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When emotions guide your attention in line with a context-specific goal: Rapid utilization of visible and masked emotional faces for anticipatory attentional orienting

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This research was supported by a grant from the German Research Foundation (DFG-WE 2284/9-1) to Dirk Wentura. All data and materials are openly accessible at *https://osf.io/3b2jq*; Folyi, Rohr, & Wentura, 2019, February 27). The authors thank Ullrich Ecker for his valuable comments on the manuscript. Correspondence concerning this article should be addressed to either Timea Folyi or Dirk Wentura, Saarland University, Department of Psychology, Campus A2.4, D-66123 Saarbruecken. E-mails: t.folyi@mx.uni-saarland.de or wentura@mx.uni-saarland.de

Abstract

The emotional value of a stimulus influences how the stimulus itself is perceived, and can "automatically" give rise to processes whose characteristics are inherently related to the emotional content of the stimuli (e.g., emotion-specific action tendencies). However, to provide optimal contextual flexibility, we propose that emotional information can be utilized in an "automatic" manner for novel, goal-directed processes that are not inherently signaled by the emotional meaning of the stimulus. We investigated this question using the endogenous cueing paradigm: Specifically, we asked how rapidly, efficiently, and to what degree of specificity emotional expressions can be utilized to anticipate the location of targets. We tested the specificity of the utilized emotional information by presenting emotional faces with contrasting affective valence (i.e., joy and anger) or pairs of negative expressions (e.g., anger and fear) as informative central cues. By presenting both masked and visible face cues, we tested whether and to what degree of specificity facial expressions can be utilized to orient attention under conditions of limited cue awareness. Cue validity effects emerged consistently in all experiments, and cuing effects built up fast, already at 300 ms cue-target asynchrony, and–at least partly–on the basis of holistic face representation. These results indicate that emotional faces can be utilized in line with a context-specific goal, with high specificity, rapidly, and even on the basis of limited perceptual input, suggesting that the utilization of emotional information can combine remarkable efficiency and situational flexibility in order to achieve optimal outcome in various critical situations.

Keywords: endogenous attention, spatial cueing, emotional facial expression, masked presentation, goal-directed processes

WORD COUNT: 13856 (main body of text incl. footnotes)

When emotions guide your attention in line with a context-specific goal: Rapid utilization of visible and masked emotional faces for anticipatory attentional orienting

Recognizing the emotional state of other individuals in our environment and using this information to prepare and execute a quick, appropriate reaction is clearly of critical significance. Emotional facial expressions are particularly important indices of our peers' emotional states, and the emotional information retrieved from faces is extensively utilized in social interactions – for example, to adjust one's own evaluations and expressive behavior (e.g., Hess & Fischer, 2013; Rohr, Degner, & Wentura, 2015). Ample evidence indicates that emotional facial expressions can be processed rapidly and efficiently (e.g., Batty & Taylor, 2003; Eimer & Holmes, 2007; Harris, Young, & Andrews, 2012; Johnson, 2005; Smith, Cottrell, Gosselin, & Schyns, 2005), and even under the conditions of limited perceptual awareness (e.g., Murphy & Zajonc, 1993; Rohr, Degner, & Wentura, 2012; Rohr et al., 2015; Rotteveel, de Groot, Geutskens, & Phaf, 2001), in line with their social and biological importance. However, an important question relating to emotional cues such as facial expressions regards not only their effective detection and recognition, but critically, how rapidly and efficiently we can utilize emotional information for further relevant processes, such as preparing an appropriate reaction or adjusting further evaluations, deploying attentional resources, and ongoing behavior.

Intuitively, we often have the impression that an emotional stimulus "automatically" triggers a cascade of processes that are inherently related to its emotional meaning ("emotional reactions") in order to reach an emotion-specific goal (e.g., avoiding a danger), with responses characterized by contextual flexibility (e.g., jumping out of the way of an approaching car or quickly saving your manuscript when your computer starts making loud noises). This intuitive view is supported by many prevailing emotion theories, which claim either (a) that some processes–such as facial mimicry or approach and avoidance action tendencies–are so tightly bound to the emotional value of the stimuli that they can be considered as inherent part of the emotional episode (for reviews, see e.g., Lang, 1994; Roseman, 2013) or (b) that emotions can give rise to intrinsically-related actions and action tendencies, such as "affect programs", to achieve emotion-specific goals (e.g., Scarantino, 2017). In line with these theoretical considerations, ample empirical evidence has demonstrated that the assessed emotional information can be utilized in an "automatic" way in processes that are inherently related to the emotional content of the stimulus: for example, to trigger facial responses (Dimberg, Thunberg, & Grunedal, 2002), prepare approach-avoidance reactions (e.g., Paulus & Wentura, 2016; Stins et al., 2011), evaluate unrelated ambiguous information (e.g., Murphy & Zajonc, 1993), or even influence consumption behavior (Winkielman, Berridge, & Wilbarger, 2005). To use a simple example, a happy face signals something positive; thus, subsequent judgments, decisions, or behavior are biased in line with or as a reaction to this evaluative meaning.

In contrast to such apparently stimulus-driven interpretations of the utilization of emotional information, recent accounts have proposed that emotional actions are primarily caused by flexible, goal-directed processes to ensure the most optimal outcome in critical situations (Moors, Boddez, & Houwer, 2017; Moors & Fischer, 2018). These goal-directed processes can be automatic in the sense that they can operate under poor conditions such as limited time or perceptual input (Moors et al., 2017). Building upon this assumption, we argue that processes utilizing emotional information are not necessarily or even predominantly "fixed" processes in the sense that a specific stimulus triggers processes that are inherently related to the emotional meaning of the stimulus (e.g., through long-term learning or even "pre-wired" associations). Rather, we suggest that the goal-directed utilization of emotional information might be highly effective and flexible across different situations in order to ensure fast and efficient learning and execution of reactions in various critical situations that are not inherently tied to the emotional meaning. More specifically, in the present research, we tested the assumption that emotional expressions can be utilized for novel, intrinsically non-emotional, goal-directed processes with high efficiency.

In the present study, we used the endogenous cueing paradigm as a measure of utilization that is comparable across emotions and independent of their a priori emotional meaning (for a review, see Chica, Martín-Arévalo, Botta, & Lupiáñez, 2014). In this paradigm, cue stimuli of a certain category (e.g., happy faces in our study) are briefly presented at the center of the screen, followed (with short stimulus onset asynchronies) by a non-emotional target stimulus left of the center in the majority of trials and right of the center in a minority of trials (or vice versa). Participants' task is to categorize the target (in the present case: the letter 'q' or 'p'). For cues of a second category (e.g., angry faces), the contingency is reversed. Faster and more accurate responses to the target in the majority trials (i.e., valid cueing: target appears at the location signaled by the cue) compared to the minority trials (i.e., invalid cueing: target appears at a different location than signaled by the cue) indicate utilization of the cue. In the endogenous cueing paradigm, participants are instructed to "tune" their attentional system voluntarily and top-down in accordance with these contingencies. Hence, this paradigm is thought to engage voluntarily controlled, endogenous attentional processes, on the assumption that anticipatory shifts of attention are executed away from the central cue toward the expected target location in accordance with the participant's intention to solve the task at hand (e.g. Chica et al., 2014; Egeth & Yantis, 1997; Jonides, 1981; Müller & Rabbitt, 1989). Thus, endogenous cueing is assumed to be dependent upon top-down processing, that is, the intention to use the cue and the accurate interpretation of its meaning. Thus, endogenous attentional orienting can be at least partially dissociated from exogenous attentional orienting, which is assumed to be triggered reflexively by an unexpected salient or important stimulus (e.g., Chica, Bartolomeo, & Lupiáñez, 2013; Jonides & Irwin, 1981; Müller & Rabbitt, 1989; Posner, 1980; Theeuwes, 1991).[1]

By using the endogenous cueing paradigm, we could investigate two important aspects of the “automaticity” of this goal-directed process: namely, its speed and its (in)dependence on the amount of perceptual input; two aspects of importance for our everyday lives, in which processing time and capacity are often limited. First, by varying the time interval between the cue faces and the targets, we tested the goal-relevant utilization of emotional faces in a situation when the available time is limited. In typical endogenous cueing studies using purely symbolic cues (i.e., cues without intrinsic spatial reference), a considerable time lag between cue and target onset is recommended and applied (e.g., a 500-600 ms cue-target stimulus onset asynchrony, SOA; for a review, see Chica et al., 2014), as the task-relevant dimension of the cue stimulus and the associated spatial meaning need to be interpreted and the corresponding attentional shift needs to be executed (e.g. Chica et al., 2013, 2014; Egeth & Yantis, 1997; Müller & Rabbitt, 1989). Hence, endogenous cueing studies have hitherto used perceptually and semantically simple cues in order to ensure relatively fast orienting (such as textures, colors, or letters, Botta et al., 2014; Brignani et al., 2009; Chica et al., 2012; Funes et al., 2007; Reuss, Kiesel, Kunde, &

[1] In this regard, central cues with over-learned or intrinsic spatial meaning, such as frequently used arrow cues or eye gaze of a centrally presented face, need to be distinguished from “purely” endogenous cues (such as color, shape or letter cues), as they can induce shifts of attention even without instructions, a familiarization phase, or when they are uninformative (e.g., Hommel, Pratt, Colzato, & Godijn, 2001; Ristic & Kingstone, 2012; Tipples, 2002). Hence, in the remainder of the article we focus on cues that are arbitrarily associated with predictive values when referring to endogenous cueing.

Wühr, 2012; Ristic & Landry, 2015). In the present study, cue and target stimuli were presented either with a brief SOA of 300 ms—which is shorter than the typical SOA in symbolic-cue studies—or with a more typical SOA of 600 ms (for a review, see Chica et al., 2014). We expected that emotional facial expressions can be utilized to orient anticipatory attention rapidly based on their intrinsic biological and/or social significance, that is, we expected emotional face cues to give rise to endogenous cueing effects already at the brief SOA. Second, by presenting masked and visible faces as informative cues, we investigated how limited visibility of the emotional faces affects their utilization for anticipating goal-relevant events. To date, there is only limited evidence on anticipatory orienting of attention by masked central cues without spatial reference; moreover, this evidence comes solely from studies using simple cues such as letters (e.g., Reuss, Kiesel, Kunde, & Wühr, 2012). In the present research, we tested whether masked emotional facial expressions can be used for anticipatory attentional orienting in accordance with current task goals based on their social-emotional importance.

Importantly, we investigated not only the use of emotional expressions as endogenous cues, but also the specificity of the emotional information that can be used for anticipatory attentional orienting, and whether and to what degree of specificity masked emotional cues can be utilized for this goal-relevant process. When it comes to processing emotional facial expressions, there is currently a controversy about the specificity of emotional information that can be processed relatively automatically. While it is well-established that the processing of facial emotions is fast, efficient, and does not require (full) perceptual awareness when it regards the differentiation of negative versus positive affective valence, it is often claimed that emotion-specific processing within the same valence domain requires more time and resources, and might not be possible under limited perceptual awareness (e.g., Murphy & Zajonc, 1993; Palermo &

Rhodes, 2007; Rotteveel et al., 2001). However, recent evidence indicates that more differentiated evaluation within the negative domain can occur at early stages of information processing even under masked presentation conditions (Rohr et al., 2012, 2015). Moreover, these studies suggest that specific processing within the same valence category is possible on the basis of affective (as opposed to semantic, see, e.g., Blaison, Imhoff, Hühnel, Hess, & Banse, 2012) processes, and that these processes can lead to patterns of differentiation beyond valence, based on arousal and/or functional appraisals such as assessing self-relevance (Rohr et al., 2012, 2015; see also Leventhal & Scherer, 1987).

In the present study, we investigated the level of specificity of the utilized emotional information under clearly visible presentation conditions. Frist, we applied a valence-based differentiation, using positive (joy) and negative (anger) expression cues. We expected participants to be able to utilize positive and negative expressions relatively easily (in line with previous research on emotional face processing using other paradigms; e.g., Murphy & Zajonc, 1993; Palermo & Rhodes, 2007; Rotteveel, et al., 2001). Second, we used different negative expressions as cues to investigate differentiation within the negative domain: (i) sadness versus anger and (ii) fear versus anger as perceptually dissimilar emotional expressions, and (iii) fear versus sadness as perceptually more similar expressions (see e.g., Calvo & Lundqvist, 2008). In line with theories claiming that emotion-specific processing requires more time and resources (e.g., Murphy & Zajonc, 1993), it may be the case that emotion cues of the same valence can only be utilized with a longer SOA, if at all. As an important related question in this regard, by testing the effect of face inversion on cueing with emotional faces, we investigated whether endogenous cueing effects can be based on the holistic percept of emotional faces or whether participants instead orient themselves on salient visual features of the expressions (e.g., exposed teeth). Furthermore, building upon recent findings indicating emotion-specific differentiation under masked presentation (Rohr et al., 2012, 2015), we examined whether specific emotional information can still be utilized for goal-relevant processes under masked presentation conditions.

Overview

Experiment 1 tested the utilization of emotional faces as endogenous cues in general and employed cues differing in valence (joy versus anger). Experiment 2 investigated the potency of emotion-specific cues in guiding spatial attention: Three parallel versions of Experiment 2 used different pairs of negative emotion cues (sadness versus anger; fear versus anger; fear versus sadness). Experiment 3 addressed the question of whether cueing effects can be based on a holistic perception of emotional expression cues or whether participants instead orient themselves on visually salient features. Experiments 4 and 5 tested the impact of cue awareness and thus used visible and masked emotional face cues. While Experiment 4 again used positive versus negative valence as the task-relevant dimension, Experiment 5 tested the hypothesis that specific emotional expressions can be utilized under conditions of limited cue visibility.

In all experiments, as is characteristic of the endogenous cueing paradigm, the centrally presented emotional cues were informative regarding the location of the upcoming target: the target appeared at the location predicted by the cue in 80% of trials (valid trials), and appeared on the opposite side in 20% of trials (invalid trials). Cue and target stimuli were presented either with a brief SOA of 300 ms, or with a longer SOA of 600 ms. Participants' task was to categorize the target letter as a 'p' or 'q' as quickly and accurately as possible. Cueing effects are thus indicated by facilitated performance (i.e., shorter response times and/or fewer errors) on valid trials compared to invalid trials.

Experiment 1

Method

For each experiment in the study, we report how we determined our sample size, all data exclusions (if any), all manipulations and all measures.

Participants. Twenty-nine students from Saarland University (16 females; aged 18–29 years, *Mdn* = 23 years; one left-handed) participated in Experiment 1 for monetary compensation (€4/half hour). All participants had normal or corrected-to-normal vision. Each participant gave written informed consent prior to the experiment. Data from one additional participant was excluded from further analyses because of an extreme error rate (mean error rate of 49.8%).[2]

Power considerations focused on the cue validity effect on response latencies, that is, the difference in target response times (RT) between the valid and invalid cue conditions. We applied a one-tailed interpretation to test the cueing effect given our specific prediction about the direction of the effect: In the informative endogenous cueing paradigm, the expected cueing effect corresponds to facilitated performance (and thus shorter RTs) in valid compared to invalid trials (for a review, see e.g., Chica et al., 2014). Experiment 1 involved positive vs. negative emotional expression cues. We expected participants to be able to efficiently differentiate between emotional expressions with contrasting valences, and thus based our power considerations on existing studies using simple symbolic cues, which typically yield medium to large effect sizes (for a review, see Chica et al., 2014). To detect a medium-sized effect (i.e., $d_Z = 0.50$; see

[2] For an additional subsample of participants (*n* = 5 in Experiment 1, *n* = 2 in Experiment 2a, *n* = 13 in Experiment 2b, *n* = 6 in Experiment 4), the refresh rate of the screen was incorrectly set, resulting in incorrect timing of the stimulus presentation. Since these data sets cannot be interpreted validly, the participants were excluded from analysis and replaced with new participants.

Cohen, 1988) with probability 1 - β = .80, given an α-value of .05 (one-tailed), a sample size of N = 27 is needed. (Factual power with N = 29 is 1- β = .84; calculated with G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007).

Design. The experiment followed a 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) within-participants design. The mapping of cue emotions (i.e., joy and anger) to the left and right target locations (e.g., a joy [anger] cue is followed by a target on the left [right] in 80% of trials) as well as the mapping of response keys to target types (see *Procedure*) were counterbalanced across participants.

Materials. The experiment was run in E-Prime, and stimulus presentation was synchronized with the 100-Hz refresh rate of 17'' CRT screens (type: Scenicview P796-2, Fujitsu, Siemens). Participants viewed the screen from a distance of 60 cm. We employed images of eight individuals (four men and four women), half from the Radboud Faces Database (RAFD; Langner et al., 2010) and half from the Karolinska Directed Emotional Faces (KDEF, Lundqvist, Flykt, & Öhman, 1998). Pictures were chosen based on recognition rates, and perceptual appearance was also taken into account (recognition per emotion based on the validation data of RAFD, Langner et al., 2010, and the validation data of KDEF, Goeleven, Raedt, Leyman, & Verschuere, 2008, were: *M* = 99% [*SD* = 1%] for joy; *M* = 91% [*SD* = 12%] for anger; *M* = 93% [*SD* = 5%] for sadness; and *M* = 81% [*SD* = 15%] for fear). Faces were framed by a gray oval such that only the facial features remained visible, while potentially distracting features (e.g., hair) were cut off; and luminance and contrast were adjusted slightly to reach perceptual equivalence between the databases (see *Figure 1* for an example; and see e.g., Rohr et al., 2012, for a comparable method). The images were resized to 150 × 150 pixels (4.72 cm × 4.72 cm on the screen; 4.8 × 4.8 degrees of viewing angle). Placeholders—four dots (each 0.3 cm × 0.3 cm on the screen) arranged in a square shape (internal dimensions 2.3 cm × 2.3 cm; external dimensions 2.9 cm × 2.9 cm on the screen; see *Figure 1*)—indicated the possible target locations to the left and right of central fixation. The distance between the center of these squares and the fixation cross was 5°. The target stimulus was either the letter “p” or the letter “q” presented centrally in one of the placeholders. The letter “g” was concurrently presented as a distractor in the center of the other placeholder. All letters were presented in Verdana font size 20 (0.5 cm × 0.6 cm on the screen). All data from this study was analyzed with SPSS version 21 (SPSS Inc, Chicago, Illinois).

Procedure. Participants were tested in groups of up to six participants. They were seated in front of individual computers that were separated by partition walls. Participants were seated at a viewing distance of 60 cm and were instructed to keep this distance throughout the experiment. Luminance and contrast were equalized via settings on the CRT screens of the computer stations (i.e., settings 55 and 100, respectively). Screen, computer and keyboard type were the same at each computer station. Participants were informed that the experiment dealt with the quick discrimination of arbitrary letters and that their task was to discriminate between the letters “p” and “q”. They were also informed that during each trial a target letter would appear on the left or right side of the screen in one of the dedicated placeholders, while a distractor would appear in the other placeholder. Participants were instructed to respond as accurately and quickly as possible via keypress using their index fingers. Participants were instructed to use both index fingers and to keep their index fingers on the response keys during the task. The experimenter checked whether participants followed these instructions. Response keys were the “2” and “8” keys of the number pad, which were labeled with stickers. These keys are aligned vertically; thus, key positions did not map onto the spatial relation of the cueing task (i.e., left/right). Participants were informed that emotional faces would be presented centrally before the target letters, and that these would correctly predict the target location in 80% of the trials. Thus, we used informative cues, and participants were informed of the contingency between cue and likely target location, and were encouraged to use this cue information in order to improve their performance.

A schematic illustration of a cueing trial is provided in *Figure 1*. Each trial started with a central fixation cross, flanked by the placeholders that marked the possible target locations. The placeholders remained on screen throughout the entire experimental block. After 500 ms, the fixation cross was replaced by the cue face, which was presented for 100 ms. Following a cue-target SOA of 300 or 600 ms, the target and distractor letters appeared at the designated locations. The letters remained on the screen until a response was recorded. Error feedback was provided after a false response. The inter-trial interval was 1,000 ms. Participants were instructed to strictly maintain central fixation during the entire experimental trial; they were told that it would be sufficient to covertly shift their attention to the target location in order to successfully complete the task.

The experimental phase consisted of one practice block of 40 trials and five experimental blocks of 80 trials each. SOA conditions (300 vs. 600 ms), target letters ("p" vs. "q"), and cue emotion (joy vs. anger) were varied randomly, with the constraint that each option was used equally often in each experimental block. These factors were combined such that the target appeared at the location predicted by the specific cue emotion in 80% of the trials (valid trials), while in 20% of the trials the target appeared at the opposite location (invalid trials). Thus, in a block of 80 trials, each possible combination of SOA, target letter, and cue emotion was used ten times—twice in invalid trials and eight times in valid trials. The target appeared on the left in half of the trials and on the right in the other half of the trials.

Furthermore, before the actual experiment started, participants completed 48 trials of a practice task in which they were asked to discriminate between the emotional facial expressions used in the cueing task. This preliminary task was introduced in order to control for general emotion recognition ability, which can be considered a prerequisite for successful completion of the experimental task. In this practice task, there were no targets; during each trial, only the emotional face was presented for 100 ms (after a 500 ms long presentation of the fixation cross); participants had to categorize the depicted emotion as joy or anger by pressing the “d” or “l” key on a standard German QWERTZ keyboard. Response keys were labelled with stickers; response-key assignment was counterbalanced across participants. There was no time limit for responses.

After the experiment, participants completed a short questionnaire that served to monitor task understanding and compliance (e.g., participants were asked about task strategies and task difficulty; we do not elaborate on this further as we had no specific hypotheses concerning this questionnaire variables). The experiment took about 30 minutes.

Results

Emotion recognition ability. Performance on the emotional categorization task was generally good (accuracy: M = 95.5%, SD = 4.6%) and did not show substantial variance (range: 85-100%). Thus, no participant showed deficits in emotion recognition.

Response latencies. RT analyses were restricted to trials with correct responses (4.9% of all trials were excluded because of incorrect responses). Furthermore, RT outliers were excluded

(0.9% of correct trials; upper and lower outlier criteria were defined as three interquartile ranges below the first or above the third quartile of the individual RT distribution; Tukey, 1977).

Mean RTs are depicted in *Figure 2*, while mean RTs indicated by bar graphs overlaid with individual data points are reported in the online supplemental material 1 (*Figure S1*).[3] A 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA[4] revealed a main effect of cue validity, $F(1,28) = 16.72$, $p < .001$, $\eta_p^2 = .374$ (d_Z = 0.76), indicating faster responses after valid as compared to invalid cues; this effect is in accordance with the expected cueing effect. The main effect of cue-target SOA was also significant, $F(1,28) = 10.68$, $p = .003$, $\eta_p^2 = .276$, with faster responses for longer SOA (in line with a typical cue-target foreperiod effect; Bertelson, 1967). The interaction of cue validity and SOA did not reach statistical significance, $F(1,28) = 2.01$, $p = .168$, $\eta_p^2 = .067$. Accordingly, significant cueing effects (i.e., invalid-minus-valid RT difference) emerged in both SOA conditions, with $t(28) = 3.61$, $p < .001$ (one-tailed), $d_Z = 0.67$ for the 300 ms SOA ($M = 55$ ms; $SE = 15$ ms) and $t(28) = 4.09$, $p < .001$ (one-tailed), $d_Z = 0.76$ for the 600 ms SOA ($M = 71$ ms; $SE = 17$ ms).

Errors. Error rates (ERs) were analyzed in line with the RTs; mean ERs are given in *Table 1*. The 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated measures ANOVA did not yield significant results: $F(1,28) = 0.00$, $p = .971$, $\eta_p^2 = .000$, for the

[3] See the online supplemental material 2 for reliabilities of the response time variable in the different conditions and an argument why these scores can potentially be important. For the experiments reported in this article nothing critical follows from these calculations.
[4] For results including Emotion as a further factor, see the online supplemental material 3. Briefly, Emotion did not moderate the cueing effects in any experiment.

cue validity main effect, $F(1,28) = 0.46$, $p = .505$, $\eta_p^2 = .016$, for the SOA main effect, and $F(1,28) = 0.05$, $p = .828$, $\eta_p^2 = .002$, for the interaction of cue validity and SOA.

Discussion

In Experiment 1, using positive (joy) and negative (anger) emotional faces as central symbolic cues, we found a significant cue validity effect on response latencies. Thus, perceptually and semantically complex cues such as emotional facial expressions can be utilized to induce anticipatory shifts of attention, at least when a valence-based differentiation of emotional expressions is possible. Significant cueing effects emerged in both SOA conditions, indicating that endogenous cueing by emotional faces emerges quickly—that is, within 300 ms, faster than the time suggested by previous research using simple, non-emotional symbolic cues (for a review, see Chica et al., 2014).

Experiment 2 investigated in three parallel versions whether not only valence, but also specific emotions within the negative domain can be utilized to orient anticipatory attention within our paradigm. Accordingly, in Experiment 2a, we presented sadness and anger as cue emotions; in Experiment 2b, we used fear and anger cues; and finally, in Experiment 2c, we presented fear and sadness as perceptually more similar negative expressions as cues.

Experiment 2

Method

Participants. Twenty-eight students from Saarland University participated in Experiment 2a (13 females; aged 18–29 years, *Mdn* = 22 years; four left-handed); sixty students participated in Experiment 2b (39 females; aged 19–34 years, *Mdn* = 23 years; four left-handed); sixty students participated in Experiment 2c (36 females; aged 18–34 years, *Mdn* = 23 years; nine left-handed, two both-handed). All participants had normal or corrected-to-normal vision. Each participant gave written informed consent before the experiment and received monetary compensation for participation (€4/half hour). Data from two further participants (*n* = 1 in Experiment 2b; *n* = 1 in Experiment 2c) were excluded from further analyses because of extreme response latencies (1430 and 1434 ms, respectively; the participants' overall response latency in the cueing task was extreme outlier in the overall distribution of response latencies, according to Tukey, 1977), data from four participants (*n* = 2 in Experiment 2b; and *n* = 2 in Experiment 2c) were excluded because of extreme error rates in the cueing task (≥ 29.0%), and data from three further participants (*n* = 2 in Experiment 2a; *n* = 1 in Experiment 2b) were excluded because of poor performance on the emotional categorization task (individual mean errors were 66.7% and 68.7 % in Experiment 2a and 68.7% in Experiment 2b; the overall error rates of the participants were extreme outliers in the overall distribution of error rates in the cueing or the emotional categorization tasks, respectively, according to Tukey, 1977).

Experiment 1 yielded a medium-to-large effect size (d_z = 0.67 for the cueing effect in the short SOA condition); we assumed effect sizes to be a bit lower in Experiment 2a, with valence-identical cues. Given the final sample size of *N* = 28 in Experiment 2a and an α-value of .05 (one-tailed), we were able to detect a medium-sized effect of d_z = 0.48 with a probability of 1 - β = .80. For Experiments 2b and 2c, we based our power considerations on the effect sizes obtained in Experiment 2a, which were a bit smaller than initially expected (d_z = 0.35 for short SOA; and *d* = 0.34 for long SOA; see *Results*). With a sample size of *N* = 60 in Experiments 2b and 2c and an α-value of .05 (one-tailed), we were able to detect an effect size of d_z = 0.32 with a probability of 1 - β = .80 (calculated with the aid of G*Power 3 software; Faul et al., 2007).

Design. Similarly to Experiment 1, Experiment 2 followed a 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) within-participants design. The emotion expressions that served as attentional cues varied in the three versions of Experiment 2: We used sadness and anger in Experiment 2a, fear and anger in Experiment 2b, and fear and sadness in Experiment 2c.

Materials and procedure. Materials and procedure were essentially the same as in Experiment 1, with the exception of the emotional expressions used as cues. The newly selected images depicted the same individuals as those used in Experiment 1.

Results

Emotion recognition ability. Performance on the emotional categorization task was generally good (accuracy: M = 84.0%, SD = 7.4% in Experiment 2a; M = 83.8%, SD = 10% in Experiment 2b; and M = 78.8%, SD = 11.9% in Experiment 2c). However, in line with previous findings on emotion recognition ability (e.g., Calvo & Lundqvist, 2008; Goeleven et al., 2008), participants exhibited lower emotion recognition performance within the negative domain compared to Experiment 1, in which joy and anger expressions were employed.

Response latencies. Using the same criteria as in Experiment 1, RT analyses were restricted to trials with correct responses (in Experiment 2a, 4.9% of all trials were excluded because of incorrect responses; it was 5.9% in Experiment 2b and 5.8% in Experiment 2c), and RT outliers were excluded (Experiment 2a: 0.8%; Experiment 2b: 1.0%; Experiment 2c: 1.1% of correct trials).

Mean RTs are provided in *Figure 3* (mean RTs indicated by bar graphs overlaid with individual data points are reported as supplemental material, see *Figure S2*). In *Experiment 2a*, which featured sadness and anger cues, a 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA:

300 ms vs. 600 ms) repeated-measures ANOVA showed the expected main effect of cue validity, $F(1,27) = 4.48$, $p = .044$, $\eta_p^2 = .142$ ($d_Z = 0.40$); participants responded faster in the valid-cue condition. Furthermore, the main effect of cue-target SOA was significant, $F(1,27) = 28.68$, $p < .001$, $\eta_p^2 = .515$, with faster responses for longer SOAs. Cue validity and SOA did not interact, $F(1,27) = 0.01$, $p = .918$, $\eta_p^2 = .000$, indicating comparable cueing effects for short and long cue-target SOAs. Analysis of the individual SOA conditions indicated a significant invalid-valid RT difference for both the short SOA, $t(27) = 1.86$, $p = .037$ (one-tailed), $d_Z = 0.35$, $M = 18$ ms, $SE = 10$ ms, and the long SOA, $t(27) = 1.85$, $p = .038$ (one-tailed), $d_Z = 0.35$, $M = 17$ ms, $SE = 9$ ms.

In *Experiment 2b*, which featured fear and anger cues, the 2 (cue validity) × 2 (cue-target SOA) repeated-measures ANOVA revealed a main effect of cue validity, $F(1,59) = 7.57$, $p = .008$, $\eta_p^2 = .114$ ($d_Z = 0.36$), with significantly faster target responses in the valid-cue condition. The main effect of cue-target SOA was also significant, $F(1,59) = 35.02$, $p < .001$, $\eta_p^2 = .372$, with faster responses for longer SOAs. Cue validity and SOA did not interact, $F(1,59) = 2.19$, $p = .144$, $\eta_p^2 = .036$. Correspondingly, the cueing effect was significant in each SOA condition, $t(59) = 1.79$, $p = .039$ (one-tailed), $d_Z = 0.23$ for the 300 ms SOA ($M = 13$ ms; $SE = 7$ ms), and $t(59) = 2.99$, $p = .002$ (one-tailed), $d_Z = 0.39$ for the 600 ms SOA ($M = 24$ ms; $SE = 8$ ms).

In *Experiment 2c,* which featured fear and sadness cues, a 2 (cue validity) × 2 (cue-target SOA) repeated-measures ANOVA of the RTs yielded a main effect of cue validity, $F(1,59) = 5.68$, $p = .020$, $\eta_p^2 = .088$ ($d_Z = 0.31$), with significantly faster target responses in the valid-cue condition. The main effect of cue-target SOA was also significant, $F(1,59) = 28.80$, $p < .001$, $\eta_p^2 = .328$, with faster responses for longer SOAs. Cue validity and SOA did not interact, $F(1,59) = 1.11$, $p = .296$, $\eta_p^2 = .019$. Accordingly, a significant cueing effect emerged in each

SOA condition, $t(59) = 1.69$, $p = .048$ (one-tailed), $d_Z = 0.22$ for the 300 ms SOA ($M = 12$ ms; $SE = 7$ ms), and $t(59) = 2.48$, $p = .008$ (one-tailed), $d_Z = 0.32$ for the 600 ms SOA ($M = 19$ ms; $SE = 8$ ms).

A 3 (experiment: 2a vs. 2b vs. 2c) × 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 vs. 600 ms) repeated-measures ANOVA with experiment as a between-participants factor confirmed the significant cue validity main effect, $F(1,145) = 15.38$, $p < .001$, $\eta_p^2 = .096$ ($d_Z = 0.32$) and the main effect of SOA, $F(1,145) = 83.28$, $p < .001$, $\eta_p^2 = .365$, as well as the non-significant interaction between cue validity and SOA, $F(1,145) = 1.48$, $p = .226$, $\eta_p^2 = .010$. The pattern of results was thus highly consistent across experiments. Both the cue validity × experiment interaction and the three-way interaction were non-significant, $F(2,145) = 0.05$, $p = .952$, $\eta_p^2 = .001$, and $F(2,145) = 0.45$, $p = .637$, $\eta_p^2 = .006$, respectively. No other significant results emerged: $F(2,145) = 0.80$, $p = .449$, $\eta_p^2 = .011$, for the interaction of SOA and experiment; and $F(2,145) = 0.35$, $p = .704$, $\eta_p^2 = .005$, for the main effect of experiment.

Errors. ERs were analyzed in line with the response latencies. Mean ERs for Experiment 2 are presented in *Table 1*. For *Experiment 2a*, the analysis yielded no significant results, with $F(1,27) = 0.08$, $p = .784$, $\eta_p^2 = .003$, for the cue validity main effect; $F(1,27) = 0.05$, $p = .822$, $\eta_p^2 = .002$, for the SOA main effect; and $F(1,27) = 0.75$, $p = .393$, $\eta_p^2 = .027$, for the interaction of cue validity and SOA. For *Experiment 2b*, the cue validity main effect was not significant, $F(1,59) = 2.14$, $p = .149$, $\eta_p^2 = .035$; nor was the main effect of SOA, $F(1,59) = 1.54$, $p = .220$, $\eta_p^2 = .025$; or the interaction of cue validity and SOA, $F(1,59) = 0.03$, $p = .868$, $\eta_p^2 = .000$. For *Experiment 2c*, the cue validity effect was again non-significant, $F(1,59) = 0.13$, $p = .723$, $\eta_p^2 = .002$, and no other main effects or interactions were found: $F(1,59) = 0.65$, $p = .425$, $\eta_p^2 = .011$, for the SOA main effect; and $F(1,59) = 1.74$, $p = .192$, $\eta_p^2 = .029$, for the interaction of cue validity and SOA.

Discussion

Experiment 2 addressed the question of whether specific emotional expressions can be interpreted and utilized as symbolic cues in an endogenous cueing paradigm. Hence, in the three parallel versions of Experiment 2, two emotions each from within the negative valence domain were used as cues: sadness vs. anger and fear vs. anger as perceptually dissimilar emotional expressions, and fear vs. sadness as perceptually more similar expressions. The results were clear-cut: The endogenous cueing effect emerged consistently, indicating that cueing effects can occur not only on the basis of contrasting valence information, as in Experiment 1, but also on the basis of specific emotions when valence is held constant. Notably, across all three variants of Experiment 2, cueing by emotional faces emerged with a short 300 ms cue-target SOA, and thus earlier than typical endogenous cueing effects with simple cues according to the endogenous cueing literature (for a review, see Chica et al., 2014).

Altogether, across Experiment 1 and the three versions of Experiment 2, significant cueing effects were consistently evident regardless of the specificity of the presented emotional information. However, the question emerges how complex is the information that participants retrieve and utilize from these faces? Experiment 3 addressed the question of whether participants utilize a holistic emotional perception of the emotional expression cues, or whether they orient themselves on salient features of the emotional expressions, such as exposed teeth in angry or joyful faces, frowning eyebrows in angry faces, a downturned mouth and narrow eyes in sad faces, or wide-open eyes in fearful expressions. If the latter is the case, one could argue that the cueing task with emotional face cues can be solved purely on the basis of matching simple patterns (e.g., in the presence of exposed teeth, the target will appear on the right, while in the absence of exposed teeth, the target will appear on the left), similarly to endogenous cueing tasks with simple cues. To address this issue, we used upright and inverted faces as endogenous cues in Experiment 3.

It is well-established in the facial perception literature that faces are less salient and harder to recognize when they are presented inverted (i.e., rotated by 180°), a phenomenon referred to as the face inversion effect (e.g., Tanaka & Farah, 1991; Yin, 1969). The prevailing view interprets the face inversion effect as a hallmark of the configural processing of regularly presented faces: As inversion disrupts the formation of a holistic face representation, inverted face recognition necessarily relies on less effective feature-based processing (Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Grand, & Mondloch, 2002; Tanaka & Farah, 1993; Yin, 1969). Furthermore, a line of evidence indicates that face inversion also impedes preferential detection and efficient recognition of emotional expressions, suggesting that the recognition of emotional expressions relies more on configural than feature-based processing (e.g., Bombari et al., 2013; Calder, Young, Keane, & Dean, 2000; Eimer & Holmes, 2002; McKelvie, 1995; Song et al., 2017; however, see also e.g., Savage & Lipp, 2015).

Thus, by using upright and inverted faces in Experiment 3, we tested whether the observed endogenous cueing effect is based on feature-based or configural processing of the emotional expression cues. It is conceivable that the cueing effect disappears or significantly weakens with inverted face cues as compared to upright presented cues, which would support the holistic processing of emotional expression cues. Alternatively, a similarly effective cueing by upright and inverted expressions would suggest that the endogenous cueing task with emotional face cues can be solved based on visually salient features.

We used again two expressions within the negative domain, so that participants could not rely on the relatively salient valence information (i.e., exposed teeth for smiles). Similarly to Experiment 2a, we presented sad and angry expressions as cues (i.e., the cueing effect within the negative domain that was associated with the highest effect size for the cue validity main effect, $d_Z = 0.40$). The cue faces were presented either upright or inverted in different blocks of the cueing task, with the first half of the experiment featuring blocks with cues of upright or inverted orientation (first orientation phase), and the second half of the experiment featuring blocks with cues of the opposite orientation (second orientation phase). The presentation order of the upright and inverted face orientation phases was counterbalanced across participants. As is characteristic of the endogenous cueing paradigm, both inverted and upright face cues were predictive of the target location with $p = .80$. In Experiment 3, we used only the 600 ms SOA condition, which was associated with more pronounced cueing effects in Experiments 1-2.

Experiment 3

Method

Participants. Sixty-one students from Saarland University participated in Experiment 3 (36 females; aged 18–29 years, *Mdn* = 21 years; eight left-handed, one both-handed). All participants had normal or corrected-to-normal vision. Each participant gave written informed consent before the experiment and received monetary compensation for participation (€4/half hour). Data from one further participant was excluded before analysis because of technical problems resulting in incomplete data. Data from two further participants were excluded from further analyses because of extreme error rates (24.6%) and response latencies (1329 ms), respectively (the participants' overall error rate and response latency in the cueing task were extreme outliers in the overall distribution of error rates and response latencies, respectively, according to Tukey, 1977).

Power calculations were based on two considerations: First, power should be sufficient to replicate the cueing effect of Experiment 2a for upright faces (d_z = 0.40 across SOA conditions), since we used visible anger and sad expressions as cues in Experiment 3 as well. Second, we wanted to ensure sufficient power to find an interaction of cueing and face orientation. Therefore, we adjusted the detectable effect size downwards. Given the final sample size of N = 61 in Experiment 3 and an α-value of .05 (one-tailed), we were able to detect a small-to-medium effect of d_z = 0.32 with a probability of 1 - β = .80 (calculated with the aid of G*Power 3 software; Faul et al., 2007).

Design. The experiment followed a 2 (face orientation: upright vs. inverted) × 2 (cue validity: invalid vs. valid) within-participants design. The face orientation factor (upright vs. inverted) was varied block-wise, with the first half of the experiment featuring blocks with cues of upright or inverted orientation and the second half of the experiment featuring blocks with cues of the opposite orientation. The presentation order of the face orientation blocks was counterbalanced across participants.

Materials. Materials and procedure were essentially the same as in Experiment 2a, with the following exceptions. We presented now three lists of 16 images depicting emotional facial expressions. As a second list of cue stimuli, eight further individuals were added. Each list contained pictures of eight individuals (four men and four women; with anger and sadness expressions in the present experiment); half were taken again from the RAFD (Langner et al., 2010), and half were from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998). Recognition per emotion based on the validation data of RAFD (Langner et al., 2010) and the validation data of KDEF (Goeleven et al., 2008) were: *M* = 98% (*SD* = 4%) for joy; *M* = 94% (*SD* = 12%) for anger; *M* = 88% (*SD* = 12%) for sadness; and *M* = 74% (*SD* = 18%) for fear.[5] Two lists of pictures served as attentional cues in the upright and inverted presentation conditions, respectively (see *Procedure* for details). The assignment of lists to face orientation conditions was counterbalanced across participants. The pictures in the third list served as targets in the preliminary emotional categorization task.

Procedure. The procedure was identical to Experiment 2a, with the following exceptions. Anger and sadness cues were presented upright in the upright orientation blocks and inverted in the inverted orientation blocks. The only difference between the upright and inverted orientation blocks was the orientation of the emotional faces that served as cues. The cueing phase started with one practice block and three experimental blocks featuring cues with one face orientation (i.e., first orientation phase), followed by one practice block and three experimental blocks featuring cues with the other face orientation (i.e., second orientation phase). Each experimental block included 80 trials. Cue emotion (anger vs. sad), and target letters (“p” vs. “q”) were varied randomly with the constraint that each option was used equally often in each experimental block. Again, cues were valid predictors of the target location in 80% of the trials and invalid in 20% of the trials. In the present experiment, we used only 600 ms cue-target asynchrony. Overall, the experiment took about 30 minutes.

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[5] Specifically, the first list of cue faces featured the following individuals: RAFD database: F27, F61, M71, M28; KDEF database: F01, F22, M11, M16. The second list of cue faces featured the following individuals: RAFD database: F14, F37, M23, M07; KDEF database: F20, F02, M10, M14. The preliminary emotional categorization featured the following individuals: RAFD database: F01, F22, M30, M25; KDEF database: F09, F07, M05, M24. Each individual displayed all emotional expressions (i.e., joy, anger, fear, sadness; only anger and sadness were employed in Experiment 3) in frontal view.

Results

Emotion recognition ability. Performance on the emotional categorization task was generally good (accuracy: $M = 85.2\%$, $SD = 10.9\%$); thus, participants did not exhibit deficits in emotion recognition.

Response latencies. Using the same criteria as in Experiments 1-2, RT analyses were restricted to trials with correct responses (5.7% of all trials were excluded because of incorrect responses), and RT outliers were excluded (0.9% of correct trials).

Mean RTs are provided in *Figure 4* (mean RTs indicated by bar graphs overlaid with individual data points are depicted in *Figure S3* of the supplemental material 1). The 2 (orientation: upright vs. inverted) × 2 (cue validity: invalid vs. valid) repeated-measures ANOVA revealed a main effect of cue validity, $F(1,60) = 26.09$, $p < .001$, $\eta_p^2 = .303$ ($d_Z = 0.65$); as expected, participants responded faster in the valid-cue condition. Furthermore, the main effect of face orientation was significant, $F(1,60) = 5.39$, $p = .024$, $\eta_p^2 = .082$, with slower responses following upright faces. Importantly, the cue validity and face orientation interaction was significant, $F(1,60) = 10.78$, $p = .002$, $\eta_p^2 = .152$, indicating more pronounced cueing with upright faces. Although the cueing effect, as expected, was more pronounced with upright cue presentation, analysis of the individual orientation conditions indicated a significant cueing effect for both upright and inverted face cues, $t(60) = 5.26$, $p < .001$ (one-tailed), $d_Z = 0.67$, $M = 44$ ms, $SE = 8$ ms with upright faces, and $t(60) = 3.28$, $p = .001$ (one-tailed), $d_Z = 0.42$, $M = 20$ ms, $SE = 6$ ms with inverted faces.

As it is possible that presenting inverted faces after upright faces might induce carry-over effects (i.e., introducing cues in the upright orientation might enable participants to more easily perceive the emotional expression of faces when presented inverted)[6], we conducted additional analyses taking orientation phase order into account.[7] Indeed, whereas the effect for upright faces was less dependent on whether the upright block came first (M = 41 ms; SE = 14 ms) or last (M = 48 ms; SE = 10 ms), the effect for inverted faces increased considerably when inverted faces were presented subsequently to upright faces (M = 26 ms; SE = 9 ms) compared to before (M = 13 ms; SE = 7 ms). In fact, reducing the design to a between-participants design by taking only the first orientation block of each participant into consideration still yielded–despite lower power in the between-participants comparison–marginally larger cueing effect for upright compared to inverted orientation, $t(59) = 1.75$, $p = .086$; the cueing effect for inverted faces, while still significant, $t(29) = 1.79$, $p = .042$ (one-tailed), $d_Z = 0.33$, was considerably reduced, $t(30) = 3.00$, $p = .003$ (one-tailed), $d_Z = 0.54$ for upright faces.

Errors. ERs were analyzed in line with the response latencies. Mean ERs for Experiment 3 are presented in *Table 2*. The analysis yielded no significant results, with $F(1,60) = 0.03$, p = .866, $\eta_p^2 = .000$, for the cue validity main effect; $F(1,60) = 0.79$, $p = .378$, $\eta_p^2 = .013$, for the face orientation main effect; and $F(1,60) = 0.97$, $p = .329$, $\eta_p^2 = .016$, for the interaction of cue validity and face orientation.

Discussion

Experiment 3 addressed the question of whether cueing by emotional facial expressions is attenuated or diminished when these cues are presented inverted, thereby hindering their holistic processing. First of all, the results of Experiment 3 revealed a significant cueing effect for upright faces, thereby replicating the endogenous cueing by emotional faces. Interestingly, the cueing

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[6] However, note that stimulus-specific carry-over effects were not possible because we presented two separate lists of pictures as cues in the upright and inverted presentation conditions.

[7] We thank an anonymous reviewer for recommending this post hoc analysis.

effect for upright faces was larger in the present experiment than in Experiment 2a. It is conceivable that participants were able to utilize the cue-target interval more effectively to orient their attention to the cue-indicated location with a constant long SOA (in Experiment 3) compared to the situation in which long and short SOA trials were intermixed (in Experiments 1-2). Moreover, responses after the inverted emotional faces were generally faster than after upright faces, that might indicate delayed attentional disengagement from upright presented and holistically processed emotional faces (for delayed disengagement in an exogenous cueing paradigm, see Fox, Russo, & Dutton, 2002; see also Koster, Crombez, Verschuere, & De Houwer, 2004; and Müller, Rothermund, & Wentura, 2016). Critically, the cue validity effect was moderated by the orientation of the cue faces, revealing a significant attenuation of the cueing effect for inverted relative to upright emotional faces. Although the cueing effect with inverted faces was numerically smaller, there was still significant cueing even after inversion. Nevertheless, this effect was quite small when focusing only on the first presentation block (thereby taking into account possible carry-over effects).

Thus, the results of Experiment 3 suggest that participants might partially orient on some salient key features of emotional faces (as evidenced by the numerically smaller but still significant cueing effect even after inversion), although they are unlikely to orient solely on such features. The significantly reduced cueing effect with inverted relative to upright presented faces supports the explanation that holistic emotional expressions are –at least partly–utilized for the effective cueing by upright presented emotional faces. However, as we used only the long, 600 ms SOA condition in Experiment 3, it is an open question for future research whether emotional face cueing relies on a more holistic or featural representation when the available time is more limited.

In sum, Experiments 1-3 provide evidence that, independently of the specificity of the emotional information, emotional facial expressions can be utilized rapidly and efficiently to orient anticipatory attention in line with task goals. Furthermore, Experiment 3 provided evidence for the utilization of the emotional information present in the face; salient visual features seem to play a minor role. Thus, emotional information is not only recognized rapidly, but also used to shift attention in a very short time (i.e., 300 ms or less). Based on these results, Experiments 4-5 addressed two intriguing questions related to the role of cue awareness: First, in general, can anticipatory attentional shifts be initiated on the basis of masked emotional expression cues, that is, under conditions of limited cue awareness? Second, how specific is the utilization of masked emotional face cues?

It is well-established that masked presented cues can trigger exogenous attentional shifts, at least when they map onto activated task settings (e.g. Ansorge, Horstmann, & Worschech, 2010; Fuchs, Theeuwes, & Ansorge, 2013; for a review, see Mulckhuyse & Theeuwes, 2010) or when they carry intrinsic motivational significance (Jiang, Costello, Fang, Huang, & He, 2006; Lin, Murray, & Boynton, 2009). These results can be reconciled with a classical view of automaticity (e.g. Schneider & Shiffrin, 1977). However, the question of whether masked cue information—especially when without intrinsic spatial reference—can influence anticipatory attention is puzzling for the classical interpretation of automaticity and taps into a recent discussion on the relation between perceptual awareness and cognitive control. Specifically, it has been proposed that conscious perception of a stimulus is not a necessary prerequisite for the stimulus to be able to modulate complex mental processes and to enable (some forms of) cognitive control (Hommel, 2007; Palmer & Mattler, 2013; Reuss, Desender, Kiesel, & Kunde, 2014). Nevertheless, to date, evidence for endogenous, anticipatory orienting of attention outside of awareness is mixed and originates from studies using very simple cues. McCormick (1997) found that participants reoriented their attention strategically as a response to counter-predictive peripheral cues only when the cues were clearly visible, but not when cue visibility was reduced by masking. Other studies have reported that centrally presented masked arrows and eye gaze cues (thus, cues with overlearned or intrinsic spatial meaning, see above; Al-Janabi & Finkbeiner, 2012; Cole & Kuhn, 2010; Reuss, Pohl, Kiesel, & Kunde, 2011; Sato, Okada, & Toichi, 2007), and simple symmetric masked cues (e.g., masked letter cues, Reuss et al., 2012; see also Palmer & Mattler, 2013; and Mattler, 2003) can initiate or modulate anticipatory attentional shifts.

Importantly, there is recent evidence suggesting that the processing of emotional faces is possible under masked presentation conditions (Rohr et al., 2012, 2015; Wentura, Rohr, & Degner, 2017). In the present research, we investigated whether emotional facial expressions can be utilized for anticipatory attentional orienting in accordance with task goals even when they are masked, and thus under conditions of limited perceptual awareness. Hence, we presented randomly intermixed visible and masked emotional faces as informative central cues: In half the trials, we presented clearly visible emotional faces, while in the other half of the trials, emotional faces of different individuals were briefly flashed, with visibility impeded by forward and backward masks. Importantly, in two experiments, we investigated the specificity of the emotional information that can be used for endogenous cueing under masked presentation conditions. Experiment 4 again used positive versus negative valence as the task-relevant dimension, while Experiment 5 investigated whether emotion-specific information can lead to anticipatory attentional orienting when visibility is constrained.

Experiment 4

Method

Participants. Fifty-seven students from Saarland University participated in Experiment 4 (37 females; aged 18–35 years, *Mdn* = 22 years; five left-handed). All participants had normal or corrected-to-normal vision. Each participant gave written informed consent before the experiment and received monetary compensation for participation (€4/half hour). Data from one further participant was excluded from further analyses because of extreme response latencies (1280 ms; the participant's overall response latency in the cueing task was extreme outlier in the overall distribution of response latencies, according to Tukey, 1977).

Power considerations were based on three sources of evidence: First, the results of our Experiment 1, which used the same emotional expressions as the present experiment (i.e., positive vs. negative expression cues); effects in Experiment 1 were medium to large. This is certainly an overestimation with regard to the effect for masked cues. Second, our results of Experiment 2, which concerned the more difficult discrimination between two negative emotions; effects in Experiment 2 were small to medium. Third, results from attentional cueing tasks using masked simple symbolic cues; these effects are of medium effect size (Reuss et al., 2012). Given a sample size of $N = 57$ in Experiment 4 and an α-value of .05 (one-tailed), we were able to detect a small-to-medium effect of $d_z = 0.33$ with a probability of $1 - \beta = .80$ (calculated with G*Power 3 software; Faul et al., 2007).

Design. The experiment followed a 2 (cue visibility: masked vs. unmasked) × 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) within-participants design.

Materials. Materials were the same as in Experiment 3, except the emotional expressions used as cues now depicted joy and anger expressions. Specifically, we again used three lists of stimuli: Two lists of pictures served as attentional cues in the masked and unmasked presentation conditions, respectively. The assignment of lists to visibility conditions was counterbalanced across participants. The pictures in the third list served as targets in the preliminary emotional categorization task. A black and white fractal image was used as the forward and backward mask (see *Procedure*).

Procedure. The procedure for Experiment 4 was identical to the procedure for Experiment 1, with the following exceptions. A schematic illustration of a cueing trial is depicted in *Figure 5*. The fixation cross was replaced by a forward mask, which was presented for 100 ms. Thereafter, the forward mask was replaced by a cue face, which was presented for 60 ms in the visible condition,[8] and for 30 ms in the masked condition. In the masked presentation condition, an additional backward mask was presented for 30 ms.

The experimental phase consisted of one practice block and twelve experimental blocks of 80 trials each. Cue visibility conditions (masked vs. unmasked), SOA (300 vs. 600 ms), target letters (“p” vs. “q”), and cue emotion (joy vs. anger) were varied randomly with the constraint that each option was used equally often in each experimental block. Again, cues were valid predictors of the target location in 80% of the trials, and invalid in 20% of the trials.

After the cueing task, participants completed a post-experiment questionnaire. The aim of this questionnaire was two-fold: it served to monitor task understanding and compliance in general, but more importantly, also served as a measure of subjective cue awareness. Participants were asked what they believed the aim of the experiment to be, and were asked to estimate the percentage of trials for which they perceived an emotional face prior to the target. After

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[8] The preliminary emotion categorization task of Experiments 3-4 also used 60 ms presentation times, for the sake of consistency.

debriefing, participants received direct questions about their awareness of the masked cues ("Did you see the masked presented faces?"; "To what degree did you recognize them?").

Finally, objective cue visibility was assessed in six blocks of 80 trials each. Cue visibility test trials were identical to the masked experimental trials, with the following exceptions: After the cue-target SOA of 300 or 600 ms, the empty placeholders changed color from white to gray; and no target or distractor letters appeared. Participants were instructed to categorize the emotional expression of the masked face as happy or angry as soon as the color of the placeholders changed. Response keys were the "d" and "l" keys, labelled with stickers; response-key assignment was counterbalanced across participants. Overall, the experiment took about 80 minutes.

Results

Emotion recognition ability. Participants showed high performance on the emotional categorization task (accuracy: $M = 94.3\%$, $SD = 5.1\%$). Thus, no participant showed a deficit in emotion recognition.

Response latencies. As in previous experiments, RT analyses were restricted to trials with correct responses (4.3% of all trials were excluded because of incorrect responses), and RT outliers were excluded (1.3% of correct trials).

Mean RTs across conditions are presented in *Figure 6* (for bar graphs overlaid with individual data points, see *Figure S4* of the supplemental material 1). A 2 (cue visibility: masked vs. unmasked) × 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA revealed a main effect of cue validity, $F(1,56) = 17.92$, $p < .001$, $\eta_p^2 = .242$ ($d_Z = 0.56$), indicating faster responses after valid as compared to invalid cues, in line with the expected cueing effect. The main effect of cue-target SOA was also significant, *F*(1,56) = 60.52, $p < .001$, $\eta_p^2 = .519$; responses were faster with longer SOAs. The main effect of cue visibility was not significant, *F*(1,56) = 2.59, $p = .113$, $\eta_p^2 = .044$. The cue validity by SOA interaction was also non-significant, *F*(1,56) = 3.07, $p = .085$, $\eta_p^2 = .052$; there was, however, a tendency for a larger cueing effect with a longer SOA. Cue validity and cue visibility did not interact, *F*(1,56) = 2.18, $p = .146$, $\eta_p^2 = .037$, indicating comparable cueing by clearly visible and masked cues. Furthermore, the SOA and cue visibility interaction was also non-significant, *F*(1,56) = 0.85, $p = .361$, $\eta_p^2 = .015$; as was the interaction of cue validity, cue visibility, and cue-target SOA, *F*(1,56) = 0.90, $p = .347$, $\eta_p^2 = .016$.

In short-SOA trials, the cue validity main effect was significant, *F*(1,56) = 7.76, $p = .007$, $\eta_p^2 = .122$ ($d_Z = 0.37$). The main effect of cue visibility was not significant, *F*(1,56) = 0.28, $p = .598$, $\eta_p^2 = .005$. There was no interaction between cue visibility and cue validity, *F*(1,56) = 0.40, $p = .528$, $\eta_p^2 = .007$, indicating comparable cueing by masked and clearly visible cues at the short SOA (see also *Table 2*). Despite the non-significant cue visibility × cue validity interaction, it is noteworthy that the masked cueing effect at the short SOA was significant, $t(56) = 1.75$, $p = .043$ (one-tailed), $d_z = 0.23$. (The same is true for the replication of the unmasked cueing effect at the short SOA, $t[56] = 1.97$, $p = .027$, one-tailed, $d_z = 0.26$.)

In long-SOA trials, the main effect of cue validity was again significant, *F*(1,56) = 16.30, $p < .001$, $\eta_p^2 = .225$ ($d_Z = 0.53$), indicating the expected cueing effect. The main effect of cue visibility was not significant, *F*(1,56) = 3.34, $p = .073$, $\eta_p^2 = .056$, similarly to the interaction of cue visibility and cue validity, *F*(1,56) = 3.23, $p = .078$, $\eta_p^2 = .055$. The cueing effects for both unmasked and masked cues were significant in the long SOA condition, with $M = 23$ ms, $t(56) = 3.37$, $p < .001$ (one-tailed), $d_z = 0.45$, for unmasked cues, and M =10 ms, $t(56) = 2.94$, $p = .002$ (one-tailed), $d_z = 0.39$, for masked cues.

Errors. Overall ERs ranged between 0.2% and 17.9%. Mean ERs across conditions are presented in *Table 3*. A 2 (cue validity: invalid vs. valid) × 2 (cue visibility: masked vs. unmasked) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA did not show a significant main effect of cue validity, $F(1,56) = 0.81$, $p = .373$, $\eta_p^2 = .014$; cue visibility, $F(1,56) = 3.81$, $p = .056$, $\eta_p^2 = .064$; or SOA, $F(1,56) = 0.81$, $p = .371$, $\eta_p^2 = .014$. Additionally, the cue validity and visibility interaction, $F(1,56) = 1.84$, $p = .180$, $\eta_p^2 = .032$; the interaction of cue validity and SOA, $F(1,56) = 0.07$, $p = .796$, $\eta_p^2 = .001$; the interaction of cue visibility and SOA, $F(1,56) = 0.05$, $p = .823$, $\eta_p^2 = .001$; and the interaction of cue validity, cue visibility and SOA, $F(1,56) = 2.34$, $p = .132$, $\eta_p^2 = .040$, were all non-significant.

Masked cue recognition. In the subjective cue awareness questionnaire, no participants referred to briefly flashed emotional faces between the masks, and no participants mentioned non-conscious processing or attentional orienting in response to masked emotional faces as the aim of the experiment. Thus, all participants were naïve to our research question. On average, participants reported seeing emotional faces on $M = 56.1\%$ ($SD = 29.8\%$) of trials, which is only slightly more than the proportion of trials with clearly visible cues (50%). After debriefing participants about the actual presence of emotional faces in all trials, twenty-nine participants (51% of the sample) reported that they had actually noticed the masked faces, and these participants reported cue recognition with moderate confidence ($M = 3.21$, $SD = 1.26$, on a seven-point scale ranging from 1 = "did not recognize at all" to 7 = "very good recognition"). However, note that answers to the latter two questions could be biased by participants' affirmative tendencies after the presence of the masked cues had been revealed. Participants' discrimination performance in the direct test of masked cue recognition was associated with a mean hit rate (taking 'anger' as the signal) of 61.0%, and a false alarm rate of 36.8%; the mean *d'* = 0.69 was significantly greater than zero, $t(54) = 8.15$, $p < .001$ (one-tailed), $d_Z = 1.10$.[9]

Discussion

Experiment 4 provided a clear pattern of results: Cueing effects emerged not only with clearly visible cues, but also with masked emotional faces as cues. Moreover, the cue validity effect was not qualified by cue visibility, indicating comparable cueing by clearly visible cues and masked cues. These results demonstrate that not only simple perceptual or semantic information (e.g., Reuss et al., 2012), but also emotional information can induce anticipatory shifts of attention under conditions of marginal visibility. Despite the complexity of this information, cueing effects emerged remarkably fast, within 300 ms. However, the task-relevant utilization of cues in Experiment 4 could have been based on contrasting valence information, which is arguably more easily accessible (Murphy & Zajonc, 1993). Thus, in Experiment 5 we investigated whether specific facial expressions from within the negative domain (i.e., sadness versus anger) could serve as symbolic attentional cues under masked presentation conditions. Such a result would indicate the utilization of specific emotional information as symbolic cues beyond valence.

Experiment 5

Method

Participants. Eighty-seven students from Saarland University participated in Experiment 5 (58 females; aged 18–35 years, *Mdn* = 23 years; ten left-handed and two both-handed). All

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[9] Data sets from two participants were excluded because of invalid responses (i.e., using only one response key throughout the awareness test task). As expected, the *d'* for the two SOA conditions (i.e., response window starting 300 or 600 ms post prime onset) did not differ, $t(54) = 0.97$, $p = .335$. Therefore, we collapsed the two SOA conditions.

participants had normal or corrected-to-normal vision. Each participant gave written informed consent before the experiment and received monetary compensation for participation (€4/half hour). Data from two further participants were excluded before data analysis, in one case because of failure to follow the experimental instructions, and in the other case because the participant had already participated in a previous experiment from this series. Data from one additional participant was excluded from further analysis because of an extreme error rate (50.9%).

We based power considerations on the results of Experiment 4 (d_z = 0.23 for the cueing effect with masked cues in the short SOA condition, and d_z = 0.39 in the long SOA condition). Given the final sample size of N = 87 and an α-value of .05 (one-tailed), we can detect an effect of d_z = 0.27 with a probability of 1 - β = .80 (calculated with G*Power 3 software; Faul et al., 2007).

Design. Experiment 5 again had a 2 (cue visibility: masked vs. unmasked) × 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) within-participants design.

Materials and procedure. Materials and procedure were essentially the same as in Experiment 4, with the exception of the cue emotions: instead of joy and anger, Experiment 5 used sadness and anger expressions; the images depicted the same individuals as in Experiment 4.

Results

Response latencies. Again, RT analyses were restricted to trials with correct responses (4.9% of all trials were excluded because of incorrect responses), and RT outliers were excluded (1.0% of correct trials).

Mean RTs across conditions are presented in *Figure 7* (for bar graphs overlaid with individual data points, see *Figure S5* of the supplemental material 1). A 2 (cue validity: invalid vs. valid) × 2 (cue visibility: masked vs. unmasked) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA revealed a main effect of cue validity, $F(1,86) = 14.68$, $p < .001$, $\eta_p^2 = .146$ ($d_Z = 0.41$), indicating faster responses after valid compared to invalid cues, in line with the expected cueing effect. The main effect of cue-target SOA was also significant, $F(1,86) = 150.13$, $p < .001$, $\eta_p^2 = .636$, reflecting faster responses with longer SOAs. The main effect of cue visibility was significant as well, $F(1,86) = 7.86$, $p = .006$, $\eta_p^2 = .084$. The cue validity and SOA interaction was non-significant, $F(1,86) = 0.33$, $p = .567$, $\eta_p^2 = .004$. SOA and cue visibility also did not interact, $F(1,86) = 1.07$, $p = .304$, $\eta_p^2 = .012$. Cue validity interacted significantly with cue visibility, $F(1,86) = 8.21$, $p = .005$, $\eta_p^2 = .087$, indicating more pronounced cueing with clearly visible cues than masked cues. The interaction of cue validity, cue visibility, and cue-target SOA was also significant, $F(1,86) = 4.57$, $p = .035$, $\eta_p^2 = .050$, suggesting that the relation between cueing and cue visibility was further moderated by the timing of the cue-target presentation.

In short-SOA trials, the cue validity main effect was significant, $F(1,86) = 13.63$, $p = .001$, $\eta_p^2 = .137$ ($d_Z = 0.40$). The main effect of cue visibility was not significant, $F(1,86) = 1.86$, $p = .177$, $\eta_p^2 = .021$. Importantly, there was no interaction between cue visibility and cue validity, $F(1,86) = 1.78$, $p = .185$, $\eta_p^2 = .020$, indicating comparable cueing with masked and clearly visible cues at the short SOA. (The cueing effects for both unmasked and masked cues in the short-SOA condition were significant, with $t(86) = 3.09$, $p = .001$ [one-tailed], $d_Z = 0.33$, for unmasked cues, and $t(86) = 2.09$, $p = .020$ [one-tailed], $d_Z = 0.22$, for masked cues).

For long-SOA trials, the cue validity main effect was significant, $F(1,86) = 9.26$, $p = .003$, $\eta_p^2 = .097$ ($d_Z = 0.33$). The main effect of cue visibility was also significant, $F(1,86) = 9.03$, $p = .003$, $\eta_p^2 = .095$. Cue visibility and validity interacted significantly, $F(1,86) = 9.57$, $p = .003$, η_p^2

= .100, indicating a cueing effect only with clearly visible cues with a long SOA (M = 21 ms, $t(86) = 3.52$, $p < .001$ [one-tailed], $d_Z = 0.38$; with masked cues, the effect was M = 0 ms, $t(86) = 0.11$, $p = .456$ [one-tailed], $d_Z = 0.01$).

Errors. Overall ERs ranged between 1% and 14%. Mean ERs across conditions are presented in *Table 4*. A 2 (cue visibility: masked vs. unmasked) × 2 (cue validity: invalid vs. valid) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA revealed a main effect of cue validity that just missed the conventional criterion of significance, $F(1,86) = 3.82$, $p = .054$, $\eta_p^2 = .043$, indicating, as expected, a tendency for more errors after invalid compared to valid cues. The main effect of cue visibility was significant, $F(1,86) = 6.57$, $p = .012$, $\eta_p^2 = .071$. Cue validity and visibility did not interact, $F(1,86) = 2.18$, $p = .144$, $\eta_p^2 = .025$. The main effect of SOA was non-significant, $F(1,86) = 0.55$, $p = .462$, $\eta_p^2 = .006$; as were the interactions of cue validity and SOA, $F(1,86) = 0.24$, $p = .623$, $\eta_p^2 = .003$; cue visibility and SOA, $F(1,86) = 0.05$, $p = .823$, $\eta_p^2 = .001$; and the interaction of cue validity, cue visibility and SOA, $F(1,86) = 0.12$, $p = .735$, $\eta_p^2 = .001$.

Masked cue recognition. In the subjective cue awareness questionnaire, one participant referred to emotional faces being flashed between the masks, and two further participants mentioned non-conscious processing of stimuli and the effect of emotions on decision making with respect to our research question.[10] Thus, in general, the majority of participants (97% of the

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[10] Excluding the data sets from these participants did not change the pattern of results reported above: A 2 (cue validity: invalid vs. valid) × 2 (cue visibility: masked vs. unmasked) × 2 (cue-target SOA: 300 ms vs. 600 ms) repeated-measures ANOVA on this subsample of participants revealed a main effect of cue validity, $F(1,83) = 15.07$, $p < .001$, $\eta_p^2 = .154$ ($d_Z = 0.42$). The main effect of cue-target SOA was also significant, $F(1,83) = 131.92$, $p < .001$, $\eta_p^2 = .614$. The main effect of cue visibility was significant as well, $F(1,83) = 7.05$, $p = .009$, $\eta_p^2 = .078$. The cue validity and SOA interaction was non-significant, $F(1,83) = 2.01$, $p = .160$, $\eta_p^2 = .024$. Cue validity interacted significantly with cue visibility, $F(1,83) = 8.15$, $p = .005$, $\eta_p^2 = .089$. The

sample) were completely naïve to the aim of the experiment. Participants reported seeing emotional faces on *M* = 55.2% (*SD* = 31.2%) of trials, which is only slightly more than the proportion of trials with clearly visible cues (50%). After participants were informed about the presence of emotional faces in all trials, 35 participants (40% of respondents) reported that they had actually noticed the masked faces; however, these participants reported cue recognition with low confidence (*M* = 2.89, *SD* = 1.43, on a seven-point scale ranging from 1 = "did not recognize at all" to 7 = "very good recognition"). Participants' discrimination performance in the direct test was associated with a mean hit rate (taking 'anger' as the signal) of 53.0% and a false alarm rate of 51.0%; the mean *d'* = 0.05 was not significantly larger than zero, $t(85) = 1.48$, $p = .071$ (one-tailed), $d_Z = 0.16$.[11]

Discussion

Experiment 5 addressed the question of whether specific emotional expressions from within the negative domain (i.e., sadness and anger) can be utilized to induce endogenous shifts of attention under conditions of limited awareness. Experiment 5 did indeed provide evidence supporting this assumption. However, Experiment 5 also yielded one interesting result that differed from the valence-based cueing effect with masked emotional faces we observed in Experiment 4: While endogenous cueing again emerged quickly, within 300 ms, in Experiment 5 the cueing effect also appeared to decline quickly—it was not found at a long, 600 ms SOA. This pattern resembles the non-conscious processing effects found in the evaluative priming

interaction of cue validity, cue visibility, and cue-target SOA was also significant, $F(1,83) = 4.60$, $p = .035$, $\eta_p^2 = .052$.

[11] The data from one participant was excluded because of invalid responses (i.e., using only one response key throughout the awareness test task). As expected, the *d'* for the two SOA conditions did not differ, $t(85) = 0.90$, $p = .369$. Therefore, we collapsed the two SOA conditions.

paradigm, where representations of masked primes often appear to decay quickly (e.g., Hermans, Houwer, & Eelen, 2001); this suggests a more transient and “automatic” utilization of masked emotional faces as informative cues. This result might be related to the effective masking of cues in Experiment 5; it is known that the activation triggered by masked information decays quickly, while visible information (or partially visible information, as in Experiment 4) remains activated for longer periods of time (Dehaene & Changeux, 2011).

Taken together, the results of Experiments 4 and 5 are in accordance with previous studies indicating that anticipatory shifts of attention can be executed on the basis of simple cues presented under conditions of limited awareness (e.g., Reuss et al., 2012, 2011). Importantly, the current research demonstrates that complex emotional information can also be utilized to orient anticipatory attention “automatically”, in the sense of quickly and even based on limited perceptual input.

General Discussion

In the present study, we proposed that emotional information can be utilized efficiently for novel, goal-directed processes that are not inherently signaled by the emotional meaning of the stimulus, in order to provide contextual flexibility in various critical situations we face in everyday life. Previous research has investigated the interplay of emotion and attention mostly in terms of “automatic”, exogenous attentional orienting towards emotional stimuli, which was assumed to ensure their fast and efficient detection (e.g., Brosch, Sander, Pourtois, & Scherer, 2008; Folyi, Liesefeld, & Wentura, 2016; Wentura, Müller, & Rothermund, 2014; Wirth & Wentura, 2017; for a review, see Carretié, 2014). However, we have little understanding of whether and how emotional information can be utilized for and possibly boost endogenous, anticipatory attentional processes.[12] The current study focused on this very question by using emotional faces as informative cues in an endogenous cueing paradigm.

Overall, the present study yielded a consistent pattern of results regarding endogenous cueing by emotional faces: First, we found cue validity effects consistently in all experiments; second, cueing effects emerged with a 300 ms cue-target SOA, and thus earlier than expected for such complex cues in a standard endogenous cueing paradigm; third, cueing effects emerged not only for cues that differed in valence but also for specific, valence-identical cues; fourth, the attenuation of the cueing effect for inverted relative to upright emotional faces suggests that the cueing effect is at least partly based on a holistic representation of the emotional face cues; fifth, attention shifts could even be initiated on the basis of emotion-specific masked cues. The rapid utilization of specific emotional information, even under conditions of limited awareness, is remarkable in light of the existing research on endogenous cueing with affectively neutral cues, which has only used simple cues and rather long SOAs. This remarkably effective utilization of emotional information as an endogenous cue with respect to speed, relative independence from the amount of perceptual input, and specificity of the utilized emotional information is possibly related to the special status of emotional faces as high-priority stimuli of great social and biological significance.

In this regard, a compelling question concerns the degree of "automaticity" of endogenous cueing in our paradigm: The cue-based facilitation of target performance built up fast (even with 300 ms SOA, and thus faster than expected on the basis of typical endogenous

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[12] As an exception, considerable research has been conducted on anticipatory biases of attention in accordance with motivational needs and reward expectations (e.g. Bayer et al., 2017; Mohanty, Egner, Monti, & Mesulam, 2009; Mohanty, Gitelman, Small, & Mesulam, 2008; Small et al., 2005; for a review, see Mohanty & Sussman, 2013). However, note that these are also intrinsically related processes.

cueing results), even after masked cue presentation, and the masked cueing effect appeared rather transient when specific negative emotions were used as masked cues. This pattern of results is consistent with an “automatic” utilization of emotional faces as symbolic cues (i.e., fast, efficient utilization based on limited input, see, e.g., Moors, 2016; Moors & De Houwer, 2006). On the one hand, this pattern is plausibly related to the relative “automaticity” of (emotional) face processing, which involves the efficient task-relevant categorization of emotional expressions. On the other hand, the pattern may speak to the “automaticity” of attentional orienting in the present paradigm. Specifically, anticipatory attentional process might proceed more quickly, efficiently or involuntarily when attentional cues are emotional (for a review of amygdala-based preferential emotional attention from the viewpoint of automatic attention to emotional stimuli, see Pourtois et al., 2013). While the prevailing view on endogenous cueing is that slow, strategic, voluntarily controlled processes underlie attentional orienting when central symbolic cues are used (e.g., Egeth & Yantis, 1997; Müller & Rabbitt, 1989; Posner, 1980), more recent evidence suggests that more “automatic” processes can also give rise or contribute to the endogenous cueing effect (e.g., Bonato, Lisi, Pegoraro, & Pourtois, 2016; Peterson & Gibson, 2011; Risko & Stolz, 2010; see also Bartolomeo, Decaix, & Siéroff, 2007). Specifically, this view assumes that in a typical endogenous cueing paradigm, participants are able to allocate their attention on the basis of implicit learning of cue-dependent target location probabilities, that is, without or independently of conscious effort and awareness of these contingencies, at least if simple central cues are used—such as color cues or cues with intrinsic spatial meaning—because salient cue information might facilitate contingency learning (Bonato et al., 2016; Peterson & Gibson, 2011). Note that this account does not rule out the possibility that endogenous cueing can be a result of strategic attentional control, but emphasizes that this is not necessarily the case:

"automatic" processes can contribute to observed performance facilitation at least at short SOAs (Risko & Stolz, 2010). In sum, it might be easier to accommodate the present pattern of results in this more recent alternative framework than in the traditional view, which interprets endogenous cueing effects as a pure reflection of strategic attentional control. Thus, a tentative explanation could be that the emotional or social significance of the informative face cues facilitates implicit learning of the contingencies between cues and target locations in the present paradigm (see also Risko & Stolz, 2010). Such a mechanism would combine situational flexibility with remarkable efficiency in order to achieve optimal outcomes in diverse situations with high importance.

In this regard, the results for the masked conditions are of particular interest, as one can assume that the processing and utilization of masked information necessarily relies to a greater degree on automatic processes. Of course, we should refrain from stating that cues of which participants are not aware can guide attention: in Experiment 4 (i.e., cue differentiation by valence), direct cue recognition was at a level that could be called "marginally perceptible"—that is, average performance was clearly above random guessing, even though far from perfect recognition. In Experiment 5, although average direct cue recognition was almost at chance level, there was still a small cueing effect. Thus, participants seem to have acquired an automatism in guiding attention during practice and unmasked trials, which was then transferred to the utilization of masked cues. Note that this automatism cannot be based on specific stimulus-response bindings acquired during unmasked trials because the stimulus lists used in unmasked and masked trials were distinct. This interpretation is also in line with recent evidence suggesting that the endogenous cueing of non-emotional, simple cues can be based on implicit cue usage (e.g., Bonato et al., 2016; Peterson & Gibson, 2011; Risko & Stolz, 2010; see also Bartolomeo et al., 2007).

Limitations and future directions

As we see our study as a starting point for further research in this area, it leaves open several questions for future research. For sure, the exact characteristics of endogenous attention and emotion interactions cannot be settled with the present study. Of note, we do not claim that there might not be other broad categories of complex social stimuli (e.g., gender, age) that can be utilized in a comparable manner to emotional expressions. However, beyond the utilization of perceptual and semantic information, it remains an asset to clarify how effectively (e.g., in terms of speed and awareness) and at what level of emotional specificity emotional information can be utilized to guide our attention in accordance with current task goals.

Although the present study yielded a consistent pattern of results, there are several potential limitations that should be noted. First, as we focused on the theoretically most important cueing effect (i.e., invalid-minus-valid difference on RTs) when determining our sample sizes, we must acknowledge that the sample sizes for some of our experiments (Experiment 1, Experiment 2a) were modest. Hence, limited power might have limited some of the statistical analyses. Second, we do not know yet whether and how our results generalize to samples with different characteristics (e.g., non-students, elderly people). In line with Simons and colleagues' (2017) guidelines, we expect the observed results to at least generalize to similar subject pools (i.e., students, facial expressions from databases made for scientific purposes) and central cues. Further boundary conditions regarding cue-target SOA, cue predictivity (i.e., whether cues are actually informative for the target location), instructions to utilize the cues, and explicit knowledge about the cue-target location contingency constitute important further empirical questions. Addressing these questions could further our understanding of the proposed mechanisms behind the remarkably effective endogenous cueing with emotional faces. We have no reason to believe that the reported results depend on other characteristics of the participants, materials, or context.

Conclusion

Our research provided consistent evidence that emotional facial expressions can be utilized efficiently to anticipate relevant events in line with context-specific goals. This held true even when specific valence-identical emotional expressions–as opposed to expressions with contrasting affective valence–were presented as cues, indicating that even emotion-specific information can be utilized efficiently. Furthermore, informative emotional expression cues facilitated target performance rapidly even under conditions of limited cue awareness. The high social and biological importance of emotional faces is likely to contribute to the remarkably efficient cueing by facial expressions. The exact processes underlying the efficient utilization of emotional faces for anticipatory attentional orienting remain a question for future research; however, we suggest that implicit goal-directed processes—as opposed to voluntary attentional control—can likely explain the observed effects at least to some extent.

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Figures

Figure 1. Illustration of a cueing trial in Experiments 1 and 2. In Experiment 1, joy and anger expressions served as attentional cues, while in the different versions of Experiment 2, negative emotional expressions (sadness and anger; fear and anger; fear and sadness) served as cues (the illustration features the picture AF01HAS form the KDEF database; Lundqvist et al., 1998).

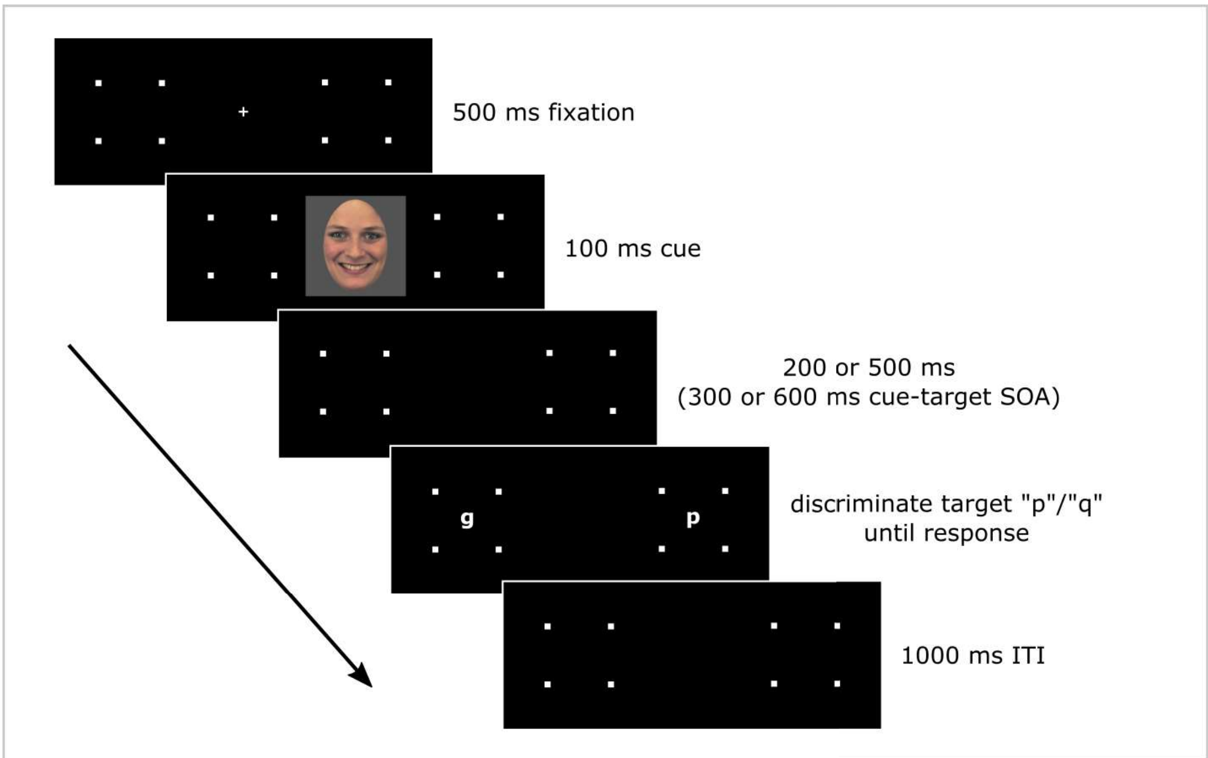


Figure 2. Mean RTs (in ms) as a function of cue validity and cue-target SOA in Experiment 1 (cue emotions: joy and anger). Error bars are 95% within-participants confidence intervals for the main effect of cue validity (Jarmasz & Hollands, 2009).

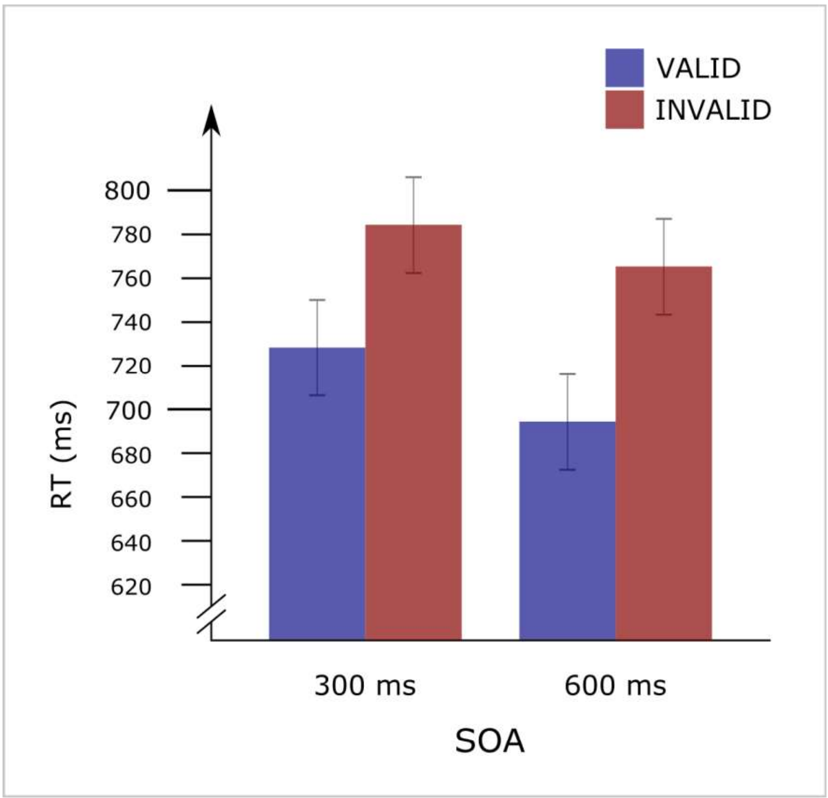
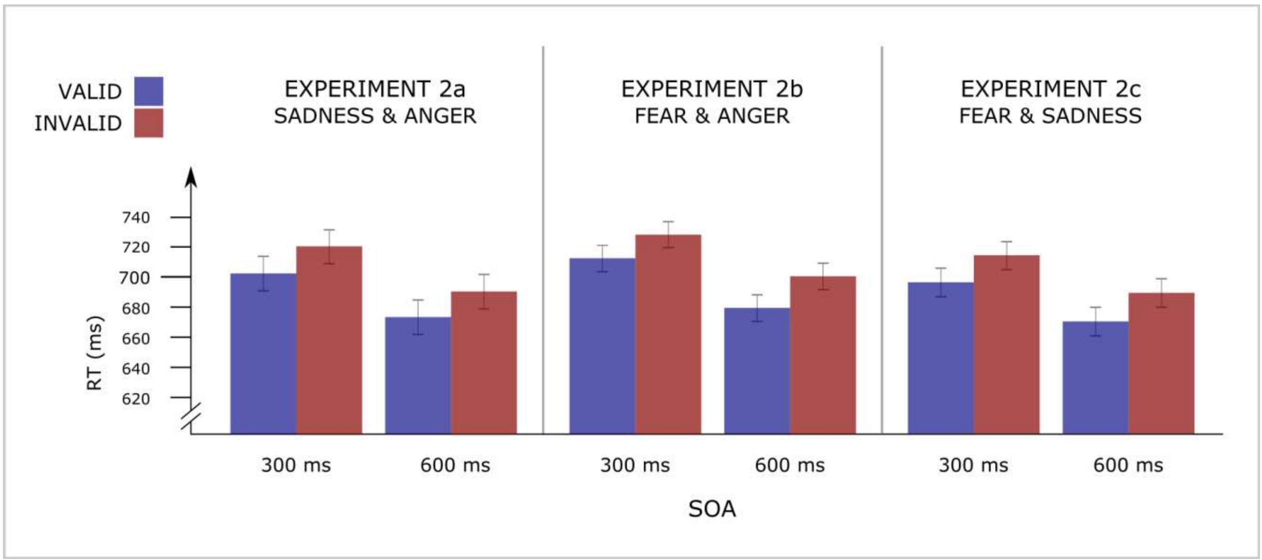


Figure 3. Mean RTs (in ms) as a function of cue validity and cue-target SOA in the three versions of Experiment 2. Error bars are 95% within-participants confidence intervals for the main effect of cue validity (Jarmasz & Hollands, 2009).[13]



[13] As visual data inspection suggests that outliers burden the distributions of cuing effects (i.e., RT-differences between valid and invalid conditions) in Experiment 2, we conducted Wilcoxon signed-rank tests for the main effect of cue validity in each version of Experiment 2. Corresponding to our main analysis, the non-parametric test also revealed significant cue validity effects; $z = -1.94$, $p = .026$ (one-tailed) in Experiment 2a; $z = -2.46$, $p = .007$ (one-tailed) in Experiment 2b; and $z = -2.53$, $p = .006$ (one-tailed) in Experiment 2c.

Figure 4. Mean RTs (in ms) as a function of cue validity and face orientation in Experiment 3 (cue emotions: sadness and anger). Error bars are 95% within-participants confidence intervals for the main effect of cue validity (Jarmasz & Hollands, 2009).

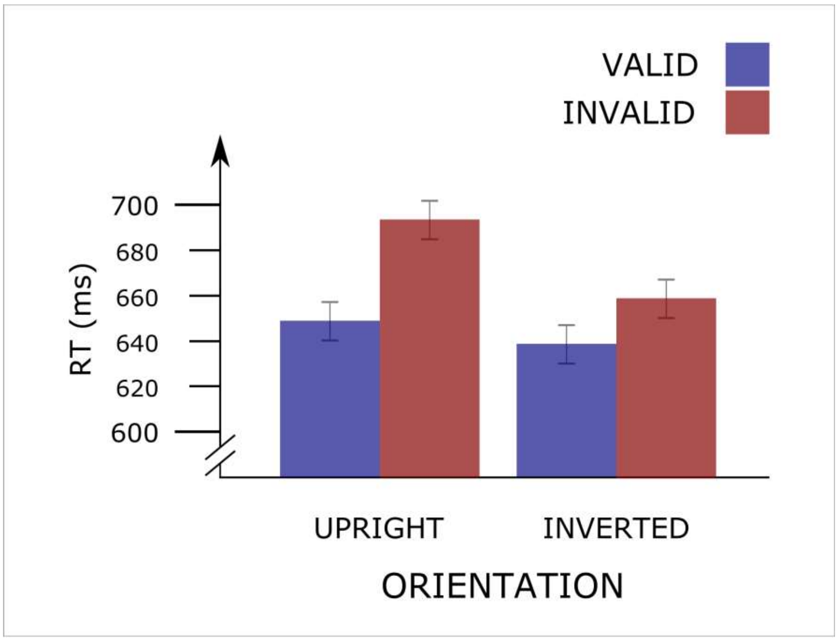


Figure 5. Illustration of a cueing trial in Experiments 4 and 5. In Experiment 4, joy and anger expressions served as attentional cues, while in Experiment 5, sadness and anger expressions served as cues (the illustration features the picture AF01HAS form the KDEF database; Lundqvist et al., 1998).

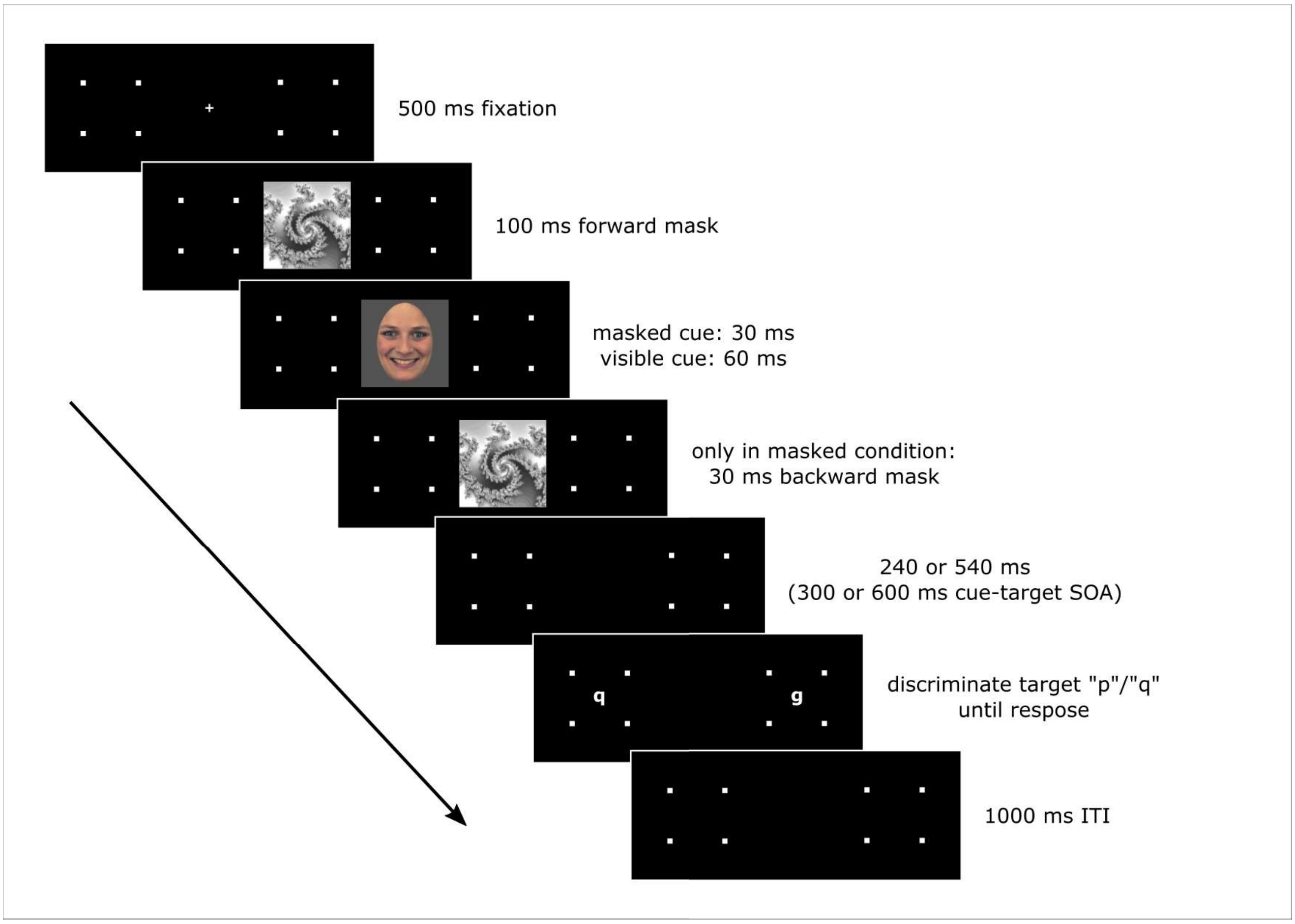


Figure 6. Mean RTs (in ms) as a function of cue validity, cue-target SOA, and cue visibility in Experiment 4 (cue emotions: joy and anger). Error bars are 95% within-participants confidence intervals for the main effect of cue validity (Jarmasz & Hollands, 2009).

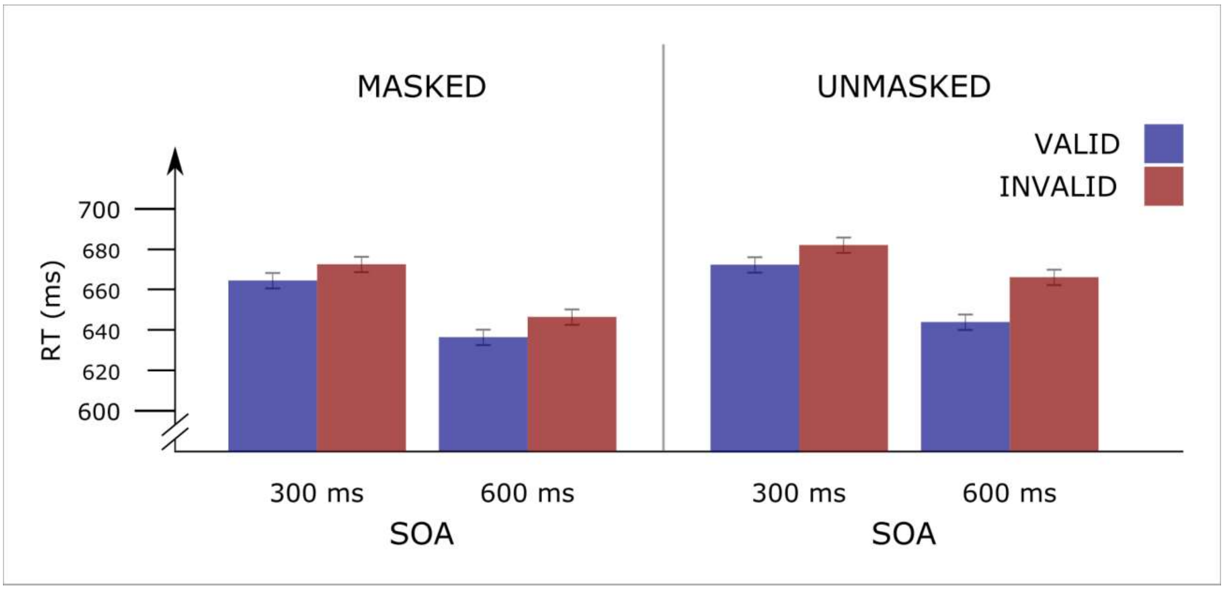
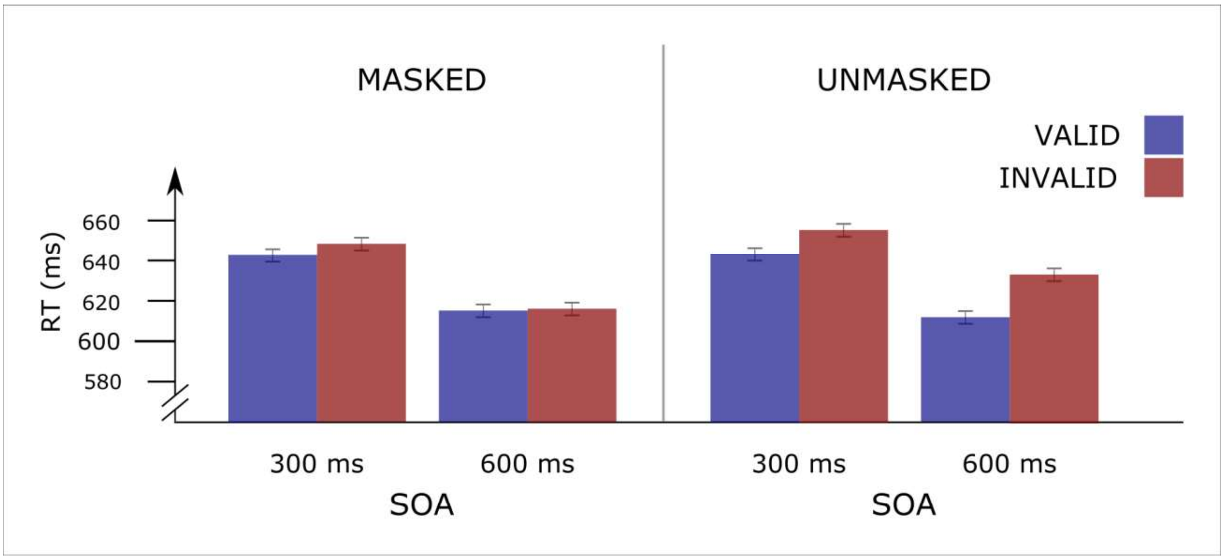


Figure 7. Mean RTs (in ms) as a function of cue validity, cue-target SOA, and cue visibility in Experiment 5 (cue emotions: sadness and anger). Error bars are 95% within-participants confidence intervals for the main effect of cue validity (Jarmasz & Hollands, 2009).



Tables

Table 1. Mean ERs (%) as a function of cue validity and cue-target SOA in Experiment 1 and Experiment 2; *SD* in parentheses.

	300 ms SOA		**600 ms SOA**	
Experiment 1 (joy and anger)				
Valid	5.1	(3.5)	4.5	(3.4)
Invalid	5.0	(5.0)	4.7	(4.6)
Cueing Effect[a]	-0.1	[0.9]	0.2	[0.8]
Experiment 2a (sadness and anger)				
Valid	5.3	(4.5)	4.6	(3.8)
Invalid	4.8	(6.0)	5.3	(4.8)
Cueing Effect[a]	-0.5	[0.9]	0.7	[0.7]
Experiment 2b (fear and anger)				
Valid	6.1	(5.0)	5.6	(4.7)
Invalid	6.7	(5.9)	6.1	(5.3)
Cueing Effect[a]	0.6	[0.6]	0.5	[0.5]
Experiment 2c (fear and sadness)				
Valid	5.6	(4.1)	5.7	(3.7)
Invalid	6.2	(5.3)	5.4	(5.6)
Cueing Effect[a]	0.6	[0.5]	-0.3	[0.5]

[a] Invalid-minus-valid difference; standard errors in brackets.

Table 2. Mean ERs (%) as a function of cue orientation and cue validity in Experiment 3 (cue emotions: sadness and anger); *SD* in parentheses.

	Upright		**Inverted**	
Valid	5.8	(5.2)	5.6	(5.0)
Invalid	6.2	(6.7)	5.3	(5.6)
Cueing Effect[a]	0.4	[0.5]	-0.3	[0.4]

[a] Invalid-minus-valid difference; standard errors in brackets.

Table 3. Mean ERs (%) as a function of cue visibility, cue validity, and cue-target SOA in Experiment 4 (cue emotions: joy and anger); *SD* in parentheses.

		300 ms SOA		**600 ms SOA**	
Masked					
	Valid	4.1	(3.4)	4.3	(3.8)
	Invalid	4.4	(4.3)	3.8	(4.1)
	Cueing Effect[a]	0.3	[0.4]	-0.5	[0.4]
Unmasked					
	Valid	4.5	(3.4)	4.1	(3.6)
	Invalid	4.7	(4.9)	4.8	(5.1)
	Cueing Effect[a]	0.2	[0.4]	0.7	[0.5]

[a] Invalid-minus-valid difference; standard errors in brackets.

Table 4. Mean ERs (%) as a function of cue visibility, cue validity, and cue-target SOA in Experiment 5 (cue emotions: sadness and anger); *SD* in parentheses.

		300 ms SOA		**600 ms SOA**	
Masked					
	Valid	4.7	(3.1)	4.7	(3.5)
	Invalid	4.9	(4.3)	4.6	(4.2)
	Cueing Effect[a]	0.2	[0.4]	-0.1	[0.3]
Unmasked					
	Valid	5.0	(3.5)	4.8	(3.5)
	Invalid	5.8	(5.3)	5.5	(5.2)
	Cueing Effect[a]	0.8	[0.5]	0.7	[0.4]

[a] Invalid-minus-valid difference; standard errors in brackets.