rohr, Degner, & Wentura, 2012). In our earlier research, we presented happy, angry, fearful, and sad facial primes for brief durations. Primes were always masked, thereby precluding at least subjective awareness for most participants. Subsequent to the masks, emotional faces (Experiment 1 and 2) or emotional words (Experiment 3) were presented as targets, which had to be categorized with regard to emotion. In all experiments, we observed significant congruency effects, that is, on average responses to emotion-congruent prime-target pairings (i.e., the prime emotion matching the target emotion) were faster than average responses to incongruent pairings. Further analyses revealed that the priming effects were based on (a) a differentiation of valence (i.e., happy expressions being clearly differentiated from all negative emotions) and (b) on a differentiation within the negative emotion domain with anger being clearly differentiated from fear and sadness.

These results indicate that more than the distinction between happy versus negative expressions (i.e., mere valence) is extracted from briefly presented and masked prime faces. Specifically, the differentiation of anger vs. fear/sadness faces is expected from different theoretical perspectives: First, Adams and Kleck (2003) argue that happy and anger expressions are signals of approach for the perceiver, whereas fear and sadness are signals of avoidance (see also Paulus & Wentura, 2016). Therefore, approach- versus avoidance types of emotions may be discriminated automatically, potentially non-consciously. Second, appraisal theories (Moors, Ellsworth, Scherer, & Frijda, 2013; Scherer, 1984; Scherer, 2013) assume that individuals first and immediately engage in appraisal checks of novelty, valence, and relevance when encountering a stimulus. In this regard, joy and anger can be seen as more relevant, given their direct implications for the social interaction. In a similar account, emotions can be classified as possessor- vs. other-relevant (Peeters, 1983).[1] Within the negative domain, angry faces are predominantly *other-relevant:* They unequivocally signal behavioral relevance for an observer

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[1] Originally, Peeters (1983) used the terms self- vs. other-profitable.

(i.e., the anger is directed at him or her). Sad or fearful faces predominantly signal *possessor-relevance*: They are unequivocally negative for the person experiencing (and expressing) this emotional state; their implications for observers are, however, more ambiguous (i.e., an out-group member signalling fear might be seen as relatively positive; Paulus & Wentura, 2014). We have repeatedly demonstrated evidence for automatic processing of this type of relevance for social attributes (i.e., adjectives; e.g., Degner & Wentura, 2011; Wentura & Degner, 2010; Wentura, Rothermund, & Bak, 2000; see also Prochnow, Brunheim, Steinhauser, & Seitz, 2014).

Our previous research revealed that this type of differentiation within negative emotions was even found under limited processing conditions (Rohr et al., 2012), a finding which is in line with the functional perspectives on emotions outlined above. Without taking a specific theoretical perspective, we refer to this priming effect as a *relevance priming effect*. Finally, we did not find evidence for category-specific processing of emotional faces, that is, the interaction contrast, which tested for the differentiation between fear and sadness was not significant throughout the experiments. This result indicates that the paradigm does not simply reflect a semantic categorization of all prime types.

With the current research we explore to what extent the differentiated priming effects observed in our previous research (Rohr et al., 2012) are based on non-conscious processing. We therefore use the dissociation approach suggested by Schmidt and Vorberg (2006): We manipulated SOA in the emotional priming paradigm, comparing a short SOA condition (i.e., 43 ms; replicating Experiment 2 in Rohr et al., 2012) with a long SOA condition (i.e., 143 ms).

Note, that any SOA manipulation in a masked priming experiment has an inevitable confound because the SOA is either extended by increasing the mask duration or by presenting a blank screen between mask and target. Thus short and long SOA conditions either additionally differ regarding the duration of mask presentation (which may differentially impact prime processing; see Breitmeyer & Ögmen, 2006) or regarding the absence or presence of a blank screen. For the current research we chose the latter option and kept mask presentation duration constant to avoid the risk that increased mask duration interferes with prime processing to a greater degree than in the short SOA condition (see the *General Discussion* for an elaborated discussion).

2. Method

2.1 Participants. One-hundred students of various department of Saarland University (71 female, age *Md* = 22 years, range: 18 – 34) participated in this experiment for a remuneration of 8 Euro. All participants had normal or corrected to normal vision. Three further participants were excluded from analyses, one because of extremely high error rates (i.e., a far out value in the distribution of the overall error rate according to Tukey, 1977), one because s/he completely ignored the fear response option in one SOA condition, and one because of language barriers limiting understanding of task instructions.

The relevance effect observed in our previous research (Rohr et al., 2012; Exp. 2) had an effect size of $d_Z = 0.39$. To replicate this effect with power $1-\beta = .95$ (assuming $\alpha = .05$, two-tailed), a minimum sample of N = 88 is needed (according to G*Power; Faul, Erdfelder, Lang, & Buchner, 2007).

2.2 Design. For the indirect priming task, we employed a 5 (Prime emotion: joy vs. anger vs. sadness vs. fear vs. neutral) × 4 (Target emotion: joy vs. anger vs. sadness vs. fear) × 2 (SOA: 43 vs. 143 ms) × 2 (Block sequence: long SOA first vs. short SOA first) mixed design with prime emotion, target emotion, and SOA as within-participants factor and Block sequence as a between-participants factor.

We varied SOA block-wise (and not trial-by-trial) for two reasons: The main reason was that varying SOA trial-by-trial has been shown to lead to unwanted adaptations of response criteria (see Schmidt, Haberkamp, & Schmidt, 2011, p. 126, for a discussion of this problem). A further reason was that we wanted to have a replication condition with regard to Rohr et al. (2012), which was the short SOA condition.

For the direct task, we employed a 4 (Prime emotion: joy vs. anger vs. sadness vs. fear) × 2 (SOA: 43 vs. 143 ms) mixed design with prime emotion as within-participants factor and SOA as a between-participants factor. Precisely, given the choice of a blocked SOA for the priming task (see above), a trial-by-trial version in the direct test was not possible, since direct and indirect test should be as similar as possible. Moreover, pilot testing demonstrated that exhaustion and/or reduced motivation increased error variance in the direct test. Thus, we decided to administer only one SOA condition in the direct test (counterbalanced between participants), and refrained from varying SOA block-wise within participants. With this choice, we accepted that some statistical comparisons are between participants, with the consequence of losing some test power.

2.3 Materials. We employed the same stimuli as in our previous research (Rohr et al., 2012). Face stimuli were obtained from the Karolinska Directed Emotional Faces databank (KDEF, Lundqvist, Flykt, & Öhman, 1998). To avoid perceptual priming effects, prime pictures depicted frontal views of the faces whereas target pictures depicted profile views. All pictures were set to a size of 188 x 188 pixel (approx. 49 x 49 mm).[2] As primes, four instances each of happy, angry, fearful, sad, and neutral expressions were employed, all displayed by the same four individuals (two men, two women). Note that expressions of the different emotion categories of

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[2] In the experiments by Rohr et al. (2012), the size was 162 × 220 pixel. The change is due to a modification of the target pictures to have a stricter cutout of the face region.

the KDEF do not differ in arousal (Goeleven, De Raedt, Leyman, & Verschuere, 2008). Prime faces were framed by a grey oval, such that only the facial features were visible, whereas unrelated distracting features were cut off (e.g., hair; see Figure 1 for an example). As targets, 10 instances of happy, angry, fearful, and sad facial expressions were used, displayed by another five men and five women. For the direct test of prime sensibility, the profile views of the same individuals displaying neutral expressions were used as target stimuli. Masking pictures were created by converting two additional frontal views of faces with neutral expressions into spatially quantized face masks resulting in face-like images with unidentifiable characteristics (Bachmann, Luiga, & Pöder, 2005, see Figure 1). Thus, masking by structure was employed.

2.4 Procedure. Participants were seated at individual computers, separated by partition walls. The experiment was implemented in E-Prime (Version 1.2) on standard PCs with 17'' CRT monitors with a refresh rate of 70 Hz, all instructions were given on the computer screen. Participants were informed that portraits would be presented on the computer screen and that their task was to identify the emotional expression. The four possible responses "joy", "anger", "fear", and "sadness" were assigned to the A-key and the S-key on the left side and the semicolon- and comma-keys on the right side of a German standard QWERTZ keyboard. Assignment of response keys to emotions was counterbalanced across participants. Response keys were marked with color stickers on the keyboard. Reminders of the emotion assignment to response keys were displayed in the corresponding colors in the left and right lower corners of the computer screen throughout the whole experiment (see Figure 1). The beginning of a trial was signaled by a black fixation cross that remained for 300 ms in the middle of the grey screen. It was followed by the succession of a forward mask presented for 100 ms, the prime presented for 14 ms and the backward mask presented for 29 ms. In the SOA=43 ms condition, the mask was directly overwritten by the target. This trial sequence thus corresponds exactly to Experiment 2 of Rohr et al., 2012. In the SOA=143 ms condition, the screen was blank for 100 ms until the target was presented. The target remained on screen for maximal 500 ms but disappeared as soon as a response was given. We instructed participants to make fast decisions and to respond before a deadline of 1500 ms after target onset. In case of late responses, participants received written feedback on the screen that their response was too slow.

Initially, participants worked through two blocks of 40 practice trials, in which no primes were presented in the trial sequence (i.e., instead of the prime the mask was presented). In the main experiment participants completed three blocks of 80 trials in one SOA condition (43 or 143 ms) and then proceeded with three blocks of the other SOA condition without explicit information about this change. The complete priming task thus comprised 480 trials in total. The order of SOA was counter-balanced across participants. A funneled debriefing procedure served as subjective measure of awareness, that is, participants were asked increasingly specific questions to explore their subjective awareness of primes and their content (e.g., Did you notice a flickering preceding the clearly visible portraits? Did you notice something within the flickering? If so, what did you notice?).This procedure also included general questions on the experiment (i.e., What do you think is the aim of the experiment? Did you notice anything special?) to check if participants noticed the changes in SOA.

Finally, participants completed the direct test in which they were instructed to categorize the emotional expression of the prime faces using the identical response keys as in the previous task. The direct test comprised 128 trials (i.e., 32 trials per emotion). All presentation parameters equaled that of the priming task, with the exception of using target stimuli with neutral facial expressions. Participants were under no time pressure to respond; the neutral targets remained on screen until participants gave their response. The direct test only employed the SOA condition that was administered last in the priming experiment (see *2.2 Design*).

3. Results

The mean response times (RT) of correct trials served as dependent variable of interest. Trials with reaction times below 200 ms and above three interquartile ranges above the third quartile with respect to the individual distribution of reaction times were discarded (Tukey, 1977; 1.35 % of all trials). Mean error rate was 22.21 % (*SD* = 12.31). Mean RTs and errors rates are reported in Table 1.

3.1 Priming effects

First, we calculated the mean RT for congruent pairings (i.e., prime/target pairs with matching emotions) and for incongruent pairings (i.e., prime/target pairs with non-matching emotions), separately for the two SOA conditions. For reasons of comparison with our former study (Rohr et al., 2012, Exp. 2), we first report results separately for SOA conditions. For the short SOA condition (i.e., the replication condition), a 3 (Priming: congruent vs. incongruent vs. neutral prime) MANOVA for repeated measures yielded a significant overall priming effect, $F(2,98) = 4.26$, $p = .017$, $\eta_p^2 = .080$. More important, the a priori planned contrast of dominant interest, that is, the comparison of mean RTs in congruent trials (*M* = 857 ms, *SD* = 124 ms) to mean RTs in incongruent trials (*M* = 869 ms, *SD* = 133 ms) was significant, $F(1,99) = 8.38$, $p = .005$, $\eta_p^2 = .078$. The priming effect (i.e., mean RT incongruent – mean RT congruent) was M = 12 ms (*SD* = 42 ms; $d_Z = 0.29$).

For the long SOA condition, the corresponding analysis yielded a null effect of priming, *Fs* < 1 for the overall analysis and the contrast of interest. Mean RTs for congruent (*M* = 867 ms, *SD* = 139 ms), incongruent (*M* = 870 ms, *SD* = 132 ms), and neutral trials (*M* = 868 ms, *SD* =

126 ms) did not differ significantly. For the sake of completeness, in a combined 2 (SOA) × 2 (Priming: congruent vs. incongruent vs. neutral prime) MANOVA for repeated measures, the main effect of priming missed the criterion of significance, $F(2,98) = 2.70$, $p = .072$, $\eta_p^2 = .052$ (Fs < 1.01 for the SOA main effect and the interaction). However, the a priori planned contrast of dominant interest, that is, the comparison of mean RTs in congruent trials to mean RTs in incongruent trials was significant, $F(1,99) = 5.46$, $p = .021$, $\eta_p^2 = .052$; it was not moderated by SOA, $F(1,99) = 1.85$, $p = .176$, $\eta_p^2 = .018$. However, this analysis disguises which form of differentiation underlies the congruency effect and whether SOA conditions differ in the form of differentiation.

To analyze the specificity of priming effects, we conducted a 2 (SOA) × 4 (prime emotion) × 4 (target emotion) MANOVA for repeated measures with planned orthogonal contrasts (Helmert; see Rohr et al., 2012). The first contrast (C1) compared happy expressions to the averaged negative expressions. Thus, this contrast represents an unspecified valence distinction: The test for interaction of C1(prime) and C1(target) corresponds to the hypothesis of a valence-congruency effect. The second contrast (C2) related angry expressions to the aggregation of sad and fear expressions (thereby disregarding happy prime and happy target trials). The test for interaction of C2(prime) × C2(target) corresponds to the hypothesis of a differentiated priming effect within the negative valence domain. As outlined in the introduction, we refer to this priming effect as a relevance priming effect. The final contrast (C3) tested for a fear/sadness differentiation. The test for interaction of C3(prime) × C3(target) corresponds to an emotion-specific priming effect.

The 2 (SOA) × 4 (prime emotion) × 4 (target emotion) MANOVA for repeated measures yielded a significant main effect of target emotion, $F(3,97) = 134.03$, $p < .001$, $\eta_p^2 = .806$. It is dominantly due to the fact that happy faces are categorized much faster than the negative faces. This result is typically found in this task (see Rohr et al., 2012). Most important, we found the expected prime by target interaction for the three a priori contrasts (i.e., C1×C1, C2×C2, C3×C3), $F(3,97) = 4.06$, $p = .009$, $\eta_p^2 = .112$, but a non-significant result for the six non-meaningful contrasts (e.g., C1×C2, C2×C3), $F(6,94) = 1.07$, $p = .389$, $\eta_p^2 = .064$ ($F(9,91) = 2.51$, $p = .013$, $\eta_p^2 = .199$ for the overall interaction). The prime × target interaction was further moderated by SOA for the contrasts of interest, $F(3,97) = 2.81$, $p = .043$, $\eta_p^2 = .080$ ($F(6,94) = 1.17$, $p = .329$, $\eta_p^2 = .069$ for the non-meaningful contrasts and $F(9,91) = 1.40$, $p = .200$, $\eta_p^2 = .122$ for the overall three-way interaction).

More specifically, the C1×C1 interaction (i.e., the valence priming effect) was significant, $F(1,99) = 6.84$, $p = .010$, $\eta_p^2 = .065$, and it was not moderated by SOA, $F < 1$. The overall valence-based priming effect amounted to $M = 7$ ms ($SD = 28$ ms; $d_Z = .26$). The C2×C2 interaction (i.e., the relevance priming effect) was significant as well, $F(1,99) = 3.52$, $p = .032$ (one-tailed)[3], $\eta_p^2 = .034$. This interaction contrast was further moderated by SOA, $F(1,99) = 7.70$, $p = .007$, $\eta_p^2 = .072$. For the short SOA condition (i.e., the replication condition), the contrast was significant, $F(1,99) = 11.69$, $p = .001$, $\eta_p^2 = .106$, with a priming effect of $M = 22$ ms ($SD = 64$ ms; $d_Z = .34$). For the long SOA condition, the contrast was not significant, $F < 1$; the priming effect was $M = -3$ ms ($SD = 70$ ms; $d_Z = .05$). The third interaction contrast (C3×C3; i.e., fear vs. sadness, testing for an emotion-category specific priming effect) was not significant in the present experiment, $F < 1$, replicating our earlier findings (Rohr et al., 2012). There was also

[3] Since an F-test with 1 df in the numerator is equivalent to a t-test and, given our specific predictions, a one-tailed test is permissible (see Maxwell & Delaney, 2004, p. 164). Anyway, this test is not central because of the subsequently reported interaction with SOA.

no significant moderation by SOA ($F < 1$). The planned contrasts are graphically depicted in Figure 2.

Analyses of error rates yielded only a main effect of target, $F(3,97) = 179.49$, $p < .001$, $\eta_p^2 = .847$ and a prime × target interaction for the six non-meaningful contrasts[4], $F(6,94) = 2.77$, $p = .016$, $\eta_p^2 = .150$, for all other effects Fs < 1.71.

3.2 Funneled debriefing data. Only fifteen participants mentioned to have seen faces in the flickering[5]. (Note that due to using a face-like mask, see Figure 1, this report does not necessarily mean that *emotional* faces were identified.) Thus, as in the prior experiments, our masking procedure yielded subjective unawareness for most of the participants. All tests reported above are qualitatively the same (with regard to the criterion of significance) if the 15 participants are excluded from the analyses, with a single exception. The triple interaction of SOA, prime emotion, and target emotion was no longer significant, $F(3,82) = 1.88$, $p = .139$, $\eta_p^2 = .064$. However, as we will see in the next paragraph, the long SOA is associated with better prime detection. Thus, part of the dissociative pattern is removed by excluding the sub-sample. Beyond, the changes in SOA remained unnoticed for the majority of participants. Only seven participants made reference to some timing differences in the experiment (e.g., that the sequence of the pictures was faster in one block).

3.3 Objective prime awareness. The mean frequency of responses in the direct test of both SOA conditions is depicted in Table 2. Kappa served as an overall index of prime awareness. Furthermore, we calculated signal detection sensitivity indices *d'* in analogy with the

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[4] This interaction is dominantly due to a significant C3×C1 contrast, $F(1,99) = 10.79$, $p = .001$, $\eta_p^2 = .098$: The error rate in happy target trials is relatively lower following fear than following sad primes compared to negative target trials.

[5] We scored any reference to "emotion" or "face" in the free-text response, except explicit reference to "*pixelated* faces" (because this obviously refers to the masks).

Helmert contrasts reported above (see also below for more details).[6]

First, we conducted a one-way ANOVA with Kappa as dependent variable and SOA as between-subjects factor across the whole sample. This analysis yielded that Kappa was significantly above chance, $F(1,98) = 377.03$, $p < .001$, $\eta_p^2 = .794$. Furthermore, SOA had an influence on the overall awareness, $F(1,98) = 69.95$, $p < .001$, $\eta_p^2 = .416$, with mean Kappa at the long SOA, $M\kappa = .38$ (SD =.14) being larger than mean Kappa at the short SOA, $M\kappa = .15$ (SD =.14). Both Kappa indices, however, were clearly above zero (both $ts(49) > 7.81$, $ps < .001$), indicating that participants were able to discriminate the primes to some extent.

For the *d'* indices, we took happy primes as "signal" and any negative prime as "noise" for *valence sensitivity*; hits are defined as happy responses to happy primes, whereas false alarms are defined as happy responses to negative primes. For *relevance sensitivity*, hits are defined as angry responses to angry primes, whereas false alarms are defined as angry responses to the remaining negative primes (i.e., happy primes are disregarded). For *fear/sad sensitivity* (i.e., emotion-category specific discrimination), hits are defined as fear responses to fear primes whereas false alarms are defined as fear responses to sad primes (i.e., happy and angry primes are disregarded). As can be seen in Table 3, mean *d'*-values are larger for the longer SOA condition. A 2 (SOA) × 3 (sensitivity: valence, relevance, fear/sad) MANOVA for repeated measures with SOA as a between-participants factor and *d'* as dependent variable yielded significant main effects of sensitivity, $F(2,97) = 181.99$, $p < .001$, $\eta_p^2 = .790$, and SOA, $F(1,98) = 80.90$, $p < .001$, $\eta_p^2 = .452$, as well as a significant interaction, $F(2,97) = 27.08$, $p < .001$, $\eta_p^2 = .358$. For the long SOA condition, the one-way MANOVA for repeated measures demonstrated a significant main

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[6] We followed the log-linear approach to account for cases with 100 % hits or 0 % false alarms (see Hautus, 1995; Stanislaw & Todorov, 1999).

effect of sensitivity, $F(2,48) = 193.26$, $p < .001$, $\eta_p^2 = .890$. The first Helmert contrast yielded a significant difference between valence sensitivity on the one hand and relevance and fear/sad sensitivity on the other hand, $F(1,49) = 382.31$, $p < .001$, $\eta_p^2 = .886$. The second Helmert contrast (i.e., relevance versus fear/sad sensitivity) was significant as well with larger fear/sad sensitivity, $F(1,49) = 24.20$, $p < .001$, $\eta_p^2 = .331$. However, all three mean *d'* values deviated significantly from zero, $ts(49) > 4.06$, $ps < .001$, $d_Z = 3.11$, .57, 1.03 for *valence sensitivity*, *relevance sensitivity*, and *fear/sad sensitivity*, respectively.

For the short SOA condition, the one-way MANOVA for repeated measures also demonstrated a significant main effect, $F(2,48) = 32.48$, $p < .001$, $\eta_p^2 = .575$. The first Helmert contrast yielded a significant difference between valence sensitivity on the one hand and relevance and fear/sad sensitivity on the other hand, $F(1,49) = 65.74$, $p < .001$, $\eta_p^2 = .573$. The second Helmert contrast (i.e., relevance versus fear/sad sensitivity) was non-significant, $F < 1$. Valence sensitivity deviated significantly from zero, $t(49) = 8.52$, $p < .001$, $d_Z = 1.20$, whereas relevance sensitivity, $t(49) = 1.05$, $p = .301$, $d_Z = 0.15$, and fear/sad sensitivity, $t(49) = 1.15$, $p = .254$, $d_Z = 0.16$, did not.

3.4 Dissociation analyses. To directly compare direct and indirect prime sensitivity, we followed the suggestions by Schmidt and Vorberg (2006), transforming direct and indirect effects into a shared metric: direct effects (i.e., prime awareness) were assessed with *d'* (see above) and indirect priming effects were recalculated (separately for valence, relevance, and fear/sadness) according to the following formula:[7]

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[7] For the calculation of within-participants standard deviations we used RTs that were adjusted for the target main effect and winsorized (see Schmidt & Vorberg, 2006).

$$d_a = \frac{\bar{x}_{incongruent} - \bar{x}_{congruent}}{s_{pooled}} = \frac{\bar{x}_{incongruent} - \bar{x}_{congruent}}{\sqrt{\frac{1}{2}\left(s^2_{incongruent} + s^2_{congruent}\right)}}$$

Figure 3 shows the d_a-values of the indirect test plotted against the *d'*-values of the direct test. We conducted a 2 (SOA) × 3 (sensitivity: valence, relevance, specific) × 2 (test: indirect vs. direct) MANOVA for repeated measures with SOA as a between-participants factor[8] and d_a and *d'*, respectively, as the dependent variable. For reasons of conciseness, we report only interaction effects involving SOA. The three-way interaction effect was significant, $F(2,97) = 13.29$, $p < .001$, $\eta_p^2 = .215$.

For valence, the 2 (SOA) × 2 (test: indirect vs. direct) mixed-model ANOVA with test as a within-participants factor and SOA as a between-participants factor yielded a significant SOA × test interaction, $F(1,98) = 49.08$, $p < .001$, $\eta_p^2 = .334$. This interaction effect, however, is of ordinal type: Both indices significantly increase from short to long SOA, $F(1,98) = 7.84$, $p = .006$, $\eta_p^2 = .074$ for d_a and $F(1,98) = 68.72$, $p < .001$, $\eta_p^2 = .412$ for *d'*.[9]

For relevance, the 2 (SOA) × 2 (test: indirect vs. direct) mixed-model ANOVA with test as a within-participants factor and SOA as a between-participants factor yielded a significant SOA × test interaction as well, $F(1,98) = 7.91$, $p = .006$, $\eta_p^2 = .075$. This interaction effect, however, is of disordinal type: Whereas *d*' significantly increases, $F(1,98) = 5.29$, $p = .024$, $\eta_p^2 = .051$, d_a decreases, albeit non-significantly in this analysis, $F(1,98) = 2.98$, $p = .088$, $\eta_p^2 = .029$.

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[8] Note, for these analyses, only those experimental blocks of the indirect test are considered, which match the SOA in the direct test.

[9] The reader might notice that the significant SOA effect for d_a is in contrast to the result reported above for RTs, where we did not find a SOA effect for the valence effect. The discrepancy is due to the fact that the valence effect for SOA=143 ms shows a dependence on block sequence. Participants who started with the SOA=143 ms block, yielded a numerically negative but non-significant valence effect, whereas participants who started with the SOA=43 ms block yielded a positive and significant priming effect. None of the other priming indices was significantly affected by block sequence.

Note, that this non-significance may be due to insufficient test power: Remember that the corresponding within-participants analysis reported in the section on RTs was significant and there is no evidence that block order (i.e., whether SOA=43 ms comes first or last), made a difference for the relevance effect.

Finally, for the fear/sadness contrast, the 2 (SOA) × 2 (test: indirect vs. direct) mixed-model ANOVA with test as a within-participants factor and SOA as a between-participants factor yielded again a significant SOA × test interaction, $F(1,98) = 21.60$, $p < .001$, $\eta_p^2 = .181$ and it was again of disordinal type. Whereas d' significantly increases, $F(1,98) = 33.06$, $p < .001$, $\eta_p^2 = .252$, d_a numerically, but not significantly, decreases, $F < 1$.

4. Discussion

The present study provides important insights into masked processing of emotional faces by observing a significant moderation by SOA: With the short SOA (i.e., 43 ms), we observed a differentiation of valence and a differentiation of anger versus sadness/fear (i.e., a relevance distinction) within the negative emotions, suggesting an early differentiation of relevance of emotional facial expressions. As in our previous experiments (Rohr et al., 2012), there was no further differentiation between fear and sadness. With the long SOA (i.e., 143 ms), only a valence priming effect occurred.

Most importantly, the dissociation analyses revealed a significant dissociation between direct and indirect effects for all three contrasts. The most meaningful for our research is the relevance contrast, for which we observed a double dissociation (see Schmidt & Vorberg, 2006): The indirect priming effect was significant in the short SOA condition, but a null effect occurred in the long SOA. The direct test revealed the opposite pattern: there was a null effect for *d'* in the short SOA condition, but a significant effect in the long SOA condition. For the fear/sadness contrast a comparable pattern was found in the direct test (i.e., null detection at short SOA;

significant detection at long SOA). There was, however, no hint of an indirect priming effect of fear versus sadness primes. Finally, for the valence contrast, criteria of objective unawareness were not reached in either of the SOA conditions, but the direct priming effect was considerably larger in the long SOA condition. The indirect priming effect, however, did not change to the same degree.[10] These results suggest that indirect and direct test are both sensible to conscious processing of valence, albeit to different degrees (Schmidt & Vorberg, 2006).

Given these results, we conclude that the observed priming effects – at least the one beyond mere valence processing – are based on different processes than direct prime detection effects. Otherwise, the priming effects would have paralleled the prime discrimination effects: greater and more differentiated priming at the longer SOA at which prime detection was better. Rather, the observed emotional priming effects do not become more differentiated at the longer SOA; they appear even to be less differentiated with an increased SOA, given the reduction in relevance priming. Thus, our results suggest that prime detection effects and masked emotional priming effects underlie different processes, which are differently affected by the same change in SOA. Such a dissociation between masked priming and prime detection is usually regarded as indication that non-conscious processes contribute to masked priming effects (Schmidt & Vorberg, 2006). Thus, the different influence of SOA regarding the priming and the prime detection effects strengthens the assumption that the observed differentiated priming effects observed here and in earlier research are – at least partly – based on non-conscious processes.

Does affective processing require awareness?

[10] As noted above, it did not change overall; an increase from the short to the long SOA was only observed for the subsample of participants who received the long SOA as second condition. This change was less pronounced than in the direct test.

Thus, the present results are highly relevant to the intensely debated question whether or to what extent affective processing requires awareness. Our results contribute to a negation of this proposition and adds to evidence from other labs who found masked emotional priming for happy versus sad faces (Jiang, Bailey, Chen, Cui, & Zhang, 2013) and happy versus fearful faces (Ye, He, Hu, Yu, & Wang, 2014).

However, Andrews, Lipp, Mallan, and König (2011) – who searched for masked priming with emotional faces in parallel to our earlier research (Rohr et al., 2012) – did not observe significant masked priming effects with emotional faces (i.e., happy vs. angry faces as primes, words as targets, using SOAs of 80 ms and 300 ms). The discrepancy between their results and ours cannot be entirely clarified. One reason may be that the test-power of the study by Andrews et al. (2011) was too low to detect small effects – our present results suggest that the valence effect might be smaller than suggested by previous studies. Moreover, our results indicate that priming effects might become less differentiated or decrease with increasing SOA, and Andrews et al. (2011) employed comparably long SOAs.

Lähteenmäki and colleagues (2015) recently proposed an entirely different method to test the hypothesis of non-conscious priming by emotional faces and presented results that – on first sight – lead to an opposite conclusion. They tested for non-conscious processing by instructing participants to give a rating of prime awareness on a 4-point scale in each trial (1 = I did not see the stimulus at all; 2 = I saw a glimpse of something, but don't know what it was; 3 = I saw something, and think I can determine what it was; 4 = I saw the stimulus clearly), subsequently to the target-related response. The authors argued that this is the most direct and most valid assessment of phenomenal awareness. At the heart of their article are two masked priming experiments – one a standard evaluative priming experiment with pleasant and unpleasant object primes and targets and one with happy and fearful faces. They observed priming effects only for trials with ratings 3 and 4, but for not trials with ratings 1 and 2. The authors therefore concluded that affective processing requires awareness. However, besides a general critique of this route to non-conscious processing (see, e.g., Schmidt, 2015), there are two caveats that compromise an evaluation of this approach at this point of time. First, to obtain variation in ratings the authors employed two prime duration conditions; 10 ms and 80 ms. Of course, average ratings for the 10 ms condition were low, but they were high for the 80 ms condition. Prime duration, however, was not taken as an additional predictor (concurrently to rating) for congruence effects (e.g., in a linear mixed model analysis). Thus, it is an open question whether their main result simply means that they found priming for the 80 ms prime duration (which is rather long for masked studies) but not for the 10 ms condition (which is comparably short). Second, they selected primes from the same set as the targets (i.e., a given prime was categorized as positive or negative in other trials). It is well documented that priming effects using the same stimuli as primes and targets do not reflect genuine processing of a prime according to the response-relevant feature (here: valence), but retrieval of stimulus-response associations that are created while the stimulus was presented as a target (see, e.g., for evidence in the field of evaluative priming, Abrams & Greenwald, 2000; Abrams, Klinger, & Greenwald, 2002; Klauer et al., 2007).

The SOA manipulation: Elapsed time or presentation gap?

We employed relatively short prime durations and sandwich masking by structure. This type of masking usually yields Type A masking (Breitmeyer & Ögmen, 2006). Thus, it can be expected that masking is best at the shortest SOA. Specifically, the development of the masks is based on an article by Bachmann, Luiga, and Põder (2004), who showed that spatially quantized masks of different faces introduce distortion regarding local features as well as in the configuration of the masked image. In their study, masking was also less effective at longer SOAs. Moreover, depending on the coarseness of quantization of the mask local features and configuration can be differently masked. With increases in quantization local features can come through while configurational processing can still be inhibited. In our case, it seems that we have chosen such a level of intermediate quantization. While prime discrimination within the negative domain was at chance level, it seems that the salient smiles of the happy prime face were recognizable. Thus, the observed results of the direct test can be relatively well explained by the employed mask and Type A masking function. The decline in differentiation of the indirect priming effect despite increasing awareness with increasing SOA seems more surprising. However, it is known that non-conscious processes dissipate quickly (i.e., within 300 ms; Mattler, 2005, see also Dehaene, 2008); Greenwald, Draine, and Abrams (1996) have already reported a quick decline in masked priming effects with increasing SOA. Thus, it seems plausible to assume that the amount of elapsed time is responsible for the observed results.

However, it has to be noted that any SOA manipulation in a masked priming experiment has an inevitable confound: Either the mask duration increases with increasing SOA or the contrast of long and short SOA is confounded with the presence vs. absence of a blank screen gap between mask and target or not. Since we have chosen the latter version in our experiment, we have to discuss the results not only in terms of elapsed time but in terms of this gap as well.

In the priming task, the gap (in the long SOA condition) might shield target processing from prime processing. There are several assumptions in the literature, which fit to such a gap-based interpretation. In their psycho-physical account of priming results, Klauer, Teige-Mocimgemba, and Spruyt (2009; see also Klauer & Dittrich, 2010) explain positive evaluative priming effects by the relative increase of response evidence within an “evaluation window”: If the evaluation window includes the prime event, the increase of evidence in favor of the target-related response is steeper, if the prime is congruent to the target, compared to a neutral prime. If, however, the specific presentation parameters lead to an evaluation window that starts not before target presentation, the priming effect vanishes. Even more, reversed priming effects can be expected in this case since a congruent prime will increase the base line level for the target-related response, such that the relative increase within the window is not as steep as in the neutral prime condition. Without a gap (i.e., in the short SOA condition), the evaluation window may already start with the beginning of the uninterrupted sequence of prime-mask-target. The gap (i.e., in the long SOA condition) might be a clear signal to start the evaluation window not before this gap. Wentura and Rothermund (2003) pointed out that participants can adopt two different strategies in priming experiments: First, they can respond on the basis of accumulated evidence gathered throughout a trial in favor of one of the response alternatives, whatever the source of this evidence might be, thereby disregarding whether it is unequivocally related to the target. Second, they can select a response not before univocal evidence is accumulated that a response stems from the target. Clear positive priming effects will only be expected in the former case. Details of the experimental setting – as our gap vs. no-gap variation – might moderate participants’ response strategies. In this line, Fockenberg, Koole, and Semin (2008) introduced the metaphor of a „perceptual snapshot“ that potentially combines prime and target and determines the response in case of congruency. Again, subtle differences in the presentation parameters might alter the inclusion or exclusion in the snapshot (see also Klauer et al., 2009). The longer SOA and the resulting perceptual gap between prime and target presentation may trigger exclusion of the prime from the snapshot. Thus, in sum, a gap-based interpretation of our

SOA manipulation is as plausible as a time-based one. Probably, both parameters (i.e., elapsed time and gap) contribute to our results.

Evidently, neither the gap-based nor the time-based interpretation do fit to the pattern of the valence discrimination, since both the indirect as well as the direct valence effect increased with increasing SOA (albeit in markedly different degrees). This result is probably due to the fact that conscious and non-conscious processes contributed to our results. As explained above, the happy primes were not perfectly masked, and based on the employed spatially quantized masks, it can be that salient local features (i.e., the salient happy mouth) become recognizable. This partially conscious processing thus, however, not preclude that non-conscious processing occurred. The relevance priming effect within the negative domain is based on non-conscious processing, as employed by the observed dissociation and chance level performance in the direct test.

The meaning of the missing differentiation between fear and sadness

Of note, we did not observe a differentiation of fear and sadness within the negative domain. Therefore, an interpretation of the emotion priming effect in terms of simple semantic categorization processes is undermined, otherwise we should have observed categorization of all employed emotion categories (for a more extensive discussion see Rohr, Degner, & Wentura, 2015). However, given this result, it should also be discussed whether or how early perceptual stages contribute to our results. We do not think that such stages are responsible for the observed priming effects. At first, the recognition rates of the direct test do not suggest that fear and sadness are perceptually less distinguishable from one another than from anger, precluding that perceptual similarity influences the results. Second, we already provided evidence that the masked facial expressions can be processed up to semantic levels under these presentation conditions by employing words as targets (Rohr et al., 2012). Thus, it seems that anger plays a special role among the negative emotions and that emotion-related processed contribute to the present results. We interpreted this differentiation as assessment of relevance. However, as noted in the introduction, alternative theoretical interpretations can be made (i.e., approach-avoidance, threat), and further research seems necessary to elucidate this type of processing.[11]

Interestingly, we have observed further support for a differentiated processing of masked negative faces in other variations of the emotional priming paradigm (Rohr et al., 2015), albeit in a somewhat different form: By employing neutral-looking target faces and instructing participants to categorize their “subtle emotional expressions” (a variant of the Affective Misattribution Procedure, Payne, Cheng, Govorun, & Stewart, 2005), we observed a differentiation within the negative domain between angry/fear on the one hand and sadness on the other hand; anger and fear did not differentiate in this paradigm (Rohr et al., 2015). A comparable result was found in the priming paradigm that was used in the present experiments by employing low frequency-filtered emotional prime faces (Rohr & Wentura, 2014). This differentiation fits to a core affect hypothesis of emotions (Russell, 2003) that defines valence and arousal as the core components of emotions: Happy faces can be separated from negative faces by valence and angry or fearful faces can be separated from sad-looking faces by arousal. Thus, similar (but not identical) measures of masked emotional face processing both indicate that emotional facial expressions are processed beyond a mere good and bad dimension under limited presentation conditions. However, the specific feature(s) that is/are processed from emotional

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[11] A similar argumentation can also be made to refute that the discrimination of happy vs. negative facial expressions results from perceptual processing. As we have shown that this differentiation can also be observed with word targets (Rohr et al., 2012), we consider it as a differentiation of valence, and not as a perceptual recognition of the happy mouth.

faces beyond valence – differentiations which can be interpreted as arousal or relevance – seem to depend on the slight differences in paradigms. It is up to further research to elucidate this difference.

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Tables

Table 1. *Mean reaction latencies in milliseconds and error rates (in parentheses) as a function of prime emotion, target emotion, and SOA*

		Target							
SOA	Prime	Happy		Angry		Fearful		Sad	
43 ms									
	Happy	**734**	**(6.23)**	905	(30.93)	962	(31.11)	879	(19.34)
	Angry	738	(7.31)	**885**	**(28.82)**	950	(36.18)	893	(21.10)
	Fearful	743	(6.52)	920	(30.46)	**936**	**(34.16)**	864	(19.69)
	Sad	741	(7.52)	910	(28.81)	954	(31.40)	**879**	**(19.66)**
	Neutral	738	(6.80)	913	(29.94)	950	(34.74)	877	(19.11)
143 ms									
	Happy	**721**	**(6.62)**	922	(29.07)	937	(32.59)	875	(19.00)
	Angry	737	(6.80)	**912**	**(28.68)**	949	(34.29)	881	(18.16)
	Fearful	743	(5.53)	908	(30.02)	**957**	**(33.22)**	865	(18.30)
	Sad	741	(7.56)	913	(28.34)	964	(34.67)	**879**	**(16.09)**
	Neutral	743	(7.74)	905	(30.44)	939	(33.57)	886	(17.84)

Note. Emotion-congruent trials in bold letters.

Table 2. *Mean frequencies of responses (standard deviations in parentheses) in the Direct Prime Recognition Test*

		Response							
SOA	Prime	Happy		Angry		Fearful		Sad	
43 ms									
	Happy	**19.42**	**(10.65)**	4.36	(4.30)	2.72	(3.27)	5.50	(6.74)
	Angry	5.66	(5.09)	**7.62**	**(3.86)**	5.46	(4.61)	13.26	(7.28)
	Fearful	9.88	(5.75)	6.70	(3.42)	**5.38**	**(3.53)**	10.04	(6.89)
	Sad	5.36	(5.17)	7.72	(4.07)	5.00	(4.23)	**13.92**	**(7.28)**
143 ms									
	Happy	**28.84**	**(6.73)**	0.52	(1.11)	0.56	(0.93)	2.08	(5.75)
	Angry	1.70	(2.01)	**6.52**	**(4.16)**	5.42	(3.85)	18.36	(5.02)
	Fearful	7.58	(4.45)	5.42	(3.63)	**11.04**	**(5.42)**	7.96	(5.83)
	Sad	2.10	(2.48)	4.04	(3.21)	4.22	(3.30)	**21.64**	**(5.42)**

Note. Emotion congruent trials in bold letters. The diagonal indicates the mean frequencies of correct detection of each prime emotion; row margins add to 32 (i.e., the number of trials per condition).

Table 3. *Direct prime recognition task: Means of the signal detection indices d' (standard errors in parentheses)*

	Signal detection indices		
SOA	$d'_{Valence}$	$d'_{Relevanz}$	$d'_{Specific}$
43 ms	1.21 (0.14)	0.05 (0.05)	0.07 (0.06)
143 ms	2.78 (0.13)	0.22 (0.05)	0.72 (0.10)

Figure captions

Figure 1

Schematic depiction of a priming trial in the indirect measure (short SOA condition; for the long SOA condition a blank screen of 100 ms was inserted between mask and target).

Figure 2

Priming effects for the planned orthogonal contrasts. (Error bars depict one standard error above/below the mean.)

Figure 3

Indirect effects (in d_a units) plotted against direct effects (in d' units) for the two SOA conditions. (Note: each data point is based on N=50 participants)

Figure 1

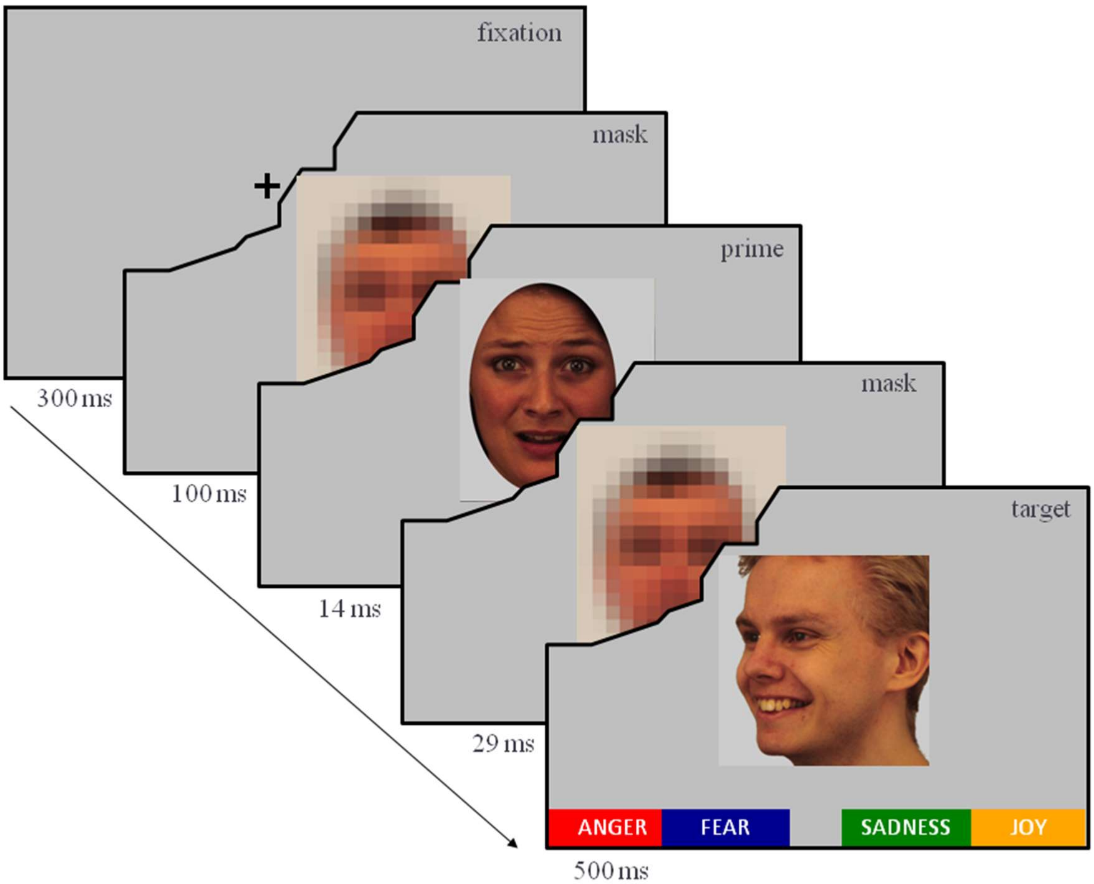

fixation
mask
prime
mask
target
300 ms
100 ms
14 ms
29 ms
500 ms
ANGER
FEAR
SADNESS
JOY

Figure 2

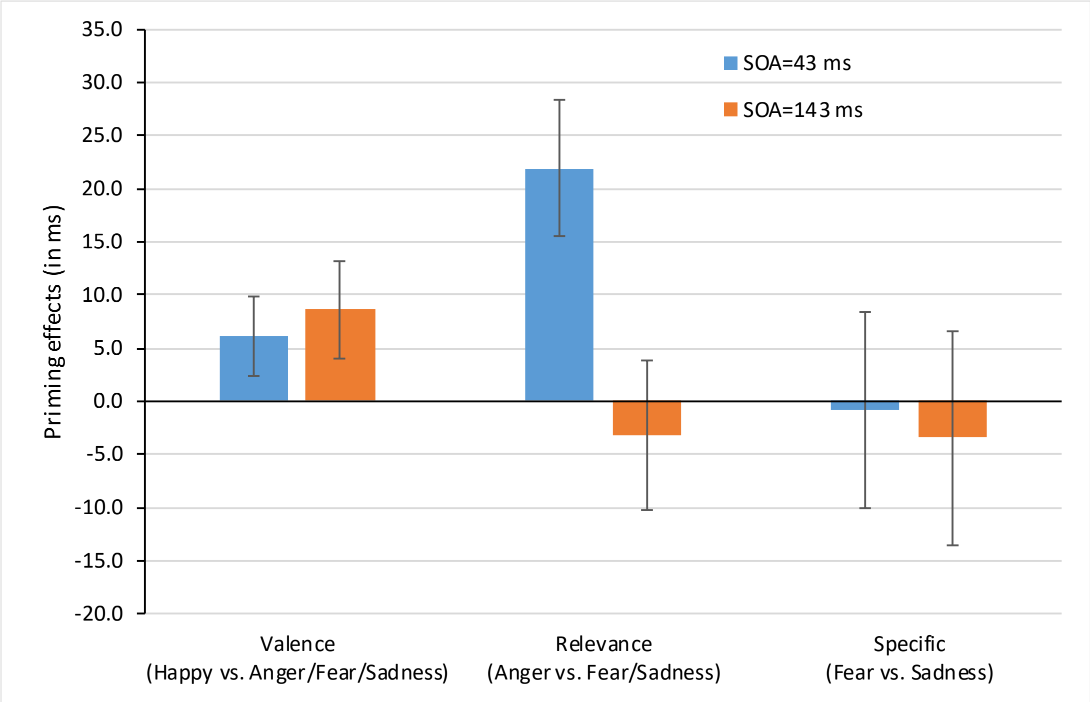
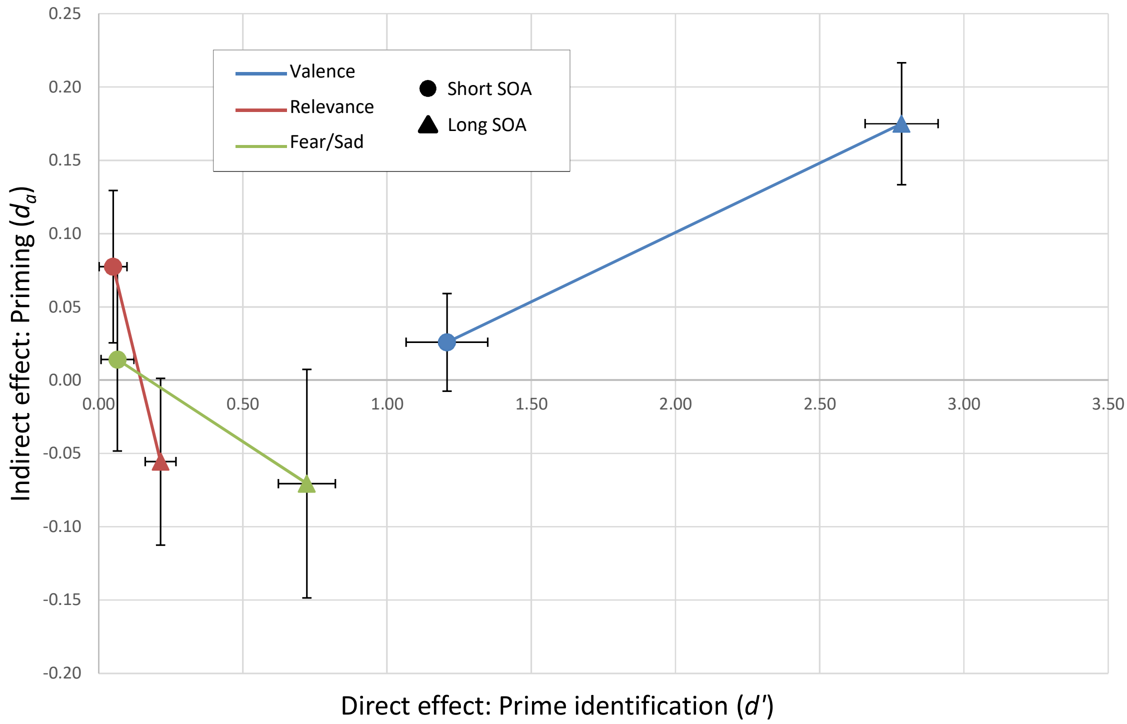

35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
Priming effects (in ms)
SOA=43 ms
SOA=143 ms
Valence
(Happy vs. Anger/Fear/Sadness)
Relevance
(Anger vs. Fear/Sadness)
Specific
(Fear vs. Sadness)

Figure 3


Valence
Relevance
Fear/Sad
Short SOA
Long SOA
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Indirect effect: Priming (d_a)
Direct effect: Prime identification (d')