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Effects of induced and naturalistic mood on the temporal allocation of attention to emotional information

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Building upon recent findings that affective states can influence the allocation of spatial attention, we investigate how state, trait and induced mood are related to the temporal allocation of attention to emotional information. In the present study, 125 unscreened undergraduates completed a modified rapid serial visual presentation task designed to assess the time course of attention to positive and negative information, comparing a neutral baseline mood induction to either a positive or negative mood induction. Induced negative mood facilitated attentional engagement to positive information while decreasing attentional engagement to negative information. Greater naturally occurring negative state mood was associated with faster or more efficient disengagement of attention from negative information in the presence of manipulated negative mood, relative to baseline. The engagement findings were inconsistent with our mood-congruence hypotheses and may be better explained by mood repair or affective counter-regulation theories. In contrast, the disengagement findings for state mood were somewhat consistent with our mood-congruence hypotheses. The relationship between mood and attention to emotional information may differ depending on the combination of attentional mechanism (engagement versus disengagement), aspect of mood (state, trait or induced), stimulus valence (positive versus negative) and timescale (early versus late) under investigation.

Keywords: Attention; Mood; Mood induction; Mood repair; Associative networks.

Moods are sustained affective states that influence many domains of cognitive processing, including attention (e.g., Derryberry & Tucker, 1994), appraisal (e.g., Wilson, MacLeod, Mathews, & Rutherford, 2006), memory (e.g., Bower, 1981) and decision-making (e.g., Loewenstein, Weber, Hsee, & Welch, 2001). Evidence suggests that mood affects attention to both non-emotional (e.g., Dreisbach, 2006) and emotional (e.g., Lystad, Rokke, & Stout, 2009) information. In addition, individuals with high trait anxiety, a dispositional propensity to experience anxious mood (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), exhibit a spatial attentional bias for threatening

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versus neutral information (for a meta-analysis, see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), compared to individuals with low trait anxiety. Moreover, research over the past several decades has shown that mood and attention have varying aspects that may influence the relationship between them (for a review, see Compton, 2003).

Aspects of mood

The relationship between mood and attentional processing of emotional information can be examined by considering variation and stability within and among individuals. We consider three aspects of mood in the current work. First, variation in mood, over time, within a single individual is labelled mood state (e.g., state anxiety; Spielberger et al., 1983). Second, components of mood that are stable within individuals, but vary between individuals, are mood traits (e.g., trait anxiety; Spielberger et al., 1983). Third, experimental mood inductions can be used to elicit different mood states. Notably, the influence of induced mood potentially can be moderated by state and trait mood. By simultaneously considering state and trait aspects of mood, along with how these components interact with induced mood, we are poised to investigate a broad range of possible interactions between mood and attention.

Associations between naturally occurring state mood and attention have long been studied in research on anxiety and attention. Prior research has found naturally occurring *state* anxiety to be more strongly associated with attentional bias for threat, compared to *trait* anxiety (Cohen's *d*s = .65 and .38, respectively; Bar-Haim et al., 2007), but there has been a relative dearth of research examining the effects of manipulated mood on attention to emotion (Fox & Knight, 2005; Jefferies, Smilek, Eich, & Enns, 2008; Olivers & Nieuwenhuis, 2005, 2006; Rowe, Hirsh, & Anderson, 2007). Such research is needed because, absent experimental manipulation of mood, associations between attention and either naturally occurring state or trait anxiety do not necessarily reveal causal effects of anxious mood on attention (Barnard, Ramponi, Battye, & Mackintosh, 2005; Fox, Russo, Bowles, & Dutton, 2001; MacLeod & Mathews, 1988).

Aspects of attention

Like mood, attention has multiple aspects that may be important to the mood-attention relationship. First, although there are many experimental examples of a mood-related attentional bias towards or away from threatening information, perception research has demonstrated that attentional selection is multifaceted; for example, stimuli are first attended to through an engagement process, followed eventually by a disengagement process that allows attention to shift to another stimulus (Posner & Petersen, 1990). These critical adaptive processes have only recently been studied in relation to manipulated state mood (Jefferies et al., 2008; Lystad et al., 2009).

A second aspect of attention is that it is deployed over both space and time. Research on mood and attention has typically examined how mood affects attentional allocation across spatial locations (Bar-Haim et al., 2007). However, temporal attention, the speed with which attention is allocated to a new stimulus at a single spatial location, is also relevant to understanding mood-related attentional processing (Most, Chun, Widders, & Zald, 2005). Threat-relevant information is processed more rapidly than positive or neutral information (e.g., Öhman, Flykt, & Esteves, 2001), possibly due to the evolutionary advantages of rapid, selective attentional processing for persistent threats over evolutionary history. Additionally, state or trait anxiety may affect the speed with which individuals engage attention to, or disengage attention from, emotional information. As with certain spatial attention paradigms (e.g., modifications to the Posner cueing paradigm; Fox et al., 2001, Study 5), temporal attention paradigms can be adapted readily to support stronger inferences about attentional engagement and disengagement processes (Nieuwenstein, Chun, Van Der Lubbe, & Hooge, 2005; Vul, Nieuwenstein, & Kanwisher, 2008). Such paradigms provide an opportunity to examine how state, trait and induced aspects of mood might modulate the temporal engagement and disengagement of attention to emotional information.

Measurement of temporal attention

To examine the time course of attention, investigators often use a variant of the rapid serial visual presentation (RSVP) paradigm (Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992). In the classic RSVP paradigm, participants view a rapid stream of stimuli presented at the same location on a screen. They are then asked to report the identity of the two targets that appear in the stream. Across trials, the targets are presented at different temporal lags. Identification of the second target (T2) typically is less accurate when it appears 200–500 ms after the first target (T1), but is more accurate when T2 appears at longer intervals (>500 ms) from T1. This well-replicated performance deficit is called the attentional blink (AB; Raymond et al., 1992). One proposed explanation for the AB is that processing of T1 occupies resources in limited-capacity visual short-term memory, temporarily limiting the extent to which T2 can be encoded and thus later reported (Chun & Potter, 1995). This *attentional bottleneck* theory of the AB is one of several that have been advanced, including *inhibition* theory (Raymond et al., 1992), *interference* theory (Shapiro, Raymond, & Arnell, 1994) and *overinvestment* theory (Olivers & Nieuwenstein, 2006).

Investigators have adapted the original RSVP to study the effects of various aspects of mood on temporal attention allocation. For example, Arend and Botella (2002) examined whether high- and low-trait-anxious participants differed in identification accuracy of neutral T2 words, given correct identification of the negative or neutral T1 word presented on the same trial. Relative to low-trait-anxious individuals, high-trait-anxious individuals identified T2 more accurately when it followed a negative compared to neutral T1, suggesting that higher trait anxiety was associated either with more efficient disengagement of attention from negative information, or with an increased capacity to engage a greater number of negative items simultaneously. Other investigators have retained the basic features of the RSVP paradigm but have manipulated mood using background music, finding greater disruption of attention to nonemotional stimuli in the presence of anxious music compared to sad, happy or calm music (e.g., Jefferies et al., 2008). Finally, manipulated anxious mood, but not manipulated neutral mood, has been associated with improved detection of a neutral T2 word appearing two positions after an anxious, relative to a neutral, T1 word (Lystad et al., 2009). The authors interpreted these results as providing evidence of mood-congruent facilitation of both attentional engagement and disengagement.

Present study

The aim of the present study was to examine the relationship between multiple aspects of mood (state, trait and induced) and the temporal allocation of attention to emotional information. To date, no prior study has examined these critical components simultaneously, and for both attentional engagement and disengagement. We modified the RSVP paradigm to assess the time course of attention to positive and negative information in both the absence and presence of a mood induction. To assess the degree to which the valence of target stimuli interacted with the valence of the mood induction, participants completed the attention task during either positive or negative mood-induction conditions (but not both). The mood-induction conditions were high in arousal to increase the likelihood of observing mood-related attentional effects. Moreover, to examine how aspects of mood are related to attentional engagement to, and disengagement from, emotional information, we manipulated the order of neutral and emotional targets within the RSVP stream.

The emotional target was presented either before the neutral target (Emotion T1 trials) or after the neutral target (Emotion T2 trials). Emotion T1 trials provide a case where an emotional target is always selected by attention, and could either interfere with or enhance subsequent processing. The emotional target could interfere if resources are limited, and attention has difficulty disengaging from the emotional words. It could enhance performance if emotional words trigger transient arousal that increases capacity limits or improves vigilance, or if they are processed more efficiently because of their congruence with pre-existing mood state. In line with mood-congruence theories (e.g., Bower, 1981) and RSVP research that has examined the characteristics of mood-congruent versus mood-incongruent temporal attention (e.g., Lystad et al., 2009), the prediction was that performance for T2 would be enhanced on trials where T1's valence was congruent with the mood induction condition, compared to the same trial type during a prior neutral mood-induction baseline condition. A further prediction was that performance for T2 would be worse on mood-incongruent trials due to interference by mood-induction-incongruent (and therefore more salient) T1s.

In contrast to Emotion T1 trials, Emotion T2 trials provide a case where the attentional system is already taxed by selection of a first stimulus (the neutral word). In this case, the emotional target word appearing second could either improve performance by capturing attention or harm performance by being suppressed or ignored. Again, based on mood-congruence theory, we hypothesised that performance would improve for mood-congruent T2s and decrease for mood-incongruent T2s relative to the same trial types administered during a prior neutral mood-induction baseline condition.

Finally, we obtained self-report measures of state mood and trait anxiety to assess the extent to which individual differences in these components of mood moderate the effect of the valence of induced mood on temporal attention to emotional information. Our general prediction was that greater state or trait anxiety would potentiate the mood-congruent and mood-incongruent predictions in the same direction as described earlier.

METHOD

Participants

The local Institutional Review Board approved the present study. Participants were 125 male students between the ages of 18 and 30 years enrolled in a private university. They were recruited to participate in a picture viewing and word-detection study.

RSVP stimuli

RSVP stimuli were composed of target words and nonword distractors ranging from 4 to 10 characters in length and containing only the letters A–Z. Target word stimuli were drawn from the following four lists, each of which was composed of 48 words: positive (e.g., *ecstatic*) and negative (e.g., *terrified*) adjectives; and neutral food (e.g., *banana*) and occupation (e.g., *gardener*) nouns.[1] The stimuli primarily were drawn from lists used in previous studies of attention and anxiety (Barnard et al., 2005; MacLeod & Mathews, 1988) and from the Affective Norms for English Words (ANEW; Bradley, 1999). The lists of target words were constructed so that both lists for a given part of speech (e.g., food vs. occupation nouns, or positive vs. negative adjectives) did not differ statistically on mean word length or written frequency (Kučera & Francis, 1967). Nonword distractor stimuli were random character strings.

Dual-task RSVP paradigm

Participants were tested individually in a sound-attenuated room while seated in a comfortable chair situated approximately 57 cm from a 19″ Dell P992 computer monitor set to a resolution of 1024 × 768 pixels and a vertical refresh rate of 120 Hz. The RSVP paradigm was implemented in Matlab (The Mathworks, 2006) using the Psychophysics Toolbox extensions (Version 3; Brainard, 1997; Pelli, 1997) on a PC running Windows XP 2002 SP2. All RSVP stimuli were

[1] Stimuli are available upon request from the first author.

presented as black, capitalised letters in Lucida Console font against a neutral gray background. The stimuli subtended vertical and horizontal visual angles of approximately .46° and 1.73°–4.32°, respectively. On each trial, participants viewed a black fixation cross at the centre of the screen for 500 ms, followed by 18 stimuli appearing at fixation individually at a rate of 120 ms per item, in immediate succession. All stimuli were nonword distractors except for two target words, T1 and T2. On each trial, T1 appeared randomly in the 6th–10th position in the stream, and T2 was equally likely to appear at the 2nd, 3rd or 8th position after T1 (i.e., at Lag 2, 3 or 8, respectively). We selected these lags to sample T2 performance at times when the processing demands of T1 would be high (i.e., Lags 2 and 3) and low (i.e., Lag 8). Immediately after offset of the RSVP stream, participants were prompted to indicate, via a key press, whether (1) the noun in the previous stream was a food or occupation word and (2) the adjective in the previous stream was positive or negative. Response prompts were presented in the order in which the noun and adjective had appeared on the preceding trial.

The attention assessment was composed of 240 trials. There were 120 trials for each mood induction phase (BL and MI). On half of the trials within each phase (n = 60), T1 was a positive or negative adjective and T2 was a food or occupation noun (i.e., Emotion T1 trials); the assignment was reversed on the other half of the trials within each phase (i.e., Emotion T2 trials). T2 appeared at Lag 2, 3 or 8 with equal frequency across all combinations of phase, adjective category and noun category. Each combination of target order, noun category, adjective category and T2 lag was randomly intermixed and balanced both within and between BL and MI phases. Thus, at the most granular level of the design, there were 10 trials per cell, although analytically, there were more than 20 per cell, since no analysis used all combinations of factors of the design at the same time.

We minimised stimulus habituation in several ways. First, each word list was divided into half, with each half serving as the stimulus list for the BL or MI phase of the study. Thus, participants never saw the same target word in both phases of the study. Further, these subsets were assigned to the two phases in a pseudorandom, counterbalanced order across participants. In addition, each target word appeared at most three times during its assigned study phase. Finally, on each trial, target words were selected randomly without replacement from the designated word lists. All words from a given list were replenished after each stimulus had been used.

Mood induction

The mood induction involved the periodic presentation of emotional pictures between trials of the RSVP paradigm. The pictures were drawn from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005), a standardised set of colour pictures varying in valence and arousal dimensions of affective space. Pleasure and arousal ratings from the IAPS normative sample of undergraduate men were used to form sets of 25 pictures for the neutral BL phase as well as the positive (e.g., pictures of opposite-sex nudes and extreme sports) and negative (e.g., pictures of bodily mutilation/injury and physical threat) MI conditions.[2] Picture sets for the negative and positive MI conditions were selected to match as closely as possible on normative arousal (negative MI: M = 6.65, SD = .25; positive MI: M = 7.04, SD = .21) and to be maximally discrepant on normative valence

[2] The following images from the IAPS were used: Neutral BL: 5740, 7000, 7004, 7006, 7010, 7020, 7025, 7030, 7031, 7035, 7040, 7041, 7050, 7055, 7080, 7090, 7110, 7140, 7150, 7175, 7179, 7217, 7224; Positive, high-arousal MI: 4001, 4002, 4141, 4142, 4180, 4220, 4225, 4235, 4250, 4300, 4310, 4311, 4608, 4647, 4651, 4652, 4658, 4659, 4660, 4670, 5621, 8030, 8080; Negative, high-arousal MI: 1050, 1300, 2730, 2811, 3000, 3010, 3030, 3060, 3068, 3071, 3080, 3110, 3130, 3170, 3400, 3500, 3530, 6260, 6370, 6550, 8485, 9250, 9252.

(negative MI: *M* = 2.56, *SD* = .66; positive MI: *M* = 7.56, *SD* = .32). Further, pictures were selected for the neutral BL phase if they were both low on normative arousal (*M* = 2.37, *SD* = .40) and had normative pleasure ratings close to 5 (*M* = 4.88, *SD* = .29), indicating neither pleasure nor displeasure.

The mood induction procedure was designed to induce and maintain the target mood state throughout the attention assessment while minimising interference with the assessment. We addressed this challenge as follows. First, each picture appeared randomly after every 3rd, 5th or 7th trial to increase uncertainty about the timing of picture onset and thus randomly scatter across lags the effects of deploying anticipatory emotion regulation strategies. Second, each picture was presented for 6 s, and participants were instructed to look at the picture the entire time it was on the screen. Third, each picture appeared only once during an experimental session, eliminating a common source of habituation. Finally, both the participant and the experimenter were blind to the randomly assigned MI condition until the MI phase began, and either positive or negative images were shown for the induction.

Self-report measures

The *State-Trait Anxiety Inventory-Trait* (STAI-T; Spielberger et al., 1983) is a widely used self-report measure composed of a 20-item trait anxiety subscale measuring the general tendency to respond anxiously to negative events. In prior research, STAI-T scores have shown excellent psychometric properties, including high internal consistency, test-retest reliability, convergent and discriminant validities and predictive validity (Bieling, Antony, & Swinson, 1998; Spielberger & Vagg, 1984). Internal consistency for STAI-T scores was high in the present study (α = .91).

The *Positive and Negative Affect Schedule* (PANAS; Watson, Clark, & Tellegen, 1988) was administered three times during breaks in the RSVP task to examine the effects of the mood manipulation on state mood. The PANAS is a 20-item self-report instrument designed to measure two dimensions of mood, positive affect and negative affect. The PANAS is widely used in research to track intra-individual change in mood state, for which it has demonstrated excellent psychometric properties (Watson & Clark, 1999; Watson et al., 1988). In the present study, the 10-item negative and positive affect subscale scores of the PANAS demonstrated high (α = .88) and good (α = .81) internal consistency, respectively, prior to the BL assessment.

The *Affect Grid* (AG; Russell, Weiss, & Mendelsohn, 1989) is a single-item self-report instrument designed to measure an individual's current affective pleasure-displeasure and arousal-calmness. Respondents place an "X" in the box within a 9 by 9 valence-by-arousal grid that best represents their current mood state. In prior research, AG scores have demonstrated good reliability (Russell et al., 1989) and moderate validity (Killgore, 1998).

Design and procedure

Participants were tested individually in a single 75–90-minute session. They first read the consent form, viewed sample pictures that were representative of (but not presented during) the neutral baseline phase and each mood induction condition and were given an opportunity to ask questions. Individuals who consented then provided basic demographic information and completed the STAI-T, followed by a brief cartoon-rating task to counteract the negative affect potentially induced by viewing sample negative mood induction images. Next, participants received instructions for the RSVP task, completed 24 practice trials and the first state mood assessment (i.e., PANAS and AG), and then began the baseline phase of the study, during which they completed the RSVP task with neutral pictures presented periodically between trials. After completing a second state mood assessment, participants completed the mood induction phase of the study (positive: *n* = 62; negative: *n* = 63). Participants completed a final state mood assessment before being debriefed and paid.

RESULTS

Figures 1 and 2 show the mean attention performance for all combinations of experimental conditions on trials where the emotional target appeared at T1 (Emotion T1) and at T2 (Emotion T2), respectively. Following standards in the attentional blink literature (e.g., Chun & Potter, 1995), T2 accuracy is defined as the mean percentage of trials on which T2 was correctly classified, given that T1 was correctly classified on the same trial (T2|T1 percent correct [PC]). We used this standard for T2 analyses, because several studies have shown a trade-off in performance between T1 and T2, such that greater attention allocation to T1 is associated with reduced attention to T2 (Sergent, Baillet, & Dehaene, 2005; Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006).

Prior to conducting the primary analyses, we confirmed that T1 performance was independent of T2 lag and that T2|T1 PC was significantly greater at Lag 8 (i.e., late lags) than at Lags 2 and 3 combined (i.e., early lags). Satisfaction of these

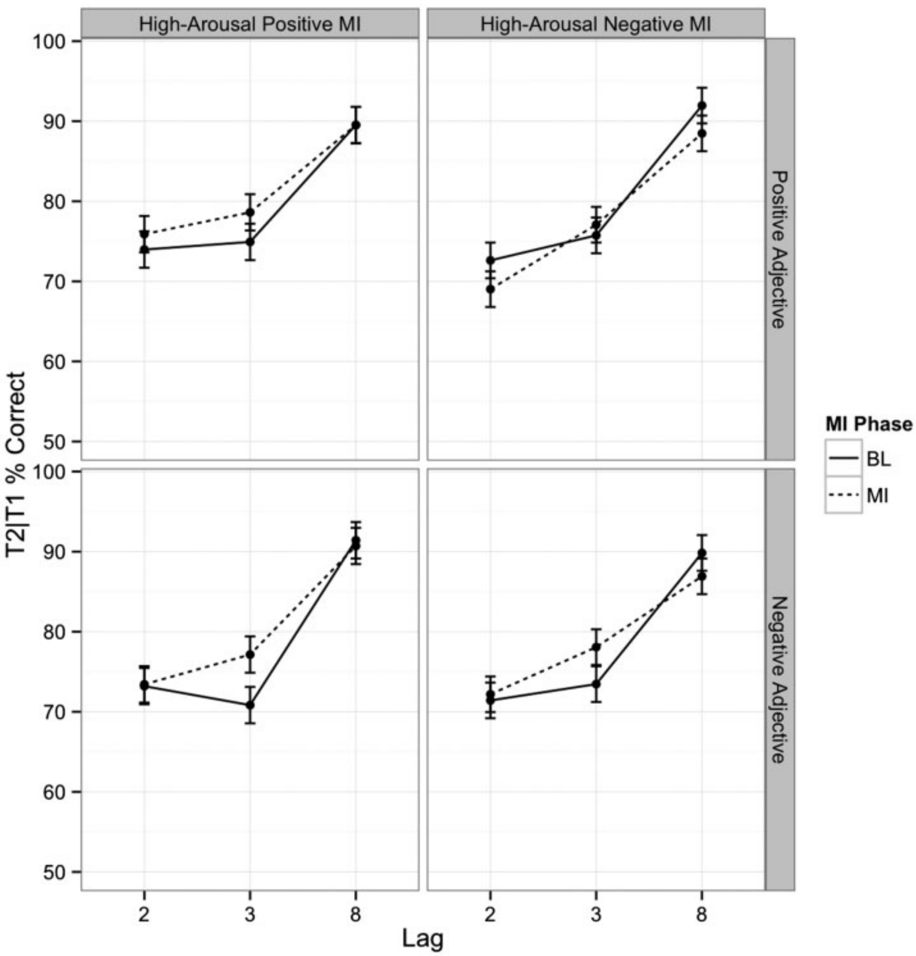

Figure 1. *Mean attention performance on Emotion T1 trials as a function of lag, mood induction phase and mood induction valence.*
Note: BL = baseline; MI = mood induction. Error bars represent ±1 SEM.

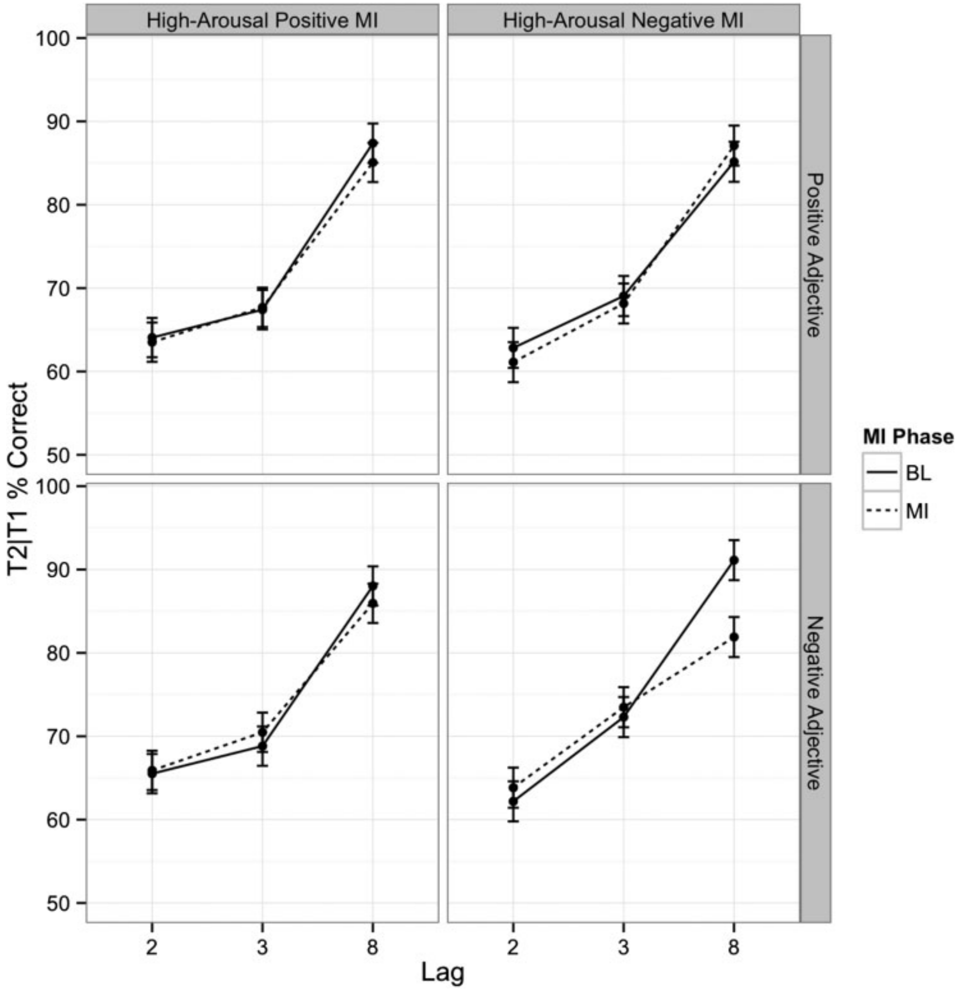

Figure 2. *Mean attention performance on Emotion T2 trials as a function of lag, mood induction phase and mood induction valence.* *Note:* BL = baseline; MI = mood induction. Error bars represent ±1 SEM.

criteria situates the current lag-dependent effects within typical findings of the attentional blink task paradigm (e.g., Chun & Potter, 1995).

Additionally, we assessed the validity of the mood induction by examining the extent to which the PANAS and AG changed across pre-BL (Time 1), pre-MI (Time 2) and post-MI (Time 3) time-points as a function of MI valence and the presence or absence of the MI. Each self-report measure of mood was regressed separately onto MI valence and time using generalised estimating equations (GEE; Zeger & Liang, 1986). Positive affect decreased significantly ($p < .001$) from Time 1 to Time 2 in both the positive and the negative mood induction groups. No other state mood measure changed significantly across the same time interval. For the change in state mood from Time 2 to Time 3, we predicted (1) increased positive affect and positive state mood valence among participants in the positive mood induction condition and (2) increased negative affect and negative state

Table 1. *Model-estimated means for mood measures at each time-point*

	Mood induction valence					
	Positive (N = 62)			*Negative (N = 63)*		
	Time 1 *M (SE)*	*Time 3* *M (SE)*	*Time 3* *M (SE)*	*Time 1* *M (SE)*	*Time 2* *M (SE)*	*Time 3* *M (SE)*
PANAS						
PA	26.10 (0.72)[a]	22.53 (0.87)[b]	26.36 (1.70)[a]	27.75 (0.96)[a]	23.46 (1.04)[b]	23.86 (1.95)[b]
NA	13.76 (0.52)[a]	12.87 (0.40)[a]	12.87 (0.95)[a]	12.89 (0.42)[a]	12.78 (0.41)[a]	17.53 (1.03)[b]
AG						
Valence	6.15 (0.16)[a]	5.73 (0.18)[a]	6.79 (0.37)[b]	6.55 (0.15)[a]	5.98 (0.18)[b]	4.12 (0.39)[c]
Arousal	4.98 (0.25)[a]	4.48 (0.27)[a]	6.35 (0.55)[b]	4.86 (0.24)[a]	4.23 (0.24)[a]	5.79 (0.51)[b]

Note: PANAS = Positive Affect and Negative Affect Schedule; PA = Positive Affect; NA = Negative Affect; AG = Affect Grid. Values with different superscripts within a single row and mood induction valence condition denote a statistically significant difference in estimated means (p < .001) on a 1 df Wald Chi Square test from a GEE model. Higher values above 5 on the AG – Valence denote greater positivity; lower values below 5 denote greater negativity.

mood valence among participants in the negative mood induction condition (Table 1).

Descriptive statistics for the state mood measures at all time-points appear in Table 1. As predicted, mood induction valence interacted significantly with time in predicting PANAS-PA (Wald $\chi^2[1] = 7.71$, $p = .005$), PANAS-NA (Wald $\chi^2[1] = 32.88$, $p < .001$), and AG-Valence (Wald $\chi^2[1] = 100.17$, $p < .001$), but not AG-Arousal (Wald $\chi^2[1] = .63$, $p = .43$). Follow-up simple slope analyses showed that PANAS-PA rose significantly from pre- to post-MI for positive MI, $b = 1.62$, $SE_b = .75$, $p = .03$, but did not change significantly for negative MI, $b = -1.16$, $SE_b = .76$, $p = .13$. PANAS-NA followed the reverse pattern, rising significantly during the negative MI condition, $b = 2.38$, $SE_b = .38$, $p < .001$, but not changing significantly during the positive MI condition. $b = -.27$, $SE_b = .35$, $p = .44$. Finally, AG-Valence rose significantly during positive MIs, $b = .67$, $SE_b = .17$, $p < .001$, indicating more positive state mood, and fell significantly during negative MIs, $b = -1.24$, $SE_b = .23$, $p < .001$, indicating more negative state mood. These manipulation checks suggest that the novel mood induction procedure affected the valence and arousal of state mood as intended.

Effects of mood induction valence on temporal attention to emotional information

We examined the extent to which the valence of the mood induction affected the temporal allocation of attention to positive and negative adjectives in the MI phase, relative to the BL phase. For each combination of trial type (i.e., Emotion T1 and Emotion T2) and dependent variable (i.e., T2|T1 PC averaged across Lags 2 and 3, and T2|T1 PC at Lag 8), we evaluated a GEE model containing the following dummy-coded predictors with all main effects and interactions: (1) MI Valence (positive or negative), (2) Adjective Valence (positive or negative) and (3) MI Phase (BL or MI). We first evaluated the MI Valence by Adjective Valence by MI Phase interaction, because our mood-congruence hypotheses required that we evaluate combinations of these three factors simultaneously. Accordingly, we examined lower-order effects only when the three-way interaction was significant.

Before analysing the data, we excluded participants on the a priori grounds of either T1 accuracy or T2|T1 accuracy at Lag 8 being statistically indistinguishable from chance performance (i.e., falling below the upper bound of the 95%

confidence interval around 50% accuracy). This conservative approach was designed to retain the best available data in the absence of a clear consensus for excluding trials in the literature. The specific rationale for applying the exclusion criterion was that subjects performing at chance on Lag 8 (averaged across all trial types) were not paying adequate attention to the task. The criterion was calculated separately for each trial type, resulting in the exclusion of 15 (12.0%) participants from analyses on Emotion T1 trials and 12 (9.6%) from Emotion T2 trials; this yielded final sample sizes of n = 110 and n = 113, respectively.

T2|T1 PC at Lags 2 and 3

We first focused on the extent to which the three-way interaction between MI Valence, Adjective Valence, and MI Phase predicted T2|T1 performance on Emotion T1 and Emotion T2 trials, where T2 appeared at early lags. The interaction was not significant for either Emotion T1 (Wald $\chi^2[1] = .03$, $p = .86$) or Emotion T2 (Wald $\chi^2[1] = .58$, $p = .45$) trials. Thus, mood-congruent and mood-incongruent adjectives were not associated with differential attention in the presence versus in the absence of a mood induction.

T2|T1 PC at Lag 8

When T2 appeared at Lag 8, the MI Valence by Adjective Valence by MI Phase interaction was not significant for Emotion T1 trials (Wald $\chi^2[1] = .09$, $p = .76$) but was significant for Emotion T2 trials (Wald $\chi^2[1] = 5.96$, $p = .015$). This indicates that, for attentional engagement but not disengagement, mood-congruent and mood-incongruent processing differed in the presence versus the absence of a mood induction. To probe this significant three-way interaction further, we

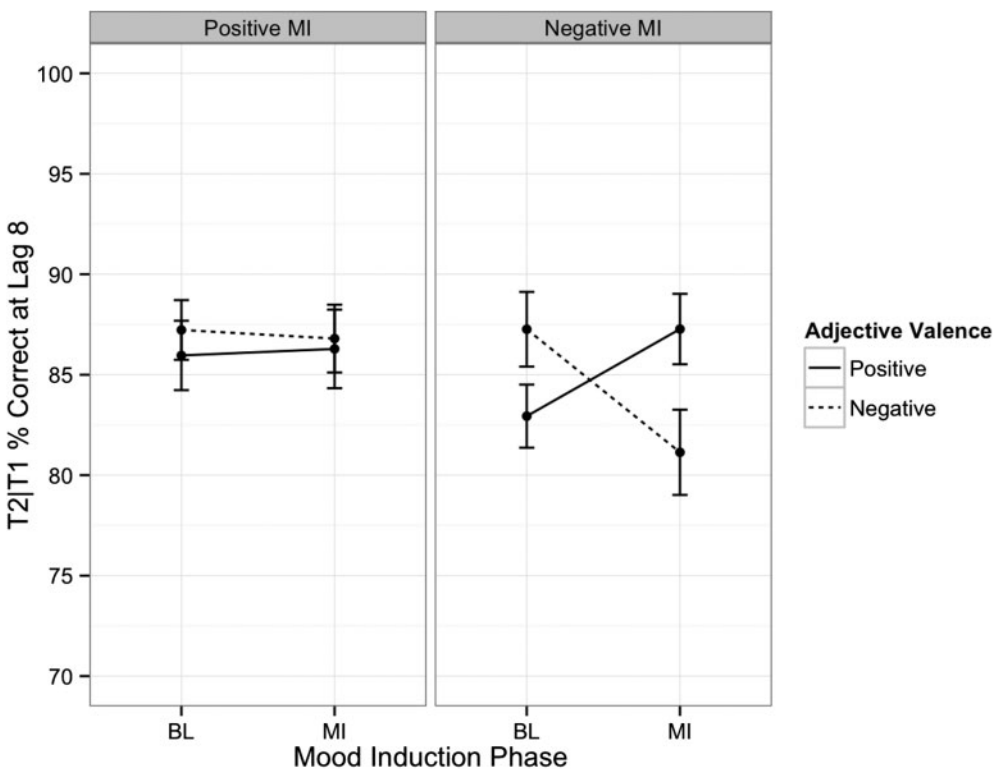

Figure 3. *Effects of mood induction and target adjective valence on T2|T1 correct performance at Lag 8 on Emotion T2 trials.* *Note:* BL = baseline phase; MI = mood induction phase. Error bars represent ± 1 SEM.

examined the Adjective Valence by MI Phase interaction separately for positive and negative MI participants, as shown in the left- and right-hand panels, respectively, of Figure 3. For participants in the positive MI condition, the change in T2|T1 PC from the baseline phase to the MI phase did not depend on the valence of the emotional adjective at T2, Wald $\chi^2(1) = .08$, $p = .78$. However, for participants in the negative MI condition, there was a significant difference between positive- and negative-adjective trials in the change in T2|T1 PC from baseline to MI Phase, Wald $\chi^2(1) = 12.43$, $p < .001$. As revealed in the right-hand panel of Figure 3, in the negative MI condition, T2|T1 PC significantly increased from BL to MI when T2 was a positive adjective ($b = 4.33\%$, $SE_b = 2.05\%$, $p = .03$, 95% CI [0.31%, 8.36%]) and significantly decreased from BL to MI when T2 was a negative adjective ($b = -6.13\%$, $SE_b = 2.64\%$, $p = .02$, 95% CI [−11.31%, −0.94%]). Contrary to our hypothesis that attention would be facilitated to T2 when it was congruent with the valence of the mood induction condition, these findings suggest that negative, but not positive, induced mood was associated with mood-incongruent attention.

Individual difference moderator analyses

We next examined the extent to which the effects of mood induction valence on the engagement and disengagement of attention involving emotional adjectives were moderated by individual differences in trait or naturally occurring state mood. We first considered the trait variables as potential moderators.

Effects of trait mood and mood induction valence on attention to emotional information

As in previous analyses, we fit a separate GEE model to the data for each of the following dependent variables on Emotion T1 and Emotion T2 trials: T2|T1 PC at Lags 2 and 3 and T2|T1 PC at Lag 8. In each model, the dependent variable was regressed onto four predictors and their higher-order interactions: trait anxiety (mean-centred), MI Valence (dummy-coded), Adjective Valence (dummy-coded), and MI Phase (dummy-coded). Trait anxiety did not interact with MI Valence, Adjective Valence, and MI Phase in predicting T2|T1 PC when T2 appeared at early lags on either Emotion T1 (Wald $\chi^2[1] = .00$, $p = .99$) or Emotion T2 trials (Wald $\chi^2[1] = .01$, $p = .92$). The same four-way interaction was not significant when T2 appeared at Lag 8 on either Emotion T1 (Wald $\chi^2[1] = 1.51$, $p = .22$) or Emotion T2 trials (Wald $\chi^2[1] = .40$, $p = .53$). Thus, trait mood did not moderate the effect of mood induction valence on attention to emotional information, regardless of the target that contained the emotional word.

Effects of state mood and mood induction valence on attention to emotional information

Next, we evaluated the extent to which naturally occurring state mood, assessed just before the MI phase (i.e., at Time 2), moderated the MI Valence by Adjective Valence by MI Phase effect on the temporal engagement of attention to and disengagement of attention from emotional information. Analyses proceeded according to the plan described in the previous section, except that self-reported positive affect, mood valence and mood arousal at Time 2 (i.e., just before the MI phase) were examined instead of the individual-difference trait variables.[3]

T2|T1 PC at Lags 2 and 3

We examined the extent to which each state mood variable interacted with MI Valence, Adjective Valence, and MI Phase in predicting T2|T1 PC on early-lag Emotion T2 trials. The four-way

[3] Pre-MI negative affect exhibited extreme positive skew ($z = 8.62$) and restricted range. On a subscale that can range from 10 to 50, 27.4% of participants had total scores of 10 (the subscale minimum), and 73.5% of participants had total scores ≤ 13. Because such extreme restriction of range would yield very low statistical power, the PANAS-NA at Time 2 was excluded from the present analyses.

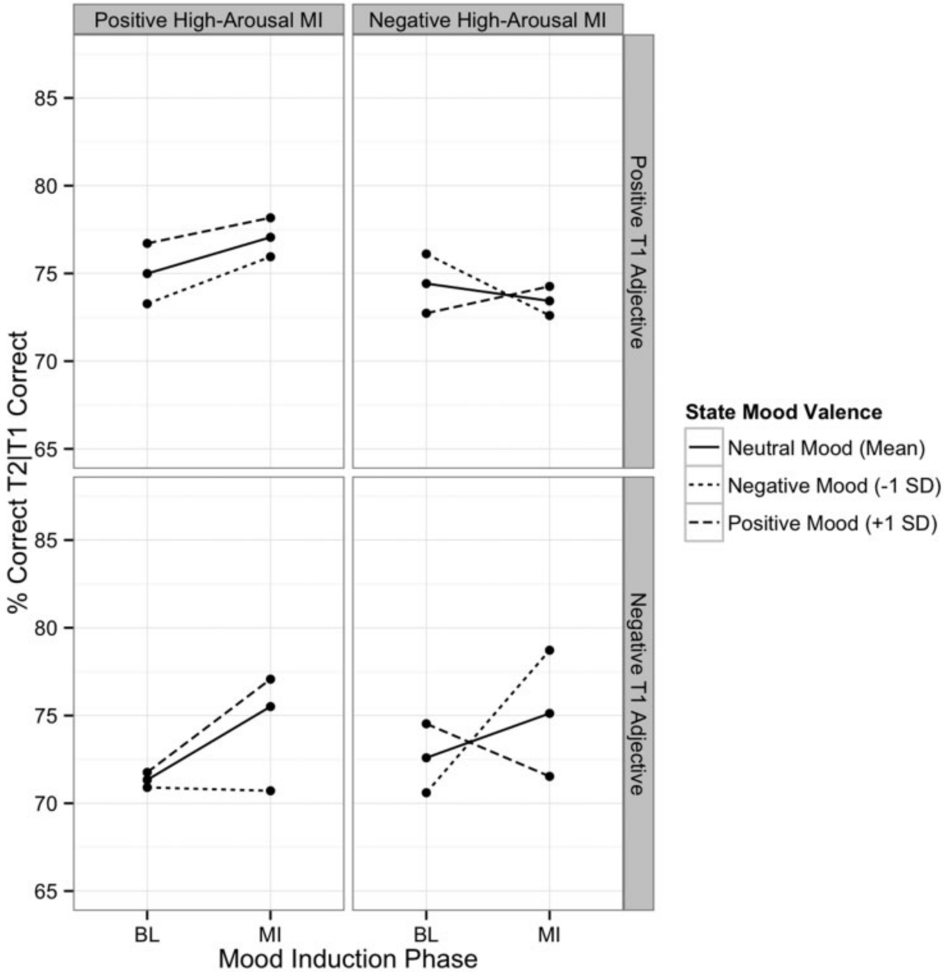

Figure 4. *State mood valence moderates attentional disengagement from negative information at early lags in the negative mood induction condition. Note:* Lags 2 and 3 are combined in this figure. BL = baseline; MI = mood induction.

interaction was not significant for PANAS-PA (Wald $\chi^2[1] = 1.25$, $p = .26$), AG-Valence (Wald $\chi^2[1] = .00$, $p = .98$), or AG-Arousal (Wald $\chi^2[1] = .72$, $p = .40$) (Figure 4).

The same effect was examined on early-lag Emotion T1 trials. Although the four-way interaction was not significant for PANAS-PA (Wald $\chi^2[1] = 1.17$, $p = .28$) or AG-Arousal (Wald $\chi^2[1] = .57$, $p = .45$), it was significant for AG-Valence (Wald $\chi^2[1] = 7.12$, $p = .008$). Participants' ratings of how positive or negative they were feeling just before the mood induction moderated the interaction among MI Valence, Adjective Valence, and MI Phase. To explore this interaction further, the conditional effect of AG-Valence on the Adjective Valence by MI Phase interaction for the positive and negative MI groups was examined (see left and right columns, respectively, of Figure 4). AG-Valence did not moderate the Adjective Valence by MI Phase interaction for the positive MI group (Wald $\chi^2[1] = 1.03$, $p = .31$), but AG-Valence did moderate the same interaction for the negative MI group (Wald $\chi^2[1] = 8.79$, $p = .003$). Examination of the conditional effect of

AG-Valence by MI Phase for each level of Adjective Valence within the negative MI group revealed a significant effect on trials where T1 was a negative adjective (see lower-right panel of Figure 4; Wald $\chi^2[1] = 8.25$, $p = .004$) and a nonsignificant effect on trials where T1 was a positive adjective (see upper-right panel of Figure 4; Wald $\chi^2[1] = 1.17$, $p = .28$).

The relationship between AG-Valence and MI Phase within the negative MI group was probed further by examining the simple slope of AG-Valence on MI Phase on trials where T1 was a negative adjective and T2 appeared at early lags. The relevant means for this effect are plotted in the lower right-hand panel of Figure 4. Specifically, the model-estimated magnitude, direction, and statistical significance of the change from BL to MI in T2|T1 PC were examined for participants with AG-Valence scores at the mean of the MI group (AG-Valence = 5.86, or "neutral" state mood) and both 1 SD below (AG-Valence = 4.38, or "negative" state mood) and 1 SD above the mean (AG-Valence = 7.34, or "positive" state mood). As shown in the lower right-hand panel of Figure 4, on trials where T1 was a negative adjective, T2|T1 PC at early lags improved nonsignificantly from BL ($M = 72.56\%$) to MI ($M = 75.12\%$) for participants with neutral state mood ($b = 2.56\%$, $SE_b = 1.94\%$, 95% CI [−1.24%, 6.36%]; Wald $\chi^2[1] = 1.75$, $p = .19$) and significantly from BL ($M = 70.60\%$) to MI ($M = 78.80\%$) for participants with negative state mood ($b = 8.24\%$, $SE_b = 2.70\%$, 95% CI [2.95%, 13.53%]; Wald $\chi^2[1] = 9.32$, $p = .002$); conversely, T2|T1 PC at early lags decreased nonsignificantly from BL ($M = 74.60\%$) to MI ($M = 71.48\%$) for participants with positive state mood ($b = -3.12\%$, $SE_b = 2.84\%$, 95% CI [−8.67%, 2.44%]; Wald $\chi^2[1] = 1.21$, $p = .27$). Thus, for participants in the negative MI group, a negative pre-MI mood state was associated with increased disengagement of attention from negative T1 adjectives at early lags during the MI relative to the BL phase; this relationship was not significant for participants with neutral or positive pre-MI mood state.

T2|T1 PC at Lag 8

Finally, we examined the extent to which each naturally occurring state mood variable interacted with MI Valence, Adjective Valence, and MI Phase in predicting T2|T1 PC on late-lag trials. The relevant four-way interaction was not significant for any of the state mood variables on either trial type (all ps > .14). Thus, in contrast to early lags, individual differences in pre-MI state mood did not moderate the effect of MI valence on either engagement or disengagement of attention to emotional information.

DISCUSSION

Investigators have long observed that both manipulated (e.g., Richards, French, Johnson, Naparstek, & Williams, 1992) and naturally occurring affective states (e.g., MacLeod & Mathews, 1988) can influence attentional performance. However, surprisingly little research has examined how these aspects of mood are related to the temporal allocation of attention to emotional information. Temporal and spatial dimensions of attention are confounded in visuospatial paradigms such as dot probe, exogenous cueing, and visual search, obscuring a clear assessment of temporal attention and its relationship to state, trait and induced mood. Thus, in the present study, we modified the RSVP paradigm to assess the time course of attention to positive and negative information in both the absence and presence of a within-subjects mood induction. To examine how the valence of target information interacted with the valence of induced mood, participants completed the attention task during a neutral baseline condition and then during either a positive or negative mood-induction condition. Moreover, we modified the RSVP paradigm to examine how aspects of mood are related to temporal attentional engagement to, and disengagement from, emotional information. Finally, self-report measures of state mood and trait anxiety were obtained to examine whether individual differences in these idiographic components of mood moderated the effect of the valence of the mood induction on temporal attention to emotional information.

Three key findings emerged. First, during the negative mood induction, positive T2 adjectives at Lag 8 were identified more accurately, and negative T2 adjectives at Lag 8 less accurately, than during a prior neutral-mood baseline condition. This suggests that, under low attentional load, induced negative mood facilitated attentional engagement to positive information but decreased attentional engagement to negative information. This finding runs counter to predictions derived from mood-congruence theories such as Bower's associative network theory, in that mood-congruent information should require a lower threshold for activation compared to mood-incongruent information (e.g., Bower, 1981). However, the finding is partially consistent with motivational accounts of attention, such as affective counter-regulation (Rothermund, Voss, & Wentura, 2008) and mood repair (Rusting, 1998; Rusting & DeHart, 2000) theories.

Affective counter-regulation theory holds that attention is allocated automatically to stimuli opposite in valence to one's motivational state (Rothermund et al., 2008). Consistent with our findings, individuals with a negative motivational focus have shown enhanced attention to positive versus negative information (Rothermund, 2003; Rothermund et al., 2008; Rothermund, Gast, & Wentura, 2011). However, this effect was not seen at earlier lags, and a complementary opposite pattern did not emerge in the positive mood induction condition.

In contrast to affective counter-regulation theory, mood repair theory (Rusting, 1998; Rusting & DeHart, 2000) holds that negative moods motivate individuals to engage in strategic mood repair processes, such as up- or down-regulating their attention to emotional stimuli as needed to regulate their negative mood state. If this view is correct, then attention to positive information should be up-regulated, and attention to negative information down-regulated, in the negative mood induction condition. It follows that induced negative mood should enhance the engagement of attention to positive information and reduce engagement to negative information. Moreover, because mood repair typically is considered to be a strategic, effortful process (Rusting & DeHart, 2000), its attentional effects would be more likely to be observed at long rather than short lags. This is consistent with the present findings. Thus, the rapid, flexible modulation of attentional engagement may be a strategic mechanism by which individuals can potentially regulate negative moods.

Individual differences in neither state nor trait negative mood moderated the reliable effects of manipulated negative mood on attentional engagement. These null findings were not predicted in advance, and are not consistent with mood repair, associative network or affective counter-regulation theories. According to mood repair theory, individuals with higher levels of either state or trait negative mood presumably would have a greater motivation to repair their negative mood. An alternative explanation is that higher levels of negative mood increase the motivation to engage in mood repair but decrease the ability to engage in it through attentional control. In support of this, trait anxiety and self-reported attentional control have shown moderately negative correlations in prior research (e.g., $r = -.55$; Derryberry & Reed, 2002). Moreover, the absence of any mood-congruent facilitation effects is inconsistent with associative network theory, which would predict the enhancement of attention to mood-congruent information through heightened activation of semantic associations between nodes in memory. Affective counter-regulation theory would predict that trait or state mood would enhance attention to mood-incongruent information because of their association with more negative motivational states. This clearly was not supported either.

The absence of an association between either state or trait mood and attentional engagement in response to a highly arousing negative mood induction is also at odds with a large literature linking both state and trait anxiety to enhanced attention to threatening information (see Bar-Haim et al., 2007, for a meta-analysis). However, whereas this literature has focused almost exclusively on the spatial allocation of attention among people responding to threatening vs. neutral stimuli (without a mood manipulation), the present study assessed how the temporal allocation of attention is affected by induced mood among people varying in state or trait negative mood. Thus, the present findings suggest that state negative mood and trait anxiety may differentially affect temporal and spatial attention to emotional information. Future research will be needed to determine the extent to which these differences are driven by different mechanisms of attentional control.

The second key finding of the present study is that, relative to the neutral-mood baseline condition, greater naturally occurring negative state mood immediately prior to the negative mood induction was associated with improved identification of neutral T2 nouns appearing at early lags after negative, but not positive, T1 adjectives. This pattern of effect suggests that negative state mood facilitated the disengagement of attention from the negative target, enabling participants to more accurately classify the neutral target word that followed it. This result was consistent with our mood congruence hypothesis for the negative, but not positive mood induction condition. Moreover, this finding occurred too quickly to be consistent with strategic mood repair theories. It is also inconsistent with automatic mood repair theories, in that identification of neutral T2 adjectives did not decline following the presumably attention-capturing mood-incongruent (positive) T1 adjectives. This finding may be explained better by associative network theory, in which negative mood lowers the activation threshold for processing negative information, both freeing attentional resources for, and improving identification of, other task-relevant information.

One potential implication of this finding is that greater naturally occurring negative state mood improves the efficiency of attentional disengagement from negative information in the presence of manipulated negative mood. The literature has been mixed on this point. Consistent with our interpretation, Lystad et al. (2009) found early-lag reductions in the magnitude of the attentional blink following anxious, but not neutral, T1 words only in a manipulated anxious mood condition. Other studies have reported faster disengagement of attention from trauma-relevant compared with negative, trauma-irrelevant stimuli among individuals with higher levels of posttraumatic stress symptoms (e.g., Amir, Taylor, Bomyea, & Badour, 2009). On the other hand, one small (N = 28) study found that, compared to non-dysphoric individuals, dysphoric individuals exhibited a greater attentional blink 300 ms after negative, compared to neutral or positive, T1 words (Koster, Raedt, Verschuere, Tibboel, & De Jong, 2009). But, as Koster et al. (2009) did not manipulate state mood, it is more appropriate to compare their findings to the pre-mood-induction neutral baseline phase of the present study. In that condition, we found with a larger sample that naturally occurring state mood was not associated with identification of neutral T2 words following negative versus positive T1 adjectives. Koster et al.'s (2009) finding also emerged when comparing discrete groupings of individuals based on dysphoria ratings derived from the Beck Depression Inventory-II (BDI-II; Beck, Steer, Ball, & Ranieri, 1996), a clinical instrument designed to capture more persistent and pronounced mood states, whereas, in the present study, the effect emerged when transient mood state was treated as a moderator. Future research will be needed to examine the extent to which this effect occurs for spatial attention, and to examine the duration of effects after the mood induction. Such information might provide clues about the source and generality of the present finding.

The third key finding of the present study was that it provided preliminary positive evidence for the feasibility, validity and utility of a novel mood induction procedure. The mood induction was designed to create robust negative or positive mood states that endure long enough to allow for concurrent assessment of the temporal allocation of attention to emotional information. In contrast to popular mood induction methods in the attentional blink literature, such as playing music in the background during administration of the RSVP task (e.g., Jefferies et al., 2008; Lystad et al., 2009;

Olivers & Nieuwenhuis, 2005), the present mood induction method minimised potentially artefactual attentional demands during the assessment by presenting the emotional images between, rather than during, trials of the attention task. Another strength of the current design was the assessment of temporal allocation of attention both in the absence and presence of a mood induction in the same individuals. The within-subjects design enhanced the strength of inferences about the mood-attention relationship. Future research on the effects of induced mood on attention may benefit from incorporating these design characteristics.

Several commonalities and differences exist across the current attentional findings. An important similarity is that attentional effects were observed only in the negative mood manipulation condition. In addition, state or trait attentional effects were found only with greater negative state mood and negative stimuli, and not with positive state mood or positive stimuli. This is consistent with the prioritised processing accorded to negative information in many models of information processing (e.g., MacLeod & Mathews, 1988). A potentially important difference between the present findings is that mood effects on attentional engagement and disengagement were observed at different stages of processing and in association with different aspects of mood. Engagement effects were seen only for the effects of manipulated negative mood on a longer timescale; this allows for, but does not necessarily entail, the influence of controlled processes such as strategic mood regulation. Unlike engagement effects, however, disengagement effects were observed only on a shorter timescale and only in association with the state aspect of negative mood.

This study had several limitations that suggest future directions for this research. First, the set of positive IAPS images was normatively more arousing than the set of negative IAPS images (M = 0.39, SE = .09, p < .001). Equivalence on arousal would be desirable in future research. However, the fact that positive photos were normatively more arousing than negative photos runs counter to the differences observed, which all occurred in the negative mood induction condition. Thus, it is unlikely that this difference produced the effects we observed. Second, women were not included in this study, because extensive normative data suggested that college-age women and men differ markedly in their subjective ratings of valence and arousal in response to the same IAPS stimuli (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Lang et al., 2005). Examination of women's responses on this task is clearly of interest for future research.

Results of the present study suggest that the relationship between mood and attention to emotional information is more complex than previously thought. The relationship may differ not only between temporal and spatial aspects of attention, but also as a function of the attention mechanisms (engagement versus disengagement), aspects of mood (state versus trait versus induced), stimulus valences (positive versus negative) and timescales (early versus late) under investigation. To better understand how these aspects of mood and attention interrelate, future research in this area should use methods that are sensitive to differences in these factors and should avoid collapsing across aspects of attention and mood. An important objective for future research is to evaluate the consistency with which the present relationships between mood and attention hold. If they do, several theories addressing the mood-attention link, such as mood repair (Rusting & DeHart, 2000), associative network (Bower, 1981) and affective counter-regulation (Rothermund et al., 2008) theories, may need to be extended to encompass these additional parameters. Moreover, investigations that seek to induce mood may benefit from manipulation procedures, such as the novel one employed in the present study, that maintain mood states throughout the attention task without contaminating the assessment of attention.

Finally, future research should examine the extent to which the pattern of findings in the present study corresponds to those found in clinically anxious individuals, in whom anxiety-related mood states and attentional abnormalities have been robustly documented (Bar-Haim et al., 2007; Cisler & Koster, 2010). Such research has the potential to bridge clinical and nonclinical models of mood and attention.

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