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Participant Mood Modulates Attention and Eye Movements in Visual Search for Emotional Faces

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Research on visual search for emotional faces has yielded discrepant results, with some studies reporting advantages for angry faces (anger superiority effect) and others reporting a happy face advantage (happiness superiority effect). Researchers have sought to explain these phenomena through an *emotional factors account*: attributing the anger superiority effect to an innate threat detector, and the happiness superiority effect to a positivity bias that gives preference to positive stimuli. The alternative *perceptual factors account* proposes that salient perceptual features inherent to angry and happy faces drive these search asymmetries. As emotional and perceptual factors are intrinsically confounded in emotional faces, it has proven difficult to distinguish between the two accounts. In the present experiments, we distinguished between the two accounts by manipulating participant mood across three different conditions (neutral, angry, and happy), and asked participants to locate a variable emotional (angry or happy) target face. Eye-tracking measures revealed a significant *mood-congruency effect* for search efficiency, where fewer fixations were required to locate a mood-congruent target than a mood-incongruent target. These findings were obtained across two experiments using different face stimuli (dynamic vs. static faces), emotional and neutral nontargets, and different search requirements, indicating that participant mood can influence attention across a wide range of conditions.

Keywords: visual search, attention, eye movements, mood, facial expressions

Emotional expressions play an integral role in effective communication by providing an avenue for onlookers to infer and react to the emotions and intentions of others (Darwin, 1872). The ability to quickly identify, interpret, and respond to the expressions of others could be evolutionarily adaptive and essential to survival in some situations. For instance, angry emotional expressions can signal potential sources of threat, providing individuals with the opportunity to protect themselves or escape the situation. Hence, it has been proposed that humans can detect angry faces fast and automatically, much faster than other nonthreatening stimuli (Öhman & Mineka, 2001). According to the *threat capture hypothesis*, humans possess an innate threat detector in the amygdala, which evolved to direct attention toward threatening stimuli (e.g., angry faces) and facilitate responding (fight or flight). The threat detector was originally proposed to operate automatically and independently of cognitive processes (Öhman et al., 2001; Öhman & Mineka, 2001) and respond to a variety of threatening stimuli with different perceptual characteristics (e.g., snakes and angry faces). Thus, according to the threat capture hypothesis, the emotional valence of the threat itself, not the perceptual characteristics of the object, attract attention.

In line with this hypothesis, several studies found that angry faces can be detected faster within a crowd of friendly faces than vice versa: a friendly face among angry faces (for a review, see Frischen et al., 2008). This effect, known as an anger superiority effect (ASE; Hansen & Hansen, 1988; Öhman et al., 2001), was initially interpreted as evidence for the threat capture hypothesis.

However, a later study (Purcell et al., 1996) showed that the ASE in Hansen and Hansen's (1988) study was caused by a confound (i.e., a dark patch in the angry face) and could not be replicated when the faces were rendered differently (such as to remove the dark patch). Moreover, studies using different variants of happy and angry faces found the opposite effect to an ASE, reporting a happiness superiority effect (HSE), whereby happy faces were found faster than angry faces (D. V. Becker, Anderson, et al., 2011; Calvo et al., 2008; Craig et al., 2014; Juth et al., 2005; Kirita & Endo, 1995). D. V. Becker, Anderson, et al. (2011) proposed that the HSE may be due to

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a *positivity bias*, which drives attention to positive emotional contents such as happy faces, which evolved to promote beneficial social connections and access to essential resources, like food and shelter.

Later studies used updated and improved methodologies to determine whether visual search for emotional faces was driven by an ASE or HSE, but ultimately failed to identify a clear results pattern of exclusively HSE or ASE (e.g., Savage et al., 2013). Rather, as further discussed below, it seems that the finding of an ASE or HSE may be primarily due to perceptual features of the expressions, not their emotional valence (e.g., Savage et al., 2016; for a review see Frischen et al., 2008).

Perceptual Factors

It is well-known that the perceptual features of stimuli, such as their colors, brightness, border orientations, line junctions, and edges, can guide visual attention and produce perceptual search asymmetries, similar to the ASE and HSE observed with emotional faces (e.g., Bundesen, 1990; Treisman & Gelade, 1980; Wolfe, 1994, 1998). For instance, a lollipop stimulus can be detected faster among circles than vice versa, a circle among lollipops (e.g., Treisman & Gelade, 1980); a pink color patch can be found faster among red patches than a red patch among pink patches, and a tilted line is found faster among vertical lines than a vertical line among tilted lines (e.g., Wolfe, 2001). Search asymmetries are in fact so ubiquitous that every combination of stimuli is equally likely to show symmetric or asymmetric search, and this seems to be true for simple stimuli such as oriented lines and color patches, as well as more complex stimuli such as faces and shapes (Wolfe, 2001).

Several different explanations have been proposed to account for these perceptual search asymmetries (e.g., Rauschenberger & Yantis, 2006; Rosenholtz, 2001; Rosenholtz et al., 2004; Treisman & Gelade, 1980; Wolfe, 2001). However, there is wide agreement that search efficiency, and thus the potential for search asymmetries, is driven by perceptual factors. Some stimulus features may facilitate biasing attention in a top–down manner to task-relevant features (e.g., Wolfe, 1994) or allow more efficient filtering of task-irrelevant features (e.g., S. I. Becker, 2007; see also Folk & Remington, 1998). In addition, perceptually unique regions may be perceptually salient and automatically elicit an orienting response and draw attention in a bottom–up, stimulus-driven fashion, independent of our top–down goals (e.g., Posner, 1980; Theeuwes, 1992). Perceptual features of the nontargets may also help or hamper grouping or other Gestalt processes, which are mostly automatic (e.g., S. I. Becker, Horstmann, & Remington, 2011), or act as bottom–up limitations that influence the ability to tune attention in a top–down controlled manner to the target (e.g., Duncan & Humphreys, 1989).

It has been proposed that these and similar perceptual features may be responsible for the discrepant findings of an ASE versus HSE in search for emotional faces. With respect to schematic emotional faces, there is abundant evidence that the search advantage for angry (or sad) faces is driven by perceptual factors. Angry/sad schematic faces are found faster than happy faces because in happy faces, the mouth line is very similar to the facial outline, which makes them easier to reject when they are the nontargets, but harder to find when they are targets and embedded among neutral or angry/sad faces, which results in an ASE for schematic faces (e.g., Horstmann et al., 2010; see also Coelho et al., 2010). Changing the facial outline so that it matches the mouth line of angry or sad faces (e.g., by "denting the chin") reverses this effect and leads to an HSE (S. I. Becker, Horstmann, & Remington, 2011; Horstmann et al., 2010). Given that altering the mouth outline did not change the reported affective valence of the faces, these results are only consistent with a perceptual account, not with an emotional account.

Studies using photographic emotional faces also provided evidence for perceptual factors driving the ASE/HSE. In line with the perceptual factors explanation, several studies found that photographic emotional faces from different databases can produce either an ASE or HSE (e.g., Savage et al., 2013, 2016). For instance, Savage et al. (2013) used photographic male faces from both the NimStim database and the Ekman and Friesen database (Ekman & Friesen, 1976). They identified a significant ASE when using the NimStim stimuli but observed a significant HSE with the equivalent expressions from the Ekman and Friesen database, despite using an identical search task and experimental design. This suggests that the perceptual differences between the stimuli from each set can drive search asymmetries (ASE; HSE), not the emotional category (see also S. I. Becker, Horstmann, & Remington, 2011).

Some studies assessed the effects of specific facial features in isolation, by presenting the features alone or manipulating them systematically in the faces (e.g., angry eyebrows and visible teeth). For instance, Horstmann et al. (2012) compared angry and happy faces with and without visible teeth and found that visible teeth determined the direction of the search asymmetry (with an ASE when the angry expression had visible teeth and an HSE when the happy expression had visible teeth; see also Calvo & Nummenmaa, 2008; Horstmann & Bauland, 2006; Lipp et al., 2009). The finding that faces with visible teeth were consistently detected faster, independent of their emotional expression, shows that perceptual factors can dominate over emotional factors and determine the direction of the search asymmetry (see Calvo & Nummenmaa, 2008; Coelho et al., 2010; Horstmann & Bauland, 2006; Horstmann et al., 2010, for similar findings).

Given that both an ASE and HSE have been observed in visual search among emotional faces, it is likely that these search asymmetries are driven by perceptual features rather than emotional factors. Still, the fact that the ASE and HSE reported in previous studies are probably predominately driven by perceptual factors does not imply that emotional factors are completely irrelevant or ineffective in guiding attention. Rather, as discussed below, there is some evidence that emotional factors can also guide attention, rendering it quite possible that emotional factors can modulate a preexisting perceptual search asymmetry.

Evidence for Emotional Factors Guiding Attention

Several studies found that different clinical populations (e.g., anxious, depressed) respond differently to emotional targets in visual search than control individuals (e.g., Ashwin et al., 2012; Gilboa-Schechtman et al., 1999; Juth et al., 2005; Suslow et al., 2001) and interpreted these effects as evidence that emotional factors and/or mood can influence attention.

In studies with anxious populations, an *anxiety bias* has been observed, where participants with greater anxiety had a more pronounced detection advantage for threatening (angry) faces than their control counterparts (Ashwin et al., 2012; Gilboa-Schechtman et al., 1999; Hadwin et al., 2003). That said—in the literature, anxiety has not been shown to consistently lead to a bias for threatening facial stimuli. For instance, Wieser et al. (2018) observed that high social anxiety populations exhibited stronger attentional engagement (as reflected in larger N2pc amplitudes) for both happy and angry targets, without showing faster or more efficient detection of angry expressions. Other studies found that trait anxiety may only strengthen an ASE when the target's emotion is task-irrelevant (Dodd et al., 2017).

However, a weakness of many studies is that they only assessed the mean response times (RTs) and accuracy. Low RTs or few errors for threat stimuli in high-anxiety populations, however, could be due to quite a number of factors other than facilitated detection and faster fixation on threatening stimuli, such as increased decision time after target fixation (Derakshan & Koster, 2010), or longer dwelling on happy face distractors (Horstmann & Becker, 2020; Horstmann et al., 2006). Still, the results currently do suggest that trait anxiety may alter some of the processes involved in visual search, indicating that emotional factors can indeed affect visual search for emotional faces.

Similar studies have been conducted with clinically depressed populations, though with even less conclusive results (e.g., Bodenschatz et al., 2021; Karparova et al., 2005; Suslow et al., 2001, 2004; Wisco et al., 2012). Bodenschatz et al. (2021) investigated the effects of depression using photographic facial stimuli but found that depression had no significant effect on RTs or attentional guidance toward either angry or happy target expressions. Other studies utilizing schematic facial expressions found discrepant results. For instance, Suslow et al. (2001) found that, despite not showing a facilitated search for schematic sad target expressions, patients with major depressive disorder displayed significantly slower responses to schematic happy faces than their control counterparts. This effect was replicated by Suslow et al. (2004), albeit only for depressed participants with comorbid anxiety diagnoses. Together, these studies suggest that depressive mood states may be able to influence attentional guidance for emotional faces, though the effects may be rather weak.

A seemingly unavoidable problem of clinical studies is that they always (necessarily) employ a between-subjects design. With this, it is unclear whether the observed differences are attributable to differences between the mood states of the two groups, or to other unmonitored characteristics of the clinical groups (e.g., reduced processing speed in depression).

The Present Study

The aim of the present study was to investigate whether participant mood can affect attention in visual search for emotional faces when using more ecologically valid, photographic faces. In advance to previous studies, we manipulated participant mood in a within-subjects design, which ensures that differences between the mood conditions can be attributed to the mood, not differences between the participants. Moreover, to allow determining whether differences in mood affected search at an early, preattentive stage or a later, perceptual or decisional stage, we monitored the participants' eye movements during search.

Experiment 1: Dynamic Faces

Experiment 1 tested whether, through inducing particular mood states (angry and happy), we could influence attention and visual search performance for dynamic emotional faces, as measured through RTs and eye-movement measures. The visual search displays contained four neutral photographic faces that changed into either an angry and three happy faces, or vice versa, a happy face and three angry faces (e.g., Horstmann & Ansorge, 2009). Participants were instructed to look for the deviant expression and to report the expression of the target (angry vs. happy) by pressing one of two mouse buttons.

The first search block always served as a baseline neutral mood condition. Prior to the second and third blocks, participants underwent a mood induction procedure (counterbalanced happy or angry) that was a modified version of Velten's (1967) procedure. In the mood induction, participants were asked to read a series of 45 self-referential statements that went from neutral to progressively more happy or angry (e.g., "Today is a great day."; Velten, 1967; see Appendix A for a complete list of statements). Participants had to first read the statements silently to themselves and then to the experimenter, enacting the feelings expressed in the statements to evoke the corresponding mood. Statements were initially neutral and then increased in intensity to ease participants into the desired mood state (Velten, 1967). To assess whether the manipulation was successful, participants completed the Positive and Negative Affect Schedule (PANAS) and a short mood questionnaire prior to the search task as a manipulation check.

We anticipated a mood-congruency effect in the visual search data that would modulate the preexisting search asymmetry (i.e., ASE), such that a perceptual ASE at baseline would be stronger after the angry mood induction and reduced after the happy mood induction. Conversely, in the event of a perceptual HSE, the HSE should be stronger after the happy mood induction and attenuated after the angry mood induction. We expected this effect to result in a significant interaction between mood condition (angry and happy) and target emotion (angry and happy). A corresponding results pattern would show that participant mood can interact with the emotional valence of the target expression itself, suggesting that the emotional content of facial expression can influence search performance over and above any perceptual-based search asymmetries.

To assess whether mood affects visual search at an early stage of guiding attention or only at later stages (e.g., decision making, response selection), we tracked the observers' eye movements during the search. As in previous studies (e.g., S. I. Becker, 2010; S. I. Becker, Horstmann, & Remington, 2011; Hamblin-Frohman & Becker, 2021), we used the proportion of first eye movements to the target to index early, attention-guiding processes. Second, we measured the number of fixations until the target was found as an intermediate measure of search efficiency that includes both early, attention-guiding processes as well as later processes of nontarget identification and rejection (including grouping; S. I. Becker, Grubert, et al., 2023; S. I. Becker, Horstmann, & Remington, 2011; Horstmann & Becker, 2020; Horstmann et al., 2017). Finally, we used the mean dwell times on the target to examine the contributions of late processes that commence after the selection of the target (including target identification, decision making, and response selection; e.g., S. I. Becker, Retell, et al., 2023).

If mood affects early, attention-guiding processes, we would expect a higher proportion of first fixations on mood-congruent targets than mood-incongruent targets. If mood affects search only at a later, attentive stage, we would expect no effect in the early measures but mood-congruency effects on search efficiency, with fewer fixations on the nontargets prior to selecting mood-congruent targets. Finally, if mood only influences search at a very late, postselection stage, we would expect mood-congruency effects only after the target has been selected, that is, on target dwell times and RTs (or accuracy). Across all experiments and measures, we evaluated possible mood-congruency effects by computing the difference values between angry and happy target conditions and comparing the difference values after the happy versus angry mood induction.

Method

Participants

To compute the required sample size for the study, we used the smallest effect reflecting a search asymmetry in one of the eye-movement parameters in the study of S. I. Becker, Horstmann, and Remington (2011; $\eta_p^2 = .32$ in the mean dwell times; S. I. Becker, Horstmann, & Remington, 2011, Experiment 1). According to G*Power, to detect this effect in the present experiment with a power of .95 at an α level of .05 would require 36 participants.

To account for possible exclusion of participants, we collected data from 42 individuals (12 male, 30 female; $M = 25.4$ years, $SD = 9.0$ years).[1] All participants reported normal or corrected-to-normal vision and participated in this experiment in exchange for course credit or monetary compensation. One participant was excluded from all analyses because of high error scores (75% in one of the conditions) and a failure to fixate on the target on more than 40% of trials. The materials and procedures of the study were approved by The University of Queensland's ethics committee and were in accord with the Declaration of Helsinki.

Apparatus

The initial experimental period was conducted with an Intel Duo 2 CPU 2.4 GHz computer. Participants viewed the stimuli from a distance of 60 cm on a 17" CRT monitor with a resolution of 1,280 × 768 pixels and a refresh rate of 60 Hz. The second experimental period was conducted using a 17" LCD monitor with the same resolution and refresh rate. The participant's gaze was tracked using a video-based, infrared eye tracker (Eyelink 1000, SR Research, Ontario, Canada), with a spatial resolution of 0.1° and a temporal resolution of 500 Hz. To ensure accurate tracking, the participants' chin and forehead were stabilized by a chin rest and forehead rest, respectively. Responses were made using the right and left buttons of a standard USB mouse. RTs and error data were collected using the Presentation Software (*Neurobehavioral Systems*).

Stimuli

The search stimuli consisted of four colored photographic faces cropped into a 5.2° × 3.8° oval to remove nonemotional facial features (e.g., hair), and presented against a white background 5.7° away from a black central fixation cross. The stimuli were the close-mouthed neutral, angry, and happy faces from eight male models (20, 22, 24, 25, 26, 30, 32, 34) from the NimStim database (Tottenham et al., 2009). To render the faces dynamic, the neutral and happy/angry face from the same model were morphed together using the FantaMorph software. On each trial, three faces morphed into one emotion (e.g., happy, distractors), while the other morphed into a different emotional expression (e.g., angry, target) over the course of 180 ms. The 100% emotional stimuli remained on the screen until a mouse response was made. The models were drawn randomly without replacement, so that each trial contained four faces from different models.

Mood Manipulation

Two mood states (angry and happy) were induced using an adapted version of the Velten method (Velten, 1967). Participants read a list of 45 happy or angry mood statements prior to the search task (e.g., "I feel fantastic!"; "Today is a bad day"; see Appendix A for statement list). The happy statements were identical to the original positive Velten's (1967) statements, but the angry mood statements were created anew (e.g., "Today is a bad day"; "People treat me unfairly"). Each statement card was printed in 12pt Times New Roman font and taped onto 12.5 × 7.5 cm lined index cards. The cards were ordered so that the statements gradually increased in intensity (e.g., Angry 2: "I feel okay today"; Angry 45: "I feel so angry I could smash something") and numbered to ensure correct order of presentation.

To assess participant mood, participants completed a brief paper questionnaire directly after each mood induction (prior to the search task). The questionnaire consisted of three Likert items on a 9-point scale, and the PANAS (Watson et al., 1988). The Likert scales ranged from happy/cheerful/positive to angry/sad/negative on a scale from 1 to 9 (see Appendix C). For the mood manipulation check, the Likert scales were averaged to produce a mood index, with a higher index (>5) indicating a more negative mood, while the PANAS scores were calculated separately for the negative and positive affect items (Watson et al., 1988).

Design

This experiment used a 3 (participant mood: baseline, angry, happy) × 2 (expression: angry, happy) design. Participant mood was manipulated within participants so that all participants underwent all three mood blocks. With the exception of baseline always being conducted first, the two mood conditions were counterbalanced across the participants.

In the visual search task, the emotional expression of the target varied randomly across trials. The first 24 participants completed three blocks of 17 angry target trials and 17 happy target trials (34 total trials) per block, for a total of 102 search trials. When we were then asked to increase the number of participants in the experiments, we decided to increase the number of trials for the remaining 18 participants, to 28 angry target trials and 28 happy target trials (56 trials) per block, resulting in a total of 168 trials. (Trial numbers were increased in the second experiment period to increase data quality when the data from the first period showed that

[1] The experiment was conducted over two distinct experimental periods, with the first 24 participants being tested by author MS, and the subsequent 18 participants being tested by author MH. To check if the two experimental periods had any differential effects, we first computed all relevant ANOVAs with the between-subjects variable "Experimental Session" included. Experimental session did not significantly interact with any mood effects in any of the dependent variables. Hence, for the main analyses, data were pooled across experimental sessions. The study was not pre-registered.

mood effects were longer lasting, i.e., did not show a decrease over the course of a block.)

Procedure

Prior to the experiment, participants were provided with a brief description of the tasks of the experiment (without informing them about the aims of the experiment or the mood induction). All participants first completed the mood questionnaire and PANAS, to assess their baseline mood, followed by the visual search task. Thereafter, participants completed two iterations of (a) mood induction (angry, happy), (b) mood test (questionnaire and PANAS), and (c) visual search task.

For the mood induction task, participants read the mood statements, one at a time, once silently and once aloud, followed by a 7-s silent period in which participants were asked to dwell on a relevant scenario that could be associated with the respective statements. After completing the mood questionnaire and PANAS, participants were presented with written instructions for the visual search task.

To ensure stable eye tracking during the visual search task, participants were calibrated with a 9-point calibration. Each search trial began with a fixation cross that was yoked to a fixation control: The search display was presented only when participants had continuously fixated (for 500 ms) within 1.2° of the center of the fixation cross (see Figure 1). If the eye tracker could not detect a continuous fixation within a 2,000 ms time window, participants were calibrated anew. Otherwise, the four neutral facial expressions were presented and, after the faces had morphed into angry and happy expressions, participants had to locate the discrepant emotional expression (e.g., angry target among three happy distractor faces). Participants had to press the left mouse button if the discrepant face was an angry face, and the right button if the discrepant face was a happy face (counterbalanced). Immediately after the button press response, the feedback display was presented, which consisted either of the word "Correct!" presented for 500 ms, or the word "Wrong" presented for 1,000 ms (to discourage trading speed for accuracy). Prior to the first mood induction, participants completed 24 practice trials which were not analyzed.

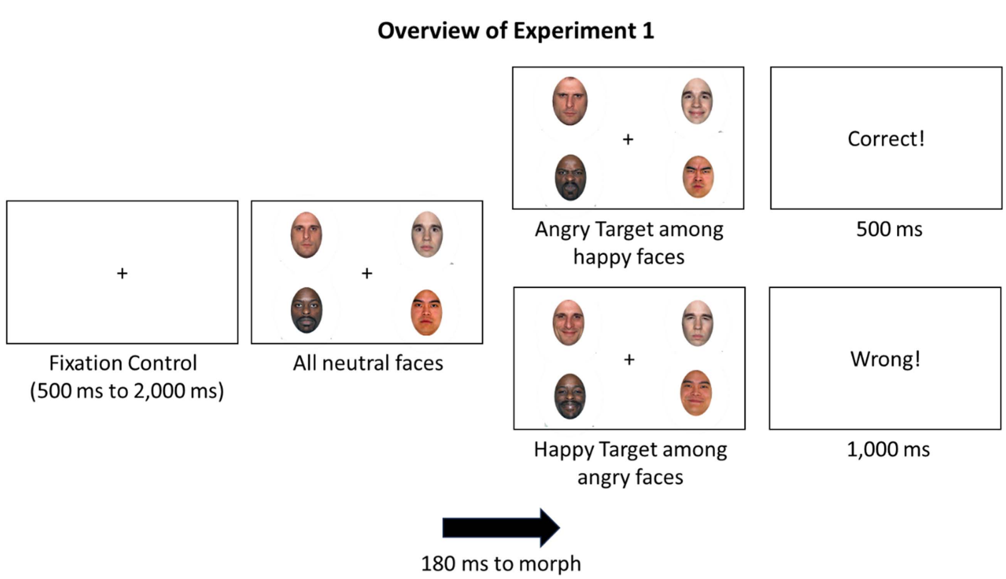
Results

Data

For both experiments, eye movements were separated into saccades and fixations using the standard parser of the Eyelink software, which classifies eye movements as saccades when they exceed a velocity of 30°/s or an acceleration of 8,000°/s. Fixations were assigned to different stimuli (target or nontarget) when the gaze was within 4.3° of the center of the face. Fixations that were made within the same stimulus region (i.e., without leaving the stimulus area) were counted as one continuous fixation, whereas fixations on different regions or outside the region of the last fixation were counted as multiple fixations.

Anticipatory responses (RTs $<$ 200 ms) and delayed responses (RTs $>$ 4,500 ms) were excluded from all analyses, which resulted in

Figure 1
Overview of Experiment 1



Note. The visual search task used in Experiment 1. After a brief fixation control, participants were first presented with four neutral faces that quickly morphed into an angry face among happy faces or vice versa, a happy face among angry faces, over the course of 180 ms. The task was to indicate whether the discrepant face was angry or happy, and was immediately followed by feedback. The faces used in the experiment were all Caucasian-looking faces and different from the depicted ones, but cannot be included in a publication due to restrictions of the NimStim database. Stimuli are not drawn to scale. Images used in Figure are from the NimStim set of Facial Expressions (Tottenham et al., 2009). See the online article for the color version of this figure.

a loss of 6.17% of data in Experiment 1. Trials where the participant failed to fixate on the target were similarly excluded, resulting in a further loss of 4.25% of data.

Data were analyzed with repeated-measures analyses of variance (ANOVA), and/or two-tailed *t*-tests. When Mauchley's test of Sphericity indicated a violation of the assumption of variance–covariance homogeneity, the Greenhouse–Geisser corrected *p* values were reported, together with the uncorrected degrees of freedom.

Mood Manipulation

To assess whether the mood induction was effective in influencing participant's mood states, we first conducted a one-way ANOVA with the variable mood (baseline, happy, angry) over the averaged mood scores for the three Likert scales. The results showed significant differences in self-reported mood, $F(2, 80) = 43.93, p < .001, \eta_p^2 = .52$ (see Figure 2).

Pairwise *t*-tests showed that participants were in a significantly more negative mood after the angry mood induction compared to the baseline mood condition, $t(40) = 6.28$, $p < .001$, and after the happy mood condition, $t(40) = 7.70$, $p < .001$. Similarly, the happy mood induction induced a significantly more positive mood when compared to the baseline mood condition, $t(40) = 3.72$, $p < .001$.

PANAS

The positive and negative scales of the PANAS were analyzed separately using the same one-way ANOVAs (baseline, happy, and angry). The positive scale of the PANAS showed significant differences in positive mood after the mood inductions, $F(2, 80) = 35.28$, $p < .001$, $\eta_p^2 = .47$. Pairwise, two-tailed *t*-tests showed that participants reported a significantly greater positive affect after the happy mood induction than at baseline, $t(42) = 4.31$, $p < .001$ and after the angry mood induction, $t(40) = 7.27$, $p < .001$. Additionally, participants reported significantly lower positive affect after the angry mood induction than at baseline, $t(40) = 4.91$, $p < .001$.

The negative affect scale of the PANAS also showed a significant effect of mood condition, $F(2, 80) = 15.44$, $p < .001$, $\eta_p^2 = .28$, with participants reporting a significantly more negative affective state after the angry mood induction, compared to their baseline scores, $t(40) = 3.41$, $p < .001$, and after the happy mood induction, $t(40) = 4.78$, $p < .001$. Moreover, participants also reported less negative affect after the happy mood induction than at baseline, $t(40) = 2.26$, $p = .029$.

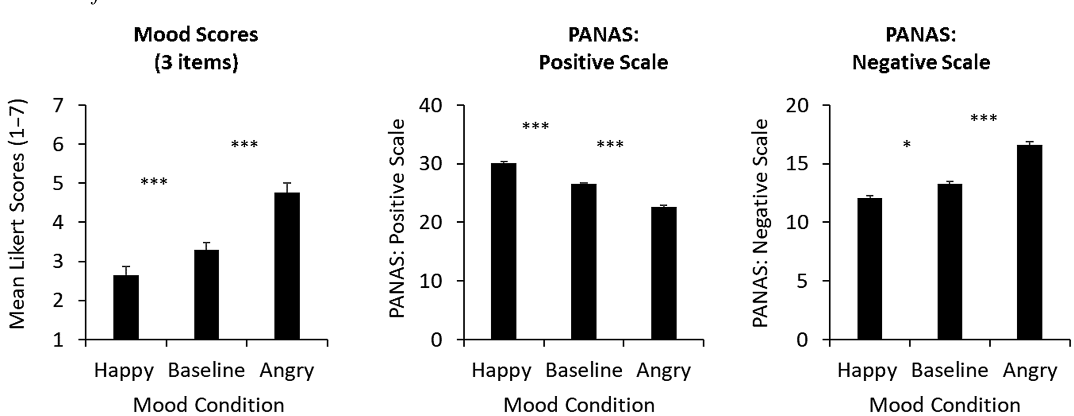
Collectively, these results indicate that the present method of manipulating participant's mood with self-referential statements was successful. Hence, it is possible to induce different participant moods in a within-subjects design. Moreover, the results show a large degree of correspondence between our mood questionnaire and the well-established PANAS, which indicates that our mood questionnaire can validly indicate participant mood.

Mean RT

To assess whether the mood manipulation also affected visual search performance, we first inspected the mean RTs. As shown in Figure 3, the mean RTs showed a trend for an ASE, which appears largest after the angry mood induction and smallest after the happy mood induction.

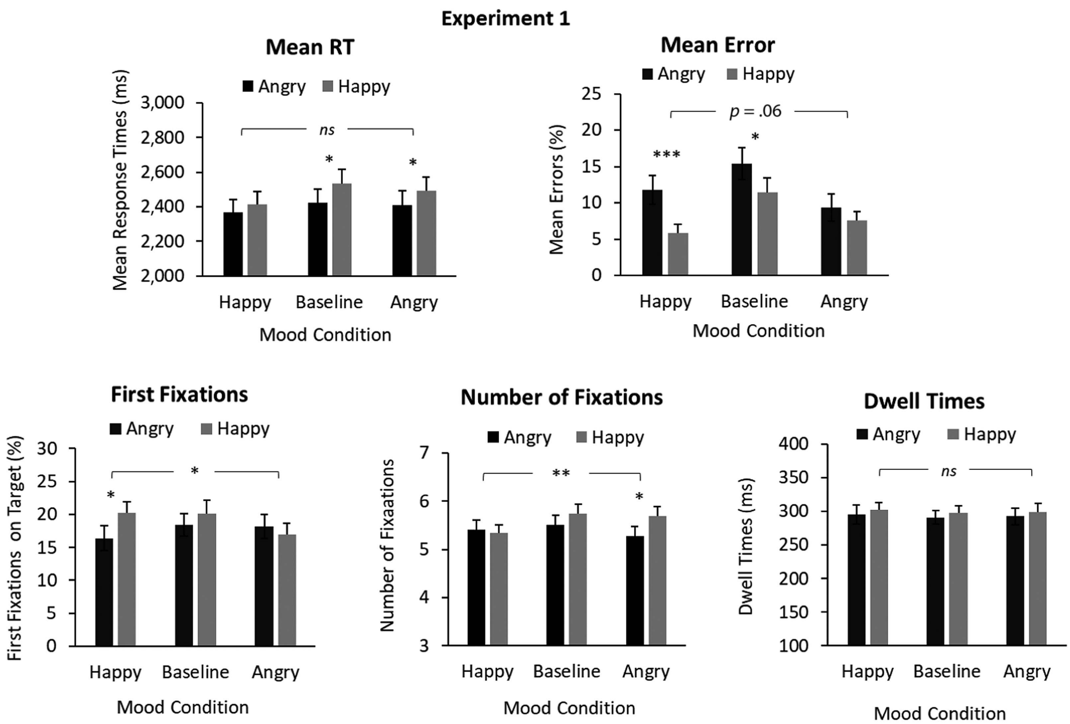
A 3 (mood) × 2 (expression) repeated-measures ANOVA conducted over the mean RTs showed only a significant main effect of target expression, with shorter RTs for angry targets than happy targets (i.e., an ASE), $F(1, 40) = 10.47$, $p = .002$, $\eta_p^2 = .21$ (all other *p*s > .26). Pairwise, two-tailed *t*-tests comparing the mean RT across the angry and happy target conditions showed that the ASE was significant after the angry mood induction, $t(40) = 2.15$, $p = .038$, and in the baseline condition, $t(40) = 2.15$, $p = .037$, but not after the

Figure 2
Results of the Mood Tests



Note. Left: self-reported mood on the three-item scale (averaged) after the mood inductions and at baseline in Experiment 1. The two right graphs show the average scores on the positive (middle) and negative (right) PANAS scales after mood inductions. All measures showed the predicted changes in self-reported mood after the angry and happy mood induction, compared to baseline, indicating that the mood manipulation was successful. Error bars depict +1 standard error of the mean (SEM). PANAS = Positive and Negative Affect Scale.
* $p < .05$. *** $p \leq .001$, as per two-tailed *t*-test.

Figure 3
Results of Experiment 1



Note. Top: Results of Experiment 1, depicted separately for each mood condition, and trials with an angry target (black histograms) and happy target (gray histograms). The mean RTs (top left) show an anger superiority effect (ASE), which was only significant after the angry mood induction and in the baseline mood condition, while the mean errors show a trend toward a happiness superiority effect (HSE), which was only significant after the happy mood induction and in the baseline mood condition. Bottom: The eye-movement results of Experiment 1 indicate that mood affected very early, preattentive processes and intermediate, attentional processes of visual search, as reflected in the significant HSE after the happy mood induction in the mean proportion of first fixations on the target (left), and the significant ASE after angry mood induction in the mean number of fixations (middle). By contrast, participant mood did not affect later processes of decision making, as reflected in the mean dwell times on the target (right). Error bars represent +1 standard error of the mean (SEM). RT = response time; ns = non-significant.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p \leq .001$.

happy mood induction, $t(40) = 1.2$, $p = .22$. These results would be expected if there is a mood-congruency effect on the data.

However, the critical comparison pairwise comparisons conducted over the difference scores (RT on angry target – happy target trials) showed no significant difference between the ASE across the mood conditions, all $ps > .31$. Thus, the mean RT shows a clear trend toward a mood-congruency effect but do not firmly establish that participant mood modulates visual search.

Mean Errors

The same 3 (mood) × 2 (expression) ANOVA computed over the mean error rates showed a main effect of participant mood, $F(2, 80) = 7.79$, $p = .003$, $\eta_p^2 = .16$, and of target expression, $F(1, 40) = 13.16$, $p < .001$, $\eta_p^2 = .25$, with more errors on angry target trials than happy target trials (i.e., an HSE, see Figure 3). However, the interaction between the two variables remained non-significant, $p = .14$. Pairwise comparisons between the angry and happy target trials showed fewer errors for happy targets than angry targets (i.e., an HSE) under the happy mood condition, $t(40) = 3.46$, $p < .001$, and under the baseline mood condition, $t(40) = 2.36$, $p = .023$, but not after the angry mood induction, $t(40) = 1.62$, $p = .21$.

The HSE difference scores (angry – happy target) after the happy versus angry mood induction approached significance, $t(40) = 1.9$, $p = .064$, but neither condition differed significantly from the baseline condition, both $ps > .30$.

Taken together, the mean RTs and errors show a pattern consistent with a speed–accuracy trade-off, as the data show an ASE in the mean RTs and an HSE in the mean error scores. However, the more important finding was that both mean RTs and errors showed the results consistent with a mood-congruency effect, with the mean RT showing an ASE after the angry mood induction but not after the happy mood induction, and the errors showing an HSE after the happy mood induction but no HSE after the (incongruent) angry mood induction. These results are in line with a mood-congruency effect and indicate that mood may have modulated visual search performance. However, the behavioral results did not provide decisive evidence for a mood-congruency effect, as the ASE and HSE in the mean RTs and errors did not differ significantly after happy versus angry mood induction.

Proportion of First Fixations

To assess whether participant mood can affect early, preattentive processes in visual search, we first inspected the proportion of first fixations on the target. As shown in Figure 3, there was an advantage for happy over angry targets (i.e., an HSE) after the happy mood induction, and a trend for an ASE after the angry mood induction (with higher selection rates for angry than happy targets).

To formally assess these differences, we conducted the same 3 (mood) × 2 (expression) ANOVA over the mean proportion of first fixations on the target. The results did not show any significant main effects or interactions, all Fs < 2.4, ps $> .13$. Pairwise comparisons between angry and happy target trials showed a significant HSE in the first fixations after the happy mood induction, $t(40) = 2.14$, $p = .039$, but no significant ASE for the angry mood condition or baseline condition, both ts < 1.1, ps $> .30$.

However, the difference scores (angry trials – happy target trials) showed that the HSE after the happy mood induction was significantly different from the nonsignificant ASE after the angry mood induction, $t(40) = 2.14$, $p = .031$, $\eta_p^2 = .11$. Neither of the conditions differed significantly from the baseline mood condition, both ps $> .28$. The differences between the angry and happy mood condition show that participant mood significantly modulated visual search already at a very early, preattentive stage, by facilitating eye movements to mood-congruent targets.

Number of Fixations

To assess possible effects of emotional factors on search efficiency, we next assessed the number of fixations until target selection for possible mood-congruency effects. The number of fixations comprised all fixations on nontarget items until a manual response was recorded. The 3 (mood) × 2 (expression) ANOVA showed a significant main effect of emotional expression, $F(1, 40) = 6.26$, $p = .017$, $\eta_p^2 = .14$, and a significant Mood × Expression interaction, $F(2, 80) = 3.31$, $p = .042$, $\eta_p^2 = .08$. Pairwise t-tests revealed a significant ASE after the angry mood induction, $t(40) = 3.45$, $p = .001$, but not in the baseline condition, $t(40) = 1.25$, $p = .19$. The results of the happy mood condition showed a trend for an HSE, which, however, failed to be significant, $t < 1$.

Comparing the difference scores (number of fixations in search for an angry target–happy target) across the different mood conditions showed that the ASE after the angry mood induction was significantly larger than the nonsignificant HSE after the happy mood induction, $t(40) = 3.10$, $p = .004$, $\eta_p^2 = .19$, whereas neither condition differed significantly from the baseline, both ps $> .12$. The significantly larger ASE after the angry mood induction than the happy mood induction is consistent with a mood-congruency effect and indicates that emotional factors such as the participants' mood can facilitate localization of mood-congruent targets by guiding attention to the respective target.

Dwell Times

To examine whether later, decision-related processes also show a mood-congruency effect, we next inspected the target dwell times—that is, the duration that participants maintained fixation on the target at the end of the trial (i.e., of the last target fixation before the response). As shown in Figure 3, the data showed trends for a slight ASE, with shorter dwell times on angry targets than happy targets. However, the results of a 3 (mood) × 2 (expression) ANOVA yielded no significant effects or an interaction, all ps $> .31$.

In addition, pairwise comparisons confirmed that there were no significant differences between the dwell times on angry versus happy targets in the baseline mood, angry mood, or happy mood condition, all ts < 1, ps $> .49$.

Discussion

Experiment 1 showed several interesting results. First, the Velten method was effective in inducing a succession of different mood states, as shown by significant changes in the mood scores on our three-item Likert scale and the PANAS after the different mood inductions. These results show that it is possible to effectively induce different mood states in a within-subjects design.

More importantly, Experiment 1 provided evidence for a mood-congruency effect that modulated a preexisting perceptual search asymmetry and facilitated search for mood-congruent targets. The proportions of first fixations already showed a significant mood-congruency effect that facilitated selection of mood-congruent targets at the earliest possible time in visual search, indicating that emotions can affect attentional processes at an early, preattentive stage of visual search. The same results were also obtained in our analysis of search efficiency, which showed significant differences in the number of nontarget fixations prior to target selection, as a function of a match or mismatch between the participants' own mood and the facial expression of the target.

These results show that emotions influence search-related processes at an early and intermediate stage of visual search. The analysis of dwell time data revealed no mood-congruency effects on late-stage decision-making/response selection processes. However, the mean errors showed an enhanced HSE after the happy mood induction, which disappeared after the angry mood induction.

Taken together, the results of the present study show that experimentally manipulated mood can potentially affect visual search performance at all stages, from the earliest, preattentive stage to the latest, response execution stage.

One notable aspect of the data was that they did not show a consistent HSE or ASE across all dependent measures. For example, while the mean RT and number of fixations showed an overarching ASE, the mean errors showed a trend for an HSE. This indicates that our dynamic faces did not show a strong underlying perceptual asymmetry, perhaps because the faces morphed into the respective emotional expressions, and because we used closed-mouth faces rather than open-mouthed faces (e.g., Horstmann et al., 2012). The HSE in the mean error scores could also be because happy faces are more reliably recognized and categorized than angry faces (e.g., Svärd et al., 2012; see also Calvo & Nummenmaa, 2008; Juth et al., 2005), which may have facilitated responding accurately to happy face targets.

While this possibility warrants further investigation, the results showed consistent mood-congruency effects in the primary eye-movement measures. Moreover, this mood-congruency effect was obtained in a within-participants design and with the same stimuli across all three mood conditions. Hence, the results cannot be attributed to any extraneous factors (e.g., perceptual differences or differences between different participant populations), but can be safely attributed to emotional factors—namely, the interaction between the participant's own emotional states and the emotional content of the facial expressions. Our findings thus provide clear evidence for the notion that emotional factors can guide visual attention and influence attention in search for emotional faces.

Of note, these results were obtained with photorealistic faces that adopted the corresponding emotion by morphing from neutral expression to an angry or happy facial expressions. As this manipulation resulted in a more compelling, natural-looking emotional expression, the results indicate that emotional factors may also guide attention in more complex, naturalistic environments.

At the same time, our use of dynamic stimuli and other aspects of the design may also be criticized because they deviate from previous studies, which may limit the comparability of our results. In particular, Experiment 1 deviated from previous studies in the use of dynamic photorealistic faces rather than static schematic or static photorealistic faces. Moreover, in previous studies, the target was often presented among neutral distractor faces (e.g., Lipp et al., 2009; see also D. V. Becker, Anderson, et al., 2011), rather than faces showing the opposite emotion. In the present study, the use of the neutral faces that morphed into the respective emotional expressions made it impractical to use neutral faces as distractors, and/or use different features as the reported feature. Still, it is unknown if the current results generalize to the more commonly used conditions.

Other factors worth considering are that the emotional expression was task-relevant and defined the correct response. As the target was always present, participants could theoretically complete the task without looking at the target, by identifying two nontarget faces showing the same emotion. The results showed only very few trials without a target fixation (4.25%; see excluded trials mentioned previously), indicating that participants did not make use of this strategy. Still, it is a possible limitation of Experiment 1 that it did not directly enforce localization of the search target.

Another potential limitation of the current experiment is the use of the baseline condition. Although always conducting the baseline condition first ensured that the results were not contaminated by the previous mood manipulations, participants always completed this condition first and as such may not have always been sufficiently practiced in the baseline condition, which may be responsible for the high error rates in the baseline condition. Furthermore, a baseline condition was used as opposed to a true neutral mood induction, which does not control for any inconsistencies in the mood that different participants brought into the experiment situation and may have produced more noise in this condition. The aim of Experiment 2 was to remedy all these potential limitations of Experiment 1.

Experiment 2: Static Photographic Faces

The aim of Experiment 2 was to assess if we could obtain the same mood-congruency effects with the more frequently used static facial expressions with a variable emotional target expression and neutral distractors, and with a mood induction protocol to induce neutral, happy, and angry moods (in a counterbalanced manner).

To these aims, we used the static close-mouthed emotional faces from the NimStim database as search stimuli in Experiment 2 and embedded them in a crowd of neutral expressions. Unlike Experiment 1, where participants had to locate the discrepant emotional expression, participants were instructed to identify the sole emotional target, which was equally likely to be an angry or happy expression, within the display of neutral distractors. The faces were all tilted slightly to the right or left, and participants were asked to respond to the direction the target face was tilted. With this, the manual response was defined independently of the emotional content of the facial expressions.

Another notable change introduced in Experiment 2 was that we substituted the baseline condition with a neutral mood induction condition, in which participants read out statements designed to induce a neutral mood (e.g., "Today is an average day"; see Appendix B). This allowed us to fully counterbalance all mood conditions across participants, which should eliminate all practice effects and other order effects, and provide a more reliable control condition than the baseline condition used in Experiment 1.

Method

Participants

Forty-two new individuals (15 men, 27 women, $M_{age} = 22.1$ years, $SD = 2.6$ years) with normal or corrected-to-normal vision participated in Experiment 2. Thirty-seven participants were compensated with \$10–\$20 per hour, while five were undergraduate students who were awarded partial course credit. Two participants were excluded due to a recurring failure to fixate on the target (on more than 15% of search trials).

Apparatus

The apparatus and materials used in Experiment 2 were identical to those used in Experiment 1, except that the stimuli were presented on a 17″ LCD monitor with a resolution of 1,280 × 1,024 pixels, and that the monitor was viewed from a distance of 63 cm (rather than the original 60 cm).

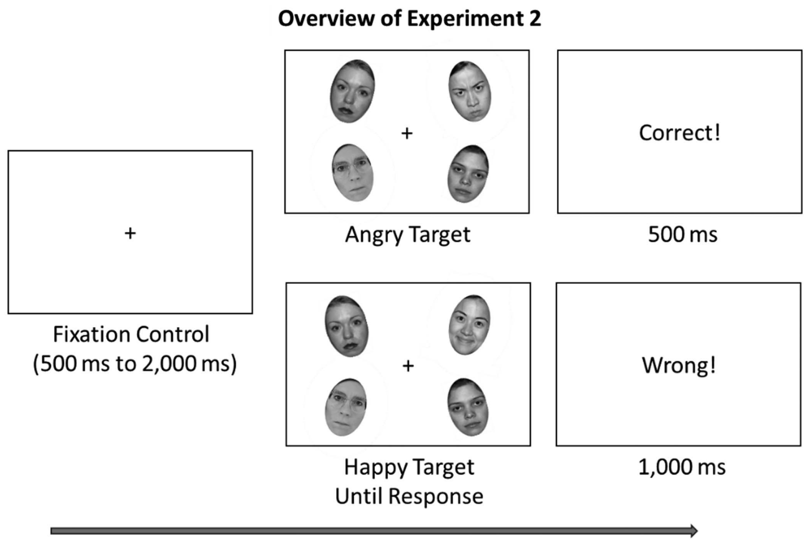
Stimuli

As in Experiment 1, stimuli were cropped to ovals (length: 5.4°, width: 3.8°) to remove nonfacial features, and were presented on a white background. Deviating from Experiment 1, the search displays always contained four female static greyscale faces that were each tilted 15° to the right or left. The four faces were presented in a square formation 8.7° of visual angle from each other and 6.5° from a central fixation cross (see Figure 4). Each stimulus display contained one emotional (close-mouthed angry or happy) face among three neutral faces sampled from eight female models (nos. 1, 2, 3, 5, 6, 7, 8, 9) of the NimStim database (Tottenham et al., 2009). The other stimulus displays (fixation control, feedback) were identical to Experiment 1.

Mood Manipulation

The self-referential statements used in the mood induction of Experiment 2 were identical to those in Experiment 1, with the following exceptions: First, to induce a neutral mood, the original Velten statements (e.g., "The doorkeeper was dressed in red") were modified to refer more directly to possible emotional states (e.g., "Today is neither better nor worse than any other day",

Figure 4
Overview of Experiment 2



Note. The visual search task in Experiment 2. Participants had to search for a variable emotional face (either angry or happy target expression) that was always presented among three neutral nontarget faces and respond to the direction in which the target face was tilted (right or left). The faces used in the experiment were different from the ones shown and could not be included due to restrictions of the NimStim database. The bottom left face is not part of the NimStim database but depicts one of the authors (SIB), as the NimStim database only allows publishing photographs from three female models but we always used four different models in each display. Stimuli are not drawn to scale. Images used in Figure are from the NimStim set of Facial Expressions (Tottenham et al., 2009).

"I feel okay today"; see Appendix A for a list of all statements). Second, the number of mood statements was reduced to 30 items per mood condition, due to time constraints.

For the same reasons, the PANAS was omitted, and the original three Likert mood questions were extended by adding three additional items from a previous mood manipulation check (M. W. Becker & Leinenger, 2011; see Appendix C for details). These six items were averaged to produce a mood index, where a higher index indicated a more negative mood.

Design

Similar to Experiment 1, Experiment 2 had a 3 (mood: neutral, angry, and happy) × 2 (expression: angry and happy) within-participants design. Participant mood was manipulated within participants in different blocks, and the order of the mood conditions was fully counterbalanced across participants.

In the visual search task, the emotional expression of the target was variable, such that each search block contained 42 angry target trials and 42 happy target trials (84 trials per block in total) randomly presented to the participant. The models were drawn randomly without replacement, so that each trial contained four faces from different models. In the search display, two of the faces were always tilted 15° to the right and two 15° to the left (randomly determined), and participants had to report the tilt of the target face with a button press (pressing the right mouse button when the target was tilted to the right, and the left mouse button when the target face was tilted to the left). In total, participants completed 252 search trials.

Procedure

The procedure for Experiment 2 was identical to that of Experiment 1, with the following exceptions. First, the baseline mood condition was replaced with the neutral mood induction and a subsequent mood assessment. Second, the mood statements were shortened to 30 per mood condition and mood induction was followed by the mood questionnaire alone (without the PANAS). Third, the visual search task differed from Experiment 1, in that participants were asked to find a sole variable emotional target face (either angry or happy expression) amid a crowd of neutral faces. Upon localizing the target face, participants were then asked to respond to the tilt of the emotional target face (left and right) using the corresponding mouse buttons (left and right). All study materials and data for Experiment 2 are available upon request.

Results

Data

As participants responded overall more quickly in Experiment 2 than in Experiment 1, we tightened the RT exclusion criteria to still effectively remove outliers, from 4,500 ms (Experiment 1) to 3,000 ms (Experiment 2). Excluding anticipatory (<200 ms) and delayed manual responses in Experiment 2 led to a loss of 1.37% of data in Experiment 2.[2] Trials in which participants failed to fixate on the target were similarly excluded, which led to a further loss of 1.6% of data.

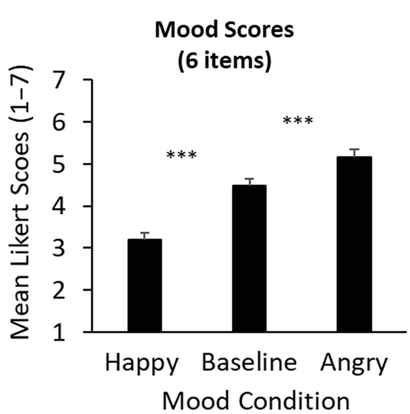
Mood Induction

To assess whether the mood manipulation was successful, a one-way (mood: neutral, angry, and happy) repeated-measures ANOVA was conducted over the average mood scores. There was a significant main effect of the mood induction (see Figure 5), $F(2, 78) = 49.42$, $p < .001$, $\eta_p^2 = .56$. Pairwise *t*-tests showed that participants reported a significantly more negative mood after the angry mood induction than after the neutral mood induction, $t(39) = 4.18$, $p < .001$, and a significantly more positive mood after the happy mood induction than after the neutral mood induction, $t(39) = 7.66$, $p < .001$. Collectively, these results show that the mood manipulation procedure was effective.

Mean RTs

We first analyzed the mean RTs with a 3 (mood: neutral, angry, and happy) × 2 (facial expression: happy and angry) repeated-measures ANOVA. The results showed only a significant main effect of target expression, $F(1, 40) = 13.20$, $p < .001$, $\eta_p^2 = .25$, such that participants responded faster to happy targets than angry targets. That is, we obtained a significant HSE, all other *F*s < 2.11; *p*s > .12. Pairwise comparisons between the angry target and happy target conditions showed significant HSEs across all mood conditions, under the happy mood, $t(40) = 3.66$, $p < .001$, neutral mood, $t(40) = 3.29$, $p = .002$, and angry mood condition, $t(40) = 2.15$, $p = .037$ (see Figure 6).

Figure 5
Mood Results of Experiment 2



Note. The Self-Reported Mood Scores on the Six-Item Mood Scale, After the Neutral, Angry, and Happy Mood Induction Conditions of Experiment 2. The results show significant differences across the three mood induction conditions, indicating that the mood induction was successful. Error bars reflect + 1 standard error of the mean (SEM).
*** $p < .001$.

Importantly, pairwise *t*-tests comparing the mean difference scores (RT on angry target trials–happy target trials) across the mood conditions revealed that the HSE was significantly larger under the happy mood condition (mean difference: 87 ms) than under the angry mood condition (mean difference: 46 ms), $t(40) = 2.07$, $p = .045$, $\eta_p^2 = .10$. Neither HSE differed significantly from the HSE under the neutral mood condition, which had intermediate magnitude (mean difference: 67 ms), both *p*s > .28. These results indicate a mood-congruency effect in the mean RT, as reflected in the significantly larger HSE after the happy mood induction than after the angry mood induction.

Errors

The same 3 (mood) × 2 (expression) repeated-measures ANOVA computed over the mean manual errors showed no significant main effects or interactions, all *F*s < 1.2, *p*s > .27. Pairwise *t*-tests comparing errors on angry versus happy target trials within each mood condition similarly showed no significant differences in responding to angry versus happy targets, all *t*s < 1.8, *p*s > .08, and comparing the difference values for happy and angry targets across the angry and happy mood induction similarly showed no differences, $p = .43$.

Proportion of First Fixations

To assess whether mood modulates visual processing at an early stage of search, we analyzed the proportion of first fixations on the target. As shown in Figure 6, the results showed a trend for an HSE after the happy mood induction, a trend for an ASE after the angry mood induction, and intermediate results for the neutral mood condition. However, a 3 (mood: neutral, angry, and happy) × 2 (facial expression: happy and angry) ANOVA showed no significant effect for mood, facial expression, or their interaction, all *F*s < 1, *p*s > .36.

Pairwise comparisons confirmed that there were no significant differences in the proportion of first fixations to either target expression under the happy mood condition, angry mood condition, or neutral mood condition, all *p*s > .42. Additionally, there were no significant differences across the difference scores (first fixations on angry target—first fixations on happy target) between the three mood conditions, all *t*s < 1.

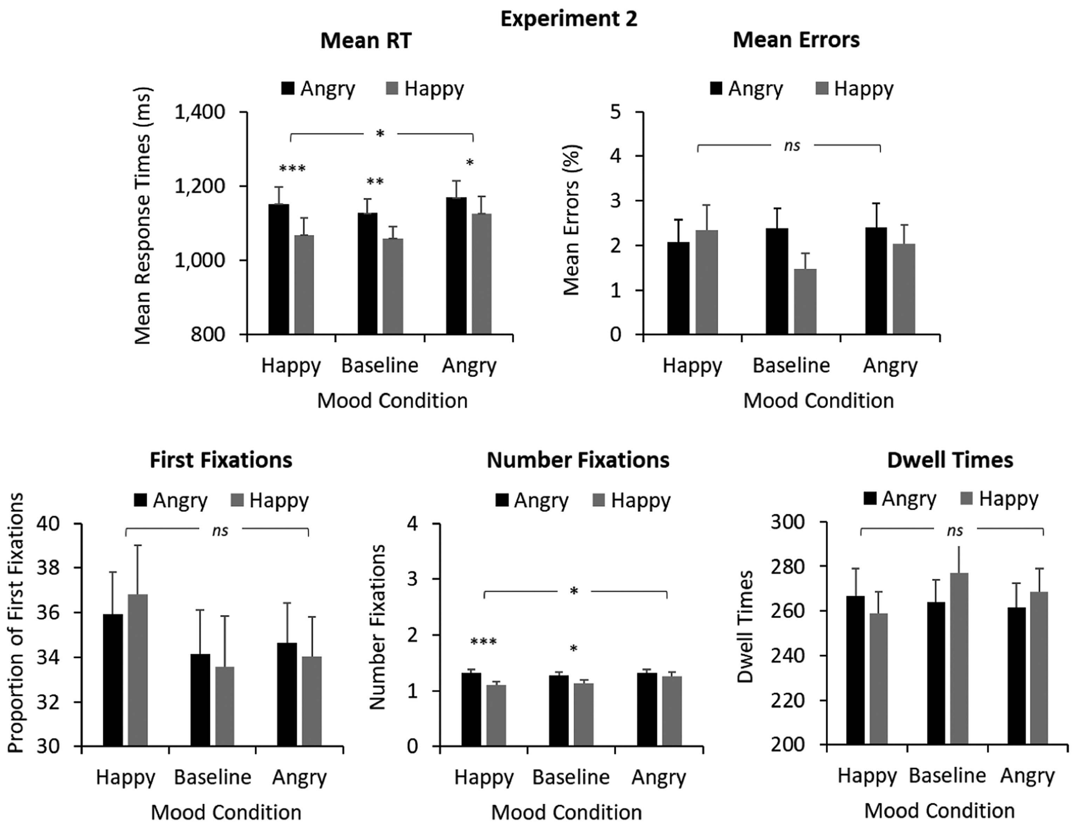
Number of Fixations

To assess whether mood modulated search efficiency in Experiment 2, we conducted the same 3 (mood) × 2 (expression) ANOVA over the number of nontarget fixations prior to target selection. There was no effect of mood, $F < 1$, but a main effect of target expression, $F(1, 40) = 9.28$, $p = .004$, $\eta_p^2 = .19$, and a marginally significant interaction between facial expression and mood, $F(2, 80) = 2.93$, $p = .060$, $\eta_p^2 = .068$.

Pairwise comparisons showed a significant HSE after the happy mood induction, $t(40) = 3.51$, $p = .001$, and after the neutral mood induction, $t(40) = 2.27$, $p = .029$, but not after the angry mood induction, $t < 1$, $p = .23$. Importantly, the HSE was significantly

[2] The 3,000 ms cut-off to remove outliers was initially our a priori outlier criterion for both experiments. We extended it to 4,500 ms for Experiment 1 when it became clear that using 3,000 ms would have removed too many trials in Experiment 1.

Figure 6
Results of Experiment 2



Note. Top Left: The mean RTs in Experiment 2, shown separately for angry targets (black histograms) versus happy targets (gray histograms), across the three mood conditions (happy, neutral, and angry). The results showed a significant happiness superiority effect (HSE), which was significantly larger after the happy mood induction than the angry mood induction. Top right: The mean error scores showed no significant differences. The bottom graphs show the eye-movement results. The proportion of first fixations on the target (left) showed a trend for an HSE after the happy mood induction, and a trend for an anger superiority effect (ASE) after the angry mood induction, which however failed to reach significance. The number of fixations prior to target selection (middle) showed a significant HSE after the happy and neutral mood inductions, and the HSE was also significantly larger in the happy than angry mood condition. The mean dwell times on the target (right) did not show any significant effects. RT = response time; ns = non-significant.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

larger under the happy mood condition than under the angry mood condition, $t(40) = 2.41$, $p = .021$, $\eta_p^2 = .13$, while neither condition differed significantly from the neutral mood condition, both *p*s > .12. The significantly larger HSE in the happy mood condition reflects a mood-congruency effect, with more efficient search for mood-congruent than mood-incongruent targets.

Dwell Times

We also inspected the mean dwell time on the targets, to investigate potential mood-congruency effects on later decision- or response-related processes. As shown in Figure 6, the dwell times showed a trend for an HSE after the happy mood induction, and an ASE after the neutral and angry mood inductions. However, the results of the 3×2 ANOVA showed no effect of mood, expression, or their interaction, all *F*s < 1.52, *p*s > .21.

Pairwise comparisons confirmed that there were no significant differences in dwell times between angry and happy targets after the angry, happy, or neutral mood induction, all *t*s < 1.6, *p*s > .12. Additionally, pairwise comparisons conducted over the difference scores (dwell time on angry target—dwell time on happy target) showed no significant differences between the three mood conditions, all *t*s < 1.7, *p*s > .10. Thus, the results failed to establish a mood-congruency effect on later decision- or response-related processes.

Discussion

Experiment 2 yielded several important results. First, the results confirmed the viability of our modified neutral mood induction, which produced scores that were approximately mid-point in-between, and significantly different from, the mood states reported after the angry and happy mood induction (see Figure 5).

Second, and more importantly, the results of Experiment 2 provided converging evidence for a mood-congruency effect in visual search, by showing that emotional factors can modulate attentional processes in visual search for emotional faces. Specifically, the results clearly showed a mood-congruency effect on search efficiency (indexed by the number of fixations prior to target selection) and the mean RTs.

The proportion of first fixations on the target and the dwell times showed similar trends for a mood-congruency effect, with a trend for an HSE after the happy mood induction and a trend for an ASE after the angry mood induction, but the HSE and ASE were not statistically significant, or statistically different from each other. This deviates from the results of Experiment 1, which showed a significant mood-congruency effect on the proportion of first fixations. However, as the data were in the direction of a mood-congruency effect and the results patterns looked very similar in both experiments, this difference probably reflects a difference in variability or noise in the data and does not signify an important difference between the experiments.

The results of Experiment 2 often showed an HSE rather than an ASE, even after the angry mood induction. This is probably due to perceptual factors or other congruency effects (e.g., use of female faces; e.g., Hugenberg & Sczesny, 2006), which conveyed an advantage to happy targets among the neutral nontarget faces. Still, the fact that the HSE was significantly larger after the happy mood condition than after the angry mood condition showed that mood modulated search in addition to possible perceptual factors driving a perceptual HSE. This is all the more so since the stimuli were the same across the conditions and were used in a within-subjects design, ensuring that differences between the mood conditions have to be attributed to the mood manipulation and cannot be attributed to other, extraneous factors.

General Discussion

The aim of the present study was to determine whether emotional factors are capable of guiding attention in visual search for emotional faces, over and above the perceptual characteristics of the stimuli, which can produce an ASE or HSE. In the present experiments, we manipulated emotional factors by manipulating the participants' mood, and then assessed their performance in the same visual search task after each mood induction. If emotional factors do not influence visual search at all, participants should exhibit identical visual search performance across all three mood conditions. This was not found. Rather, both Experiments 1 and 2 found mood-congruency effects, where performance was facilitated for mood-congruent targets but hampered for mood-incongruent targets. Notably, these effects were reliably observed in the number of fixations before target selection, which indexes processes of attentional guidance and nontarget rejection (cf. S. I. Becker, Horstmann, & Remington, 2011). In Experiment 1, in which we used the dynamically changing faces, the effects were even observed in the proportion of first fixations to the target, which indexes early attentional guidance (or preattentive processes; e.g., S. I. Becker, Horstmann, & Remington, 2011). This mood-congruency effect appeared on top of a perceptual search asymmetry that favored angry or happy targets, to further modulate a preexisting perceptual ASE or HSE.

As this mood-congruency effect was observed with both dynamic emotional faces (Experiment 1) and static emotional expressions (Experiment 2), when they were presented among emotional nontargets (Experiment 1) and neutral nontargets (Experiment 2), the mood-congruency effect seems to be quite robust. Moreover, given that the photographic faces had relatively high ecological validity (especially the dynamic faces in Experiment 1), our mood can likely influence how we attend to emotional faces in the natural environment.

We were also able to identify the specific stage at which emotional factors can influence search performance, through the use of our eye-tracking measures. Our results indicated that participant mood has the strongest and most reliable effects on the speed of locating the target (search efficiency; observed both in Experiments 1 and 2), followed by effects on preattentive processes of attentional guidance, and the weakest or no effects on late-stage decisional or response-related processes (as reflected in the dwell times, which mostly failed to show significant effects of mood).

The theoretically most important result is the mood-congruency effect on search efficiency or the speed of locating the target, which we measured with the number of fixations before target selection. This result is consistent with both facilitated attentional guidance to mood-congruent targets (e.g., Wolfe, 1994) and/or facilitated rejection of mood-incongruent nontargets (e.g., Duncan & Humphreys, 1989; see also S. I. Becker, Horstmann, & Remington, 2011; Horstmann & Becker, 2020). In the present study, we reliably observed mood-congruency effects on search efficiency, despite using different nontargets between the experiments—opposing emotional distractors in Experiment 1, and neutral distractors in Experiment 2. This renders it more likely that the mood-congruency effect is due to the target's emotional expression rather than facilitated nontarget rejection. In line with this view, we found a significant mood-congruency effect on the first fixations on the target in Experiment 1, which indicate that mood modulates preattentive processes. This demonstrates that emotional states *can* bias visual attention to mood-congruent items, which facilitates search when the target is congruent with one's own emotional state and/or hampers visual search when the target is incongruent with one's own emotional state.

Importantly, these findings were obtained using the same exact stimuli and in a within-participants design, which precludes alternative explanations and ensures that the observed effects are due to emotional factors, not perceptual differences between the stimuli or individual differences between participants. Moreover, we replicated the emotional effects across two experiments that used very different stimuli and designs, including (a) dynamic and static emotional faces with (b) variable versus blocked target faces, (c) when the response required identifying the emotion versus was unrelated to the emotional expression (and determined by the tilt of the face; Experiment 2), and (d) when compared to baseline mood measured at the start of the experiment versus induced neutral mood state in a fully counterbalanced design. The fact that we still observed a modulation of search efficiency by emotional factors suggests that emotional factors reliably modulate attention across a wide range of conditions. Taken together, both experiments provide strong support for the notion that the emotional valence of emotional faces is processed, and able to guide attention over and above the perceptual features of the stimuli themselves.

With this, our results support the findings of previous studies showing that emotional factors can modulate attention while avoiding problems of possible stimulus confounds (e.g., D. V. Becker, Anderson, et al., 2011; Juth et al., 2005; Kirita & Endo, 1995) or individual differences in the between-subjects design with clinical populations (e.g., Ashwin et al., 2012; Gilboa-Schechtman et al., 1999; Juth et al., 2005; Suslow et al., 2001).

Previous studies used different mood induction procedures (e.g., watching happy vs. sad video clips or listening to music) to study how mood affects the breadth of the attentional focus, or attention to global versus local features in a visual scene (e.g., Vanlessen et al., 2013; Wadlinger & Isaacowitz, 2006). However, the results have been mixed (e.g., Bruyneel et al., 2013; Martin & Kerns, 2011) and the studies were not designed to address the question of whether mood can bias visual attention.

The present study fills this empirical gap, by showing that emotional factors can indeed bias attention to mood-congruent stimuli, as reflected in significant mood-congruency effects in eye movements in visual search, thus providing clear evidence for the view that the emotional valence of a face can guide visual attention. Despite the evidence in favor of emotional factors guiding attention, the present results do not support strong variants of emotional factors accounts, as will be discussed in more detail later.

Threat Capture and Positivity Bias

As outlined in the introduction, previous emotional accounts have proposed a threat detector or a positivity bias to explain the occurrence of an ASE or HSE in visual search, respectively (e.g., D. V. Becker, Anderson, et al., 2011; Juth et al., 2005; Öhman & Mineka, 2001). While the present study supports the notion that positive or negative mood states can translate into an attentional bias for emotionally congruent stimuli and guide attention to angry versus happy emotional expressions in visual search, the present results do not support strong variants of emotional accounts.

First, it should be noted that the emotional accounts were originally introduced to explain the occurrence of a search asymmetry in the data—namely, an ASE or HSE, which were variably attributed to a threat detector or positivity bias that biased attention to corresponding targets. However, for any of the emotional accounts to be valid, it is necessary to establish one of the search asymmetries as the "real," reliable search asymmetry and explain the occurrence of the opposite search asymmetry by other, confounding factors. By far the most damaging finding in the previous literature and the present study is that it is equally possible to find evidence for an ASE or HSE in visual search and fixation data, using very similar designs and procedures (e.g., Horstmann et al., 2012; Savage et al., 2013). Given that the methods and stimuli are often equally sound and that only the perceptual features differ across different stimulus materials, it is unlikely that the occurrence of an ASE or HSE can ultimately be attributed to emotional factors.

Second, according to the threat capture hypothesis and other emotional factor explanations, threats should capture attention immediately, due to the emotional valence they exhibit, and independently of perceptual features. While our data showed evidence that search was modulated by emotional factors, including at an early stage of visual search, the emotional effects were not large or exclusive enough to support the strong claims of emotional accounts. In both experiments, the proportion of first fixations on the target was relatively low (see Figures 3 and 6), probably because our closed-mouth faces have low perceptual discriminability (e.g., Horstmann et al., 2012), which is inconsistent with the idea that emotional stimuli strongly attract attention, independently of perceptual factors (e.g., S. I. Becker et al., 2017; Horstmann & Becker, 2020; Lipp & Waters, 2007). Moreover, the strongest emotional effects were not observed in the first eye movements but in a slightly later measure (i.e., search efficiency), which does not support the claim of evolutionary threat detectors eliciting a very fast, immediate orienting response. These results indicate that while emotional factors can guide visual attention, their effects are not strong enough to support the claims of a threat detector account. Collectively, these findings are more consistent with a hybrid account, which suggests that emotional and perceptual factors can both modulate attentional processes.

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Appendix A

Experiment 1: Dynamic Faces' Mood Statements

Happy Statements

1. Today is neither better nor worse than any other day.
2. I do feel pretty good today, though.
3. I feel light-hearted.
4. This might turn out to be one of my good days.
5. If your attitude is good, then things are good, and my attitude is good.
6. I've certainly got energy and self-confidence to spare.
7. I feel cheerful and lively.
8. On the whole, I have very little difficulty in thinking clearly.
9. For the rest of my day, I bet things will go really well.
10. I'm pleased that most people are so friendly to me.
11. My judgment about most things is sound.
12. I'm feeling full of energy and ambition.
13. This is one of those days when I can do chores feeling quite happy.
14. When I want to, I can make friends extremely easily.
15. If I set my mind to it, I can make things turn out well.
16. I feel enthusiastic and confident now.
17. There should be an opportunity for a lot of good times coming along.
18. Some of my friends are so lively and optimistic.
19. I feel talkative—I feel like talking to almost anybody.
20. I'm full of energy, and I am really getting to like the things I'm doing.
21. I am able to do things accurately and efficiently.
22. I know that I can achieve the goals I set.
23. I have a sense of power.
24. I feel so vivacious and efficient today—I'm sitting on top of the world.

(*Appendices continue*)

25. In the long run, it's obvious that things have gotten better and better during my life.
26. I know that in the future I won't fret so much over small problems.
27. I'm optimistic that I can get along very well with most of the people that I meet.
28. I'm too absorbed in things to have time for worry.
29. I feel amazingly good today!
30. I am particularly inventive and resourceful in this mood.
31. I feel superb! I think I can work to the best of my ability.
32. Things look good. Things look great.
33. I feel that many of my friendships will stick with me in the future.
34. I can find the good in almost anything.
35. I feel and exhilarating animation in all I do.
36. I feel perceptive and refreshed.
37. In a buoyant mood like this one, I can work fast and do it right the first time.
38. I can concentrate hard on anything I do.
39. Life is so much fun; it seems to offer so many sources of fulfillment.
40. Things will be better and better today.
41. I can make decisions rapidly and correctly, and I can defend them against criticism easily.
42. Life is firmly in my control.
43. I wish somebody would play some good loud music!
44. This is great!—I really do feel good! I am elated about things.
45. I feel fantastic!

Angry Statements

1. Today is neither better nor worse than any other day.
2. I feel okay today.
3. I feel a little annoyed at things though.
4. Today is not the best day I've had.
5. Things aren't going my way.
6. Sometimes things happen that are not in my control.
7. Sometimes these things really annoy me because I can't do anything about it.
8. I get really frustrated sometimes about little things.
9. Bad things happen to good people a lot of the time.
10. Bad things happen to good people more often than bad people.
11. I don't think people really get what they deserve.
12. I often don't get credit for what I've done well, but people blame me for things that go wrong.
13. When I get mad, my mood is low for the rest of the day.
14. People treat me unfairly.
15. I get angry when people are rude to me.
16. I'm pretty annoyed at how underappreciated I am.
17. I hate people who get away with things they shouldn't get away with.
18. Its not fair that I have to work so much harder for the things I want than most other people.
19. It makes me angry when people try to give me a bad deal or charge me too much.
20. It frustrates me a lot when people get in my way and slow me down.
21. I get really angry at how long it takes to do things.
22. There isn't enough time to do what I want to do.
23. It makes me so frustrated when I have to do things that I don't want to do.
24. I have been betrayed in the past and I was very angry about it.
25. People are not trustworthy. They just use me to get their way.
26. People don't treat me with enough respect.
27. It makes me angry how little credit I get for the things I do for others.
28. I get really worked up about things that are unfair.
29. Most of the time I get the bad end of the bargain.
30. I work hard for things but other people don't, and it makes me really mad.
31. I don't feel positive today because things are not going my way.
32. Whenever I try to do something, other things get in my way and it makes me really angry.
33. People will always let me down.
34. I am really angry about how the world is—there's so many bad things happening.
35. I get so angry when I hear that bad people got away with their crimes.

(*Appendices continue*)

36. I'm so mad that people don't listen to me.
37. Today is a bad day.
38. I get angry about how people treat me—I never get the respect I deserve.
39. I get really angry when people give up so easily—why can't they just try?
40. I am so angry that all my efforts always seem wasted.
41. I never get treated as well as I should.
42. All the anger I have felt over the past 2 days is coming back.
43. I'm getting really worked up about how unfair things really are.
44. I can't think properly I'm so angry about life.
45. I feel so angry, I could smash something.

Appendix B

Experiment 2: Static Faces' Mood Statements

Happy Statements

1. Today is neither better nor worse than any other day.
2. I do feel pretty good today, though.
3. This might turn out to be one of my good days.
4. If your attitude is good, then things are good, and my attitude is good.
5. I've certainly got energy and self-confidence to spare.
6. For the rest of my day, I bet things will go really well.
7. My judgment about most things is sound.
8. This is one of those days when I can do chores feeling quite happy.
9. When I want to, I can make friends extremely easily.
10. There should be opportunity for a lot of good times coming along.
11. I feel talkative—I feel like talking to almost anybody.
12. I'm full of energy, and I am really getting to like the things I'm doing.
13. I know that I can achieve the goals I set.
14. I feel so vivacious and efficient today—I'm sitting on top of the world.
15. In the long run, it's obvious that things have gotten better and better during my life.
16. I know that in the future I won't fret so much over small problems.
17. I'm optimistic that I can get along very well with most of the people that I meet.
18. I feel amazingly good today!
19. I feel superb! I think I can work to the best of my ability.
20. Things look good. Things look great.
21. I feel that many of my friendships will stick with me in the future.
22. I can find the good in almost anything.
23. In a buoyant mood like this one, I can work fast and do it right the first time.
24. I can concentrate hard on anything I do.
25. Life is so much fun; it seems to offer so many sources of fulfillment.
26. Things will be better and better today.
27. I can make decisions rapidly and correctly, and I can defend them against criticism easily.
28. Life is firmly in my control.
29. This is great!—I really do feel good! I am elated about things.
30. I feel fantastic!

Angry Statements

1. Today is neither better nor worse than any other day.
2. I feel slightly less than okay today.
3. I feel a little annoyed at things though.
4. Today is not the best day I've had.
5. Sometimes things happen that are not in my control.
6. Sometimes these things really annoy me because I can't do anything about it.
7. Bad things happen to good people more often than bad people.
8. I often don't get credit for what I've done well, but people blame me for things that go wrong.
9. When I get mad, my mood is low for the rest of the day.
10. I get angry when people are rude to me.

(*Appendices continue*)

11. I hate people who get away with things they shouldn't get away with.
12. It frustrates me a lot when people get in my way and slow me down.
13. It makes me so frustrated when I have to do things that I don't want to do.
14. I have been betrayed in the past and I was very angry about it.
15. People are not trustworthy. They just use me to get their way.
16. It makes me angry how little credit I get for the things I do for others.
17. I work hard for things but other people don't, and it makes me really mad.
18. I don't feel positive today because things are not going my way.
19. Whenever I try to do something, other things get in my way and it makes me really angry.
20. People will always let me down.
21. I am really angry about how the world is—there's so many bad things happening.
22. I get so angry when I hear that bad people got away with their crimes.
23. I'm so mad that people don't listen to me.
24. Today is a bad day.
25. I get angry about how people treat me—I never get the respect I deserve.
26. I get really angry when people give up so easily—why can't they just try?
27. All the anger I have felt over the past 2 days is coming back.
28. I'm getting really worked up about how unfair things really are.
29. I can't think properly I'm so angry about life.
30. I feel so angry, I could smash something.

Neutral Statements

1. Today is neither better nor worse than any other day.
2. I feel okay today.
3. Today has been a regular day.
4. I have no expectations about whether today will be good or bad.
5. Today, I possess my regular level of self-confidence.
6. I feel neither excessively cheerful nor lethargic.
7. I don't mind being alone today—But I would be okay with seeing people too.
8. I do not feel excessively energetic today, but neither do I feel a lack of energy.
9. I am neither worse nor better than anyone else in a social context.
10. Today, my concentration levels are neither better nor worse than they are on a regular day.
11. I am neither frustrated nor highly relaxed.
12. I do not feel strongly affected by emotional factors currently.
13. My concentration levels are neither worse nor better than they would be on a regular day.
14. Throughout the day, both good and bad things will happen to me.
15. My decision-making skills are neither worse nor better than they are on a regular day.
16. I feel neither strongly in nor out of control of my life.
17. I feel emotionally stable—I am not fluctuating between sadness and heights of happiness.
18. My rational judgment has neither increased nor declined from that of a regular day.
19. I will perform my tasks today neither more nor less efficiently than on a regular day.
20. I feel that I get what I deserve, whether it is good or bad.
21. If one's attitude defines their day, my day will be neither horrible nor exceptional today.
22. I feel well-rested though I do not have an excess of energy.
23. In life, sometimes things don't go my way, and that is okay.
24. I feel neither positively nor negative about the future.
25. I feel neither dejected nor ecstatic.
26. I feel very objective in my reasoning today—My decisions won't be affected by my mood.
27. I am indifferent to strong negative or positive feelings currently.
28. I am impartial to any effects of emotions on my actions today.
29. I am no more or less resourceful today than I am on a regular day.
30. I don't feel any strong emotions today.

(*Appendices continue*)

Appendix C

Mood Likert Scales for Experiments 1 and 2

Mood Likert scale—experiment 1								
Happy				Neutral				Angry
1	2	3	4	5	6	7	8	9
Cheerful				Neutral				Sad
1	2	3	4	5	6	7	8	9
Positive				Neutral				Negative
1	2	3	4	5	6	7	8	9

Mood Likert scale—experiment 2								
Happy				Neutral				Angry
1	2	3	4	5	6	7	8	9
Sad[a]				Neutral				Cheerful
1	2	3	4	5	6	7	8	9
Confident				Neutral				Anxious
1	2	3	4	5	6	7	8	9
Relaxed				Neutral				Tense
1	2	3	4	5	6	7	8	9
Alert				Neutral				Tired
1	2	3	4	5	6	7	8	9
Negative[a]				Neutral				Positive
1	2	3	4	5	6	7	8	9

[a] Reverse scoring.

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