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Modulatory Effects of Positive Mood on Cognition: Lessons From Attention and Error Monitoring

Gilles Pourtois[1], Naomi Vanlessen[1], Jasmina Bakic[2], and Katharina Paul[1]
[1]Ghent University and [2]University of Maastricht

Abstract

The importance of positive mood for health and well-being is a truism. However, we still lack clear understanding of the nature and range of modulatory effects created by positive mood on cognition in humans. Here, we briefly review two recent research lines that have attempted to address this question systematically. Specifically, research on attention has explored the boundaries of the so-called broadening of attention with positive mood. Likewise, effects of positive mood on error monitoring have been scrutinized lately. The new empirical findings gathered in these two separate research domains concur on the assumption that positive mood is not merely adding noise to cognition. Instead, this mood state seems to provide the organism with meaningful (internal) information, which allows for timely and flexible exploration of new opportunities in the (external) environment and alters the motivational significance of negative events, such as response errors, in a rather flexible way. As such, these new findings provide information about the existence of complex interaction effects between positive mood and cognition and may help, in turn, to better appraise the actual role and function of this protective mood state for health and cognition.

Keywords

positive mood, attention, error monitoring, event-related potentials

The beneficial and protective role of positive emotions is well-known. Somewhat surprisingly, little is known regarding the actual modus operandi of positive mood compared to negative mood or state anxiety, and more specifically if and how it can dynamically and systematically influence cognition in humans. This imbalance in the literature may be explained by several factors, including the prevailing focus in clinical psychology on stress, depression, anxiety, pain, or vulnerability factors to emotional disorders. Although these psychopathological conditions are characterized by an increase in negative affect or distress, they are usually also accompanied by a decrease in positive affect (Larsen & McGraw, 2011; Pizzagalli, 2014). Accordingly, exploring effects of positive mood on cognition might ultimately help to prevent their onset and maintenance, thereby fostering resilience and improving life quality in the long run (Kalisch, Muller, & Tuscher, 2015).

Notably, several recent research attempts in psychology have begun to delineate the nature and range of cognitive changes brought about by positive mood during information processing in healthy adult participants (see also Goschke & Bolte, 2014; Dreisbach & Fischer, 2012). In particular, systematic efforts in two seemingly disparate research domains have advanced this field, providing a better handle on the complex interplay of cognition with positive emotion. (i) On the one hand, positive mood appears to broaden the focus of (external) attention, under specific circumstances. (ii) On the other hand, positive mood seems to decrease the motivational significance of (internal) negative events during performance monitoring, such as response errors. Although these two effects go in opposite directions, they might stem from a common or general mechanism. Positive mood appears to create a trade-off between external and internal information processing,

Corresponding Author:
Gilles Pourtois, Cognitive and Affective Psychophysiology Laboratory, Department of Experimental Clinical & Health Psychology, Ghent University, Henri Dunantlaan 2, 9000 Ghent, Belgium
E-mail: gilles.pourtois@ugent.be

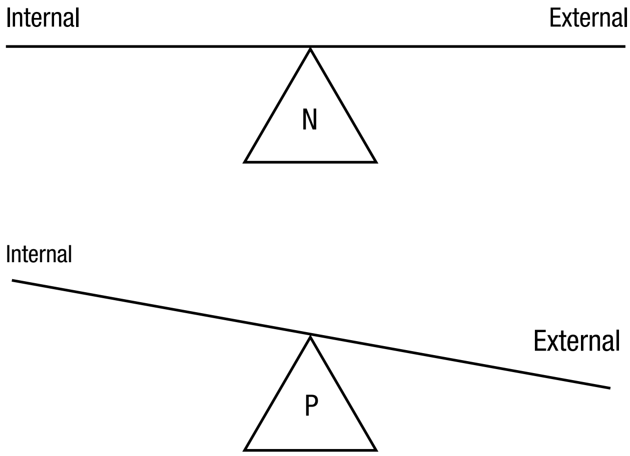

Fig. 1. Relative to neutral mood (N; upper panel), positive mood (P; lower panel) might alter the balance between internal and external information processing, increasing the latter (leading to a broadening of attention), while decreasing the former (consistent with a lowered error monitoring [EM]) (see Vanlessen, De Raedt, Koster, & Pourtois, 2016, for a similar framework).

whereby the former is increased at the expense of the latter (see Fig. 1).

More generally, these effects are informative because they suggest that positive mood likely influences cognition to improve information processing, as opposed to creating noise or mere distraction, for instance. In what follows, we first clarify what is entailed by positive mood here, before reviewing novel empirical results obtained in the field of visuospatial attention and error monitoring (EM) and assessing each time how they fit this general framework (see Fig. 1). Last, we summarize these findings and draw specific conclusions that might hopefully serve as a blueprint for a wide range of researchers interested in modulatory effects of positive mood on cognition and stimulate additional research efforts in this domain.

Positive Mood

Compared to negative emotions where clear taxonomies and some valuable differentiations have been put forward in the literature, positive emotions are usually ill-defined and therefore hard to operationalize when it comes to their elicitation and measurement in well-controlled experimental designs (Shiota et al., 2014). Moreover, positive *emotions* are often studied in response to short-lived positive or rewarding stimuli (i.e., eliciting approach motivation), whereas positive *mood* is a genuine subject-specific state that emerges from within the individual, is not necessarily bound to a specific external event, lasts a few minutes, and has potentially broad but labile effects on cognition (Berridge & Kringelbach, 2013). Positive mood corresponds to the tonic activation of a specific internal state characterized mainly by the experience of pleasure or joy at moderate intensity, which is not necessarily bound to a specific elicitation event. To overcome this problem, mood induction procedures (MIPs) can be used in the laboratory with the aim to alter the affective state of the participant (Holmes & Mathews, 2010). In this context, the use of guided imagery provides a valuable means to elevate the participants' current mood. Participants are asked to actively relive a personally relevant memory episode colored by positive emotion (such as happiness or joy), which leads to an increase in happiness, pleasantness, and/or arousal that outlasts the MIP and can therefore be combined with another task. The added value of this procedure is that it is carefully controlled from an experimental point of view as well as tailored to the specific experience of each individual participant (see Paul & Pourtois, 2017; Paul, Walentowska, Bakic, Dondaine, & Pourtois, 2017), as opposed to the use of standard movie clips, music, or reward. Further, this MIP is capable of increasing the current happy mood state of the participant, even though he or she may already experience positive affect when entering the laboratory. Two recent research lines have directly capitalized on this MIP and the generation of potent positive mood states in healthy adult participants, with the aim to explore their impact on either attention or EM processes, as outlined hereafter.

Attention

According to the dominant broaden-and-build theory (Fredrickson, 2001; Garland et al., 2010), positive emotions (and by extension positive mood) reliably influence attention and cognition. Central to this theory is the tenet that positive emotions broaden attention and fuel cognition with additional resources that could be protective against deleterious effects created by stress or negative affect. However, direct empirical evidence supporting this claim is actually scant in the extant literature. As a matter of fact, many studies have previously explored the putative broadening functions of positive emotions using tasks or experimental designs that were not entirely suited to investigate visuospatial attention per se (for a recent review, see Vanlessen et al., 2016; see Figs. 2a and 2b). For example, interference tasks, such as the flanker task, have been used often in the past to show that positive mood broadens attention (Rowe, Hirsh, & Anderson, 2007).

However, this task usually taps into cognitive control functions (such as inhibition and conflict monitoring) besides attention that could also be influenced by positive mood concurrently, making it difficult to disentangle whether attention or another cognitive process is eventually influenced by positive mood (Ashby, Isen,

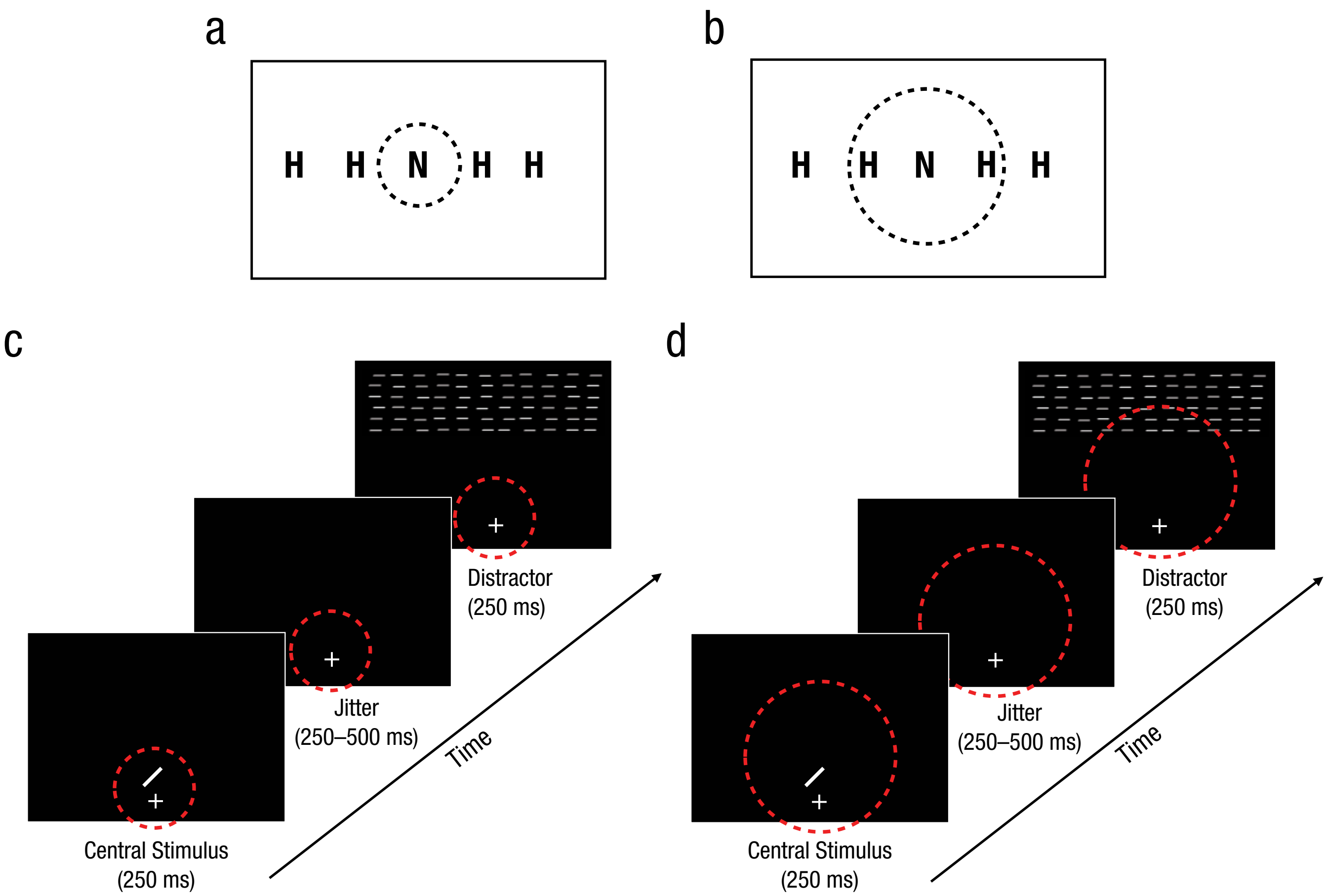

Fig. 2. (a) As used in Eriksen flanker tasks, the central stimulus (here a single letter) is flanked by either congruent or incongruent letters, used as distractors (as shown here). Participants are asked to discriminate the central stimulus. Behavioral performance is worse and slower when incongruent stimuli are used as flankers, compared to congruent ones. In a neutral mood state, attention (depicted by the dotted circle) can be focused and directed at the central target stimulus, selectively. (b) By comparison, in a positive mood state, the focus of attention is broader, hence a larger or stronger interference effect created by the distractors is reported (see Rowe, Hirsh, & Anderson, 2007). (c) A simple paradigm has been devised to explore effects of positive mood on attention without confounds related to conflict or cognitive control. In this paradigm, attention is anchored at a central location in the visual field (where specific targets have to be processed, here a little tilted line bar appearing just above fixation), while distractors (large textures) are shown at an unpredictable time and location in the upper visual field. When the mood state is neutral, the focus of attention is narrowed around the central location (as shown with the red dotted circle). (d) By comparison, in a happy mood state, attention broadens and hence the processing of the peripheral distractors is increased, as shown using event-related potential methods. The early neural response to the distractor in the visual cortex is larger in happy than neutral moods (especially if it is shown far away from fixation in the periphery; see Vanlessen, Rossi, De Raedt, & Pourtois, 2013). Moreover, when asked to process its content, participants in a happy mood are worse than in a neutral mood, as if the broader attention focus was accompanied by a drop in resolution at the attended location given that it spans a larger portion of the visual field (see Vanlessen, Rossi, De Raedt, & Pourtois, 2014).

& Turken, 1999; Vanlessen et al., 2016; Vanlessen, De Raedt, Mueller, Rossi, & Pourtois, 2015).

To overcome this limitation, we previously used a standard visual discrimination task at fixation enabling careful anchoring of selective attention at a fixed position in the visual field (see Figs. 2c and 2d), while measuring the processing of (and attention allocated to) neutral stimuli shown at various locations relative to fixation in the periphery (Rossi & Pourtois, 2013; Vanlessen et al., 2013). As expected, results showed that relative to participants in a neutral mood condition, participants in the positive mood group exhibited an early broadening of attention, as demonstrated by a stronger sensory encoding of peripheral stimuli shown far away from fixation (see Figs. 2c and 2d). These effects were visible within the first 100 ms following stimulus onset using event-related potential (ERP) methods, suggesting a perceptual locus, as opposed to changes occurring at a postperceptual or decision stage. However, this broadened attention with positive mood was accompanied by a drop in spatial resolution, as evidenced by a poorer ability to discriminate the content of these peripheral visual stimuli at the behavioral level. This finding suggests that positive mood likely yielded a coarse and diffuse information-processing style, perhaps compatible with an enhanced exploration of the periphery (Vanlessen et al., 2016). This processing style refers to the fact that while the attended portion of the peripheral visual field was seemingly larger in happy compared to neutral mood, processing low-level details in this part of the visual field was impaired, comparable with a large but unfocused zoom in happy mood. In a follow-up study (Vanlessen et al., 2014), we replicated these results and confirmed that positive mood broadens attention and was accompanied by a diffuse information-processing style. Collectively, these findings therefore lend support to the assumption that positive mood creates a trade-off in early visual processing (Muller, Bartelt, Donner, Villringer, & Brandt, 2003), which can be expressed by a broadening of the attentional focus, associated with a cost to process (fine-grained or local) details. Notably, such a trade-off in early vision with positive mood could very well result from a change in the balance between internally and externally directed attention (Chun, Golomb, & Turk-Browne, 2011). In this scenario, positive mood would actually tip the balance toward externally driven attention (see Fig. 1), which would maximize exploration and the encounter of opportunities, assuming that all processing resources have not been utilized by a demanding task (Vanlessen et al., 2016).

EM

EM is a mental process of the utmost importance that enables the swift detection of mismatches between goal or intention and action, such as unwanted response errors. EM provides a window into performance monitoring, and as such, it has been explored extensively in the literature (Koban & Pourtois, 2014; Ullsperger, Fischer, Nigbur, & Endrass, 2014). Although error detection is by definition an internal mental process, ERP methods can be used to gain insight into it. Error commission is usually associated with the generation of two well-defined ERP components (i.e., the error-related negativity [ERN], generated between 0 and 100 ms after response onset and peaking over fronto-central electrodes along the midline, followed by the error positivity [Pe], elicited between 150 and 300 ms after response onset at more posterior and parietal leads). Although the ERN reflects the early automatic detection of errors, the Pe is usually thought to capture specific attentional and/or motivational processes associated with these worse-than-expected negative events. Hence, using this framework, it is possible to assess at which stage and in which direction positive mood may influence EM. Moreover, by changing the perceived motivational significance of response errors across different task contexts, one can eventually evaluate if positive mood influences EM generically, or instead in a context-sensitive and flexible manner (Proudfit, Inzlicht, & Mennin, 2013). For example, when response errors inadvertently occur during reinforcement leaning (see Frank, Woroch, & Curran, 2005), these events are not just aversive, conflict-related or negative as such (Aarts, De Houwer, & Pourtois, 2012), but they presumably provide a potent learning signal and meaningful information for the organism. Interestingly, in this context, positive mood appears to enhance early error detection at the ERN level, specifically (Bakic, Jepma, De Raedt, & Pourtois, 2014). This result suggests the existence of a mood congruency effect, whereby the phasic and transient signal elicited by errors is temporarily augmented with happy mood, probably to provide a timely signal of their mismatching properties. In comparison, when response errors take place in a task context devoid of learning, such as during a standard interference task, the modulatory effect of positive mood on EM is notably different (Paul et al., 2017). In this context, response errors usually correspond to lapses of attention or concentration (Weissman, Roberts, Visscher, & Woldorff, 2006), and hence, they likely acquire a different meaning than response errors committed during learning (Bakic et al., 2017). In this situation, positive mood appears to decrease the (otherwise enhanced) motivational significance of response errors (at the Pe level selectively, while leaving the early ERN unchanged), consistent with a lowered processing of internal information (see Fig. 1), suggesting again the existence of a mood congruency effect (see Fig. 1). Presumably, in order to preserve the benefits associated with the experience of positive mood, it is probably useful to transiently downplay the motivational significance of these worse-than-expected events in order to avoid jeopardizing the positive mood state (Paul et al., 2017). Alternatively, positive mood might make response errors (which are presumably negatively connoted) “loom” to a larger extent than neutral mood when they conflict with the current mood state (hence creating a contrast effect during learning), while in other situations or contexts (when simple cognitive control tasks are used), it might conversely make them less salient by means of assimilation or regulation (Bless & Schwarz, 2010). All in all, this contemporary research showed that modulatory effects of positive mood on EM are actually best conceived as being primarily context-sensitive and flexible, which might be an important prerequisite to foster goal-adaptive behavior across changing contexts and situations.

Conclusions

Even though positive mood is usually acknowledged as one of the main building blocks of mental health

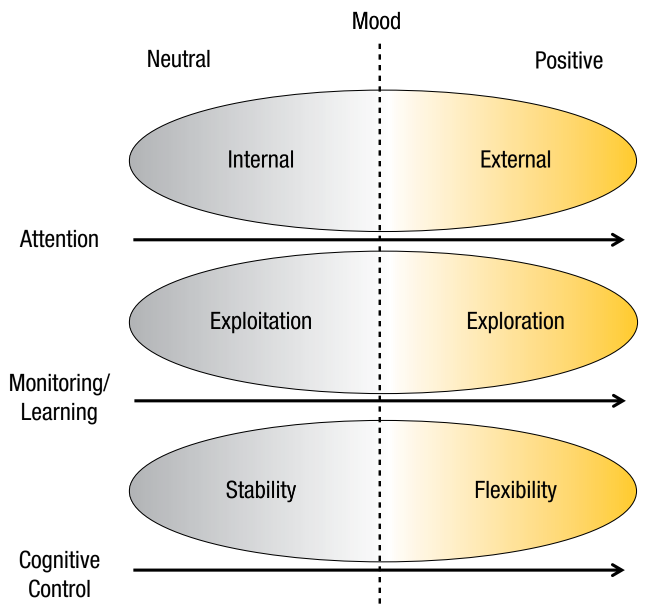

Fig. 3. Presumably, effects of positive mood on visuospatial attention and error monitoring likely stem from a change in a general or higher-up cognitive function, such as working memory (i.e., altering the balance between internal and external attention; see Chun et al., 2011; Vanlessen et al., 2016), learning (i.e., altering the trade-off between exploration and exploitation, likely via changes in dopamine neurotransmission; see Schultz, 2015), or cognitive control (i.e., enhancing flexibility, instead of stability; see Chiew & Braver, 2011; Cools & D'Esposito, 2011; Frober & Dreisbach, 2014).

and well-being (Garland et al., 2010; Gotlib & Joormann, 2010), systematic research efforts in psychology meant to elucidate its putative effects on cognition have been made only recently. In particular, two separate research domains have witnessed specific advancements regarding the nature and extent of modulatory effects created by positive mood on cognition in humans. (i) Studies on attention and visual cognition have confirmed that positive mood broadens attention but decreases spatial resolution concurrently (Vanlessen et al., 2016). (ii) In the case of EM, positive mood appears to influence it in a mood-congruent fashion, with dissociable effects depending on the specific task setting and the putative motivational significance of response errors. Although these two research lines developed relatively independently from one another, it is likely that these phenomena actually reflect a general change in cognitive processing with positive mood, with remote and seemingly opposing effects in visuospatial attention and EM. Presumably, positive mood might influence an overarching cognitive function (see Chiew & Braver, 2011; Frober & Dreisbach, 2014), such as working memory (WM), learning, or cognitive control (see Fig. 3), which in turn gives rise to increased processing of external information but decreased internal EM (see also Fig. 1).

Interestingly, such a trade-off could potentially account for the observation of a more outward- (or alternatively, less inward-) oriented focus in happy mood, with effects on complex internal processes such as mind wandering (see Killingsworth & Gilbert, 2010). At the neural level, dynamic and diffuse changes in prefrontal dopaminergic signaling with positive mood might underlie these modulatory effects of cognition with this specific mood state (Ashby et al., 1999). In this account, positive mood would not change attention or EM directly, but instead indirectly, perhaps via modulations of higher level cognitive control or WM processes. Hence, positive mood could influence prefrontal dopaminergic signaling, which in turn could affect either specific WM functions or dedicated cognitive control processes that all heavily depend on prefrontal cortex's integrity (see Fig. 3). Moreover, this would allow for maintaining the beneficial effects brought about by positive mood. Future studies are needed to assess which of these overarching cognitive processes positive mood influences systematically (see Fig. 3) and whether this effect might then account for the changes in the size of the attention's focus as well as the monitoring of response errors associated with this specific mood state, as reviewed above.

Remarkably, both research lines outlined here reveal that positive mood provides the organism with a powerful information signal (Mitchell & Phillips, 2007; Schwarz & Clore, 2003) that allows for promoting exploration (i.e., to tip the balance toward external attention, which can lead to a broadening of attention) as well as for evaluating negative (internal) states or values in a flexible and mood-congruent way (with corresponding changes in the rapid monitoring of response errors). Depending on the specific context, goals or desires, and task demands, effects of positive mood on cognition could therefore lead to either benefits or costs during information processing. Thus, broadening attention could be advantageous in specific circumstances (such as exploration of new contingencies or possible rewards in the environment) but not in others (such as exploitation of prior knowledge). Likewise, it could be beneficial to lower internal EM in specific conditions (such as associative thinking or creativity), whereas it may be detrimental to performance in other cases (when logic or reasoning needs to be used). A better understanding of these effects evidenced in healthy adult participants may also help to better appraise which factors underlie the onset and maintenance of mood disorders such as anxiety or depression, which are often marked by a breakdown in positive affect and mood, and debilitating effects on cognition, including attention and EM.

Recommended Reading

Garland, E. L., Fredrickson, B., Kring, A. M., Johnson, D. P., Meyer, P. S., & Penn, D. L. (2010). (See References). This article provides an integrative view of the role of positive and negative affect in a wide range of cognitive and mental processes.

Koban, L., & Pourtois, G. (2014). (See References). This article provides a review and model explaining the likely cognitive and brain mechanisms through which performance monitoring may be influenced by mood and affect.

Shiota, M. N., Neufeld, S. L., Danvers, A. F., Osborne, E. A., Sng, O., & Yee, C. I. (2014). (See References). This article provides one of the few attempts in the literature to break down and differentiate positive emotions into different (and functionally dissociable) subcategories.

Vanlessen, N., De Raedt, R., Koster, E. H., & Pourtois, G. (2016). (See References). This article provides a systematic and exhaustive review of existing studies (in psychology and neuroscience) that have explored the putative broadening of attention with positive mood, suggesting that positive mood might very well change the balance between internally and externally directed attention.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

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