Modulatory effects of positive mood on cognition: lessons from attention and error monitoring

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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 allowing to timely and flexibly explore new opportunities in the (external) environment, as well as alter the motivational significance of negative events, such as response errors, in a rather flexible way. As such, these new findings inform 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 ubiquitous and omnipotent. 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. While 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).

Noteworthy, 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 Goshke & 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 however. (ii) On the other hand, positive mood seems to decrease the motivational significance of (internal) negative events, 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 tradeoff between external and internal information processing, whereby the former is increased at the expense of the later one (see Figure 1).

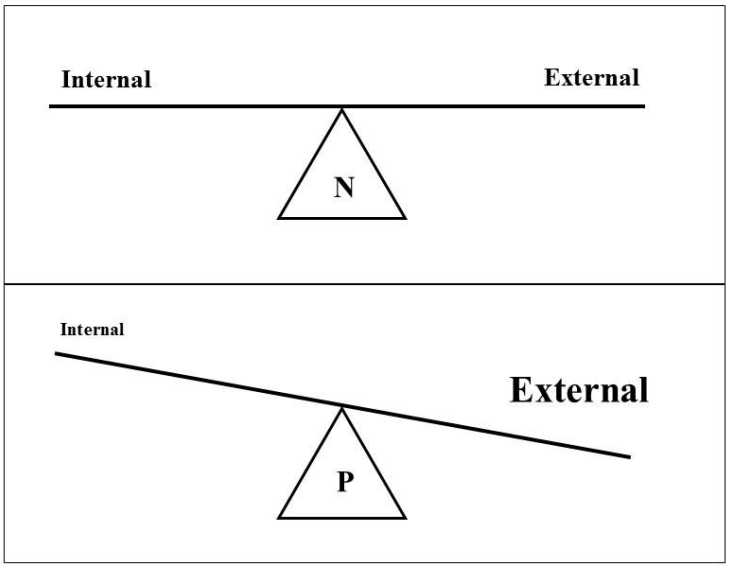

Figure 1. Relative to neutral mood (upper panel), positive mood (lower panel) might alter the balance between internal and external information processing, increasing the latter (leading for example to a broadening of attention), while decreasing the former (consistent with a lowered error monitoring for instance) (see also Vanlessen et al., 2016 for a similar framework).

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 visuo-spatial attention and error monitoring (EM), and assessing each time how they fit this general framework (see Figure 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), while positive *mood* is a genuine subject-specific state, emerging from within the individual, not necessarily bound to a specific external event, lasting a few minutes, and with potentially broad but labile effects on cognition (Berridge & Kringelbach, 2013). Hence, 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, or at least can outlast this event. 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, 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, Walentowska, Bakic, Dondaine, & Pourtois, 2016), as opposed to the use of standard movie clips, music or reward. Further, this MIP is capable to increase the current happy mood state of the participant, even though s/he may be characterized by a high level of 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 visuo-spatial attention per se (for a recent review, see Vanlessen, De Raedt, Koster, & Pourtois, 2016; see Figure 2AB). 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).

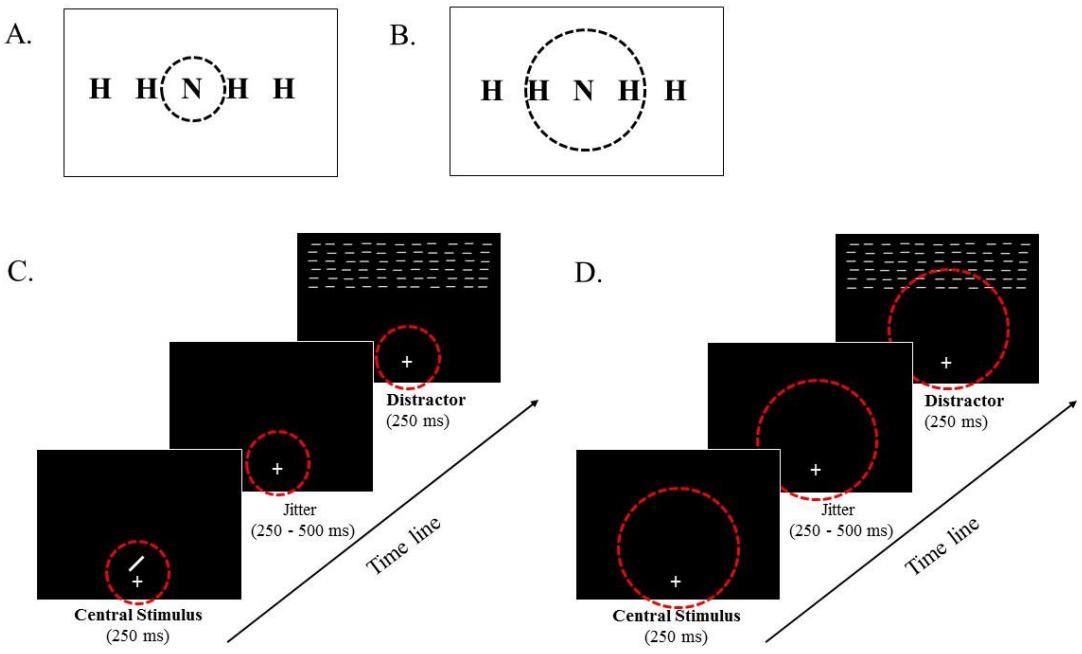

Figure 2. (A) As used in many Eriksen flanker tasks, the central stimulus (here a single letter) is flanked by either congruent or incongruent letters, used as distractors (as shown here). Participants are asked to discriminate the central stimulus. Behavioral performance is worse and slower when incongruent 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 et al., 2007). (C) To explore effects of positive mood on attention without confounds related to conflict or cognitive control, a simple paradigm has been devised where 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 narrow 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 specific ERP methods. The early neural response to the distractor in the visual cortex is larger in happy than neutral mood (especially if it is shown far away from fixation in the periphery (see Vanlessen et al., 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 is spans a larger portion of the visual field (see Vanlessen et al., 2014).

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

To overcome this limitation, we previously used a standard visual discrimination task at fixation enabling to carefully anchor selective attention at a fixed position in the visual field (see Figure 2CD), 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, Rossi, De Raedt, & Pourtois, 2013). As expected, results showed that relative to 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 Figure 2CD). 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 post-perceptual 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. This processing style refers to the fact that while the portion of the peripheral visual field attended to was seemingly larger in happy compared to neutral mood, yet processing low-level details or specific features in this part of the visual field was impaired in the former compared to the latter condition, as if happy mood was accompanied by the use of an unfocused zoom lens in the periphery. In a follow-up study (Vanlessen, Rossi, De Raedt, & Pourtois, 2014), we replicated these results, and confirmed that positive mood broadens attention and is accompanied by a diffuse information processing style. Collectively, these findings therefore lend support to the assumption that positive mood creates a tradeoff 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. Noteworthy, such a tradeoff 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 towards externally-driven attention (see Figure 1), to maximize exploration and the encounter of opportunities, if all processing resources have not been utilized by a demanding task however (Vanlessen et al., 2016).

ERROR MONITORING

EM is an utmost important mental process enabling the swift detection of mismatches between goal or intention and action, such as unwanted response errors. It has been explored extensively previously in the literature (Ullsperger, Fischer, Nigbur, & Endrass, 2014; Koban & Pourtois, 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). While the ERN reflects the early automatic detection of errors, the Pe is usually thought to capture specific attentional and/or motivational processes associated with the processing of these 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 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. 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 incongruency effect, whereby the phasic and transient signal elicited by errors is temporarily augmented with happy mood, probably to timely signal 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., 2016). 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., in press). 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 Figure 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., 2016). 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 & Schwartz, 2010). All in all, this contemporary research line on EM showed that modulatory effects of positive mood are actually best conceived as being primarily context-sensitive and flexible, which might be an important pre-requisite to foster goal adaptive behavior across changing contexts and situations.

CONCLUSIONS

Recently, 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 found depending on the specific task setting and the putative motivational significance of response errors. While 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 opposite effects seen on visuo-spatial 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 Figure 3), which in turn gives rise to an increased processing of external information but decreased internal error monitoring (see also Figure 1).

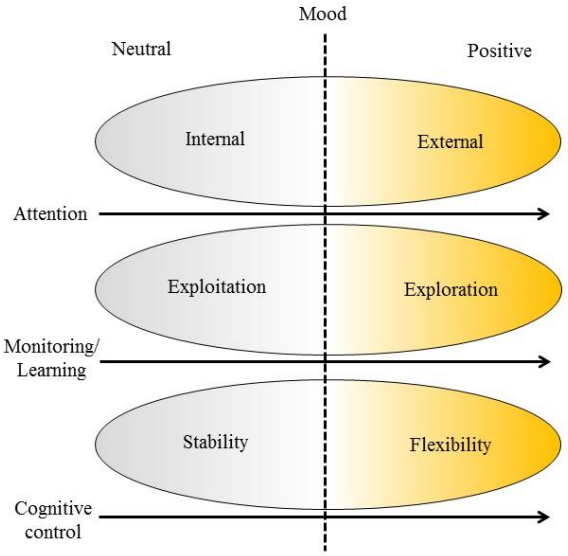

Figure 3. Presumably, effects of positive mood on visuo-spatial attention and EM likely stem from a change in a general or higher-up cognitive function, such as working memory (i.e., altering the balance between internal and external attention, see Chun et al., 2011; Vanlessen et al., 2016), learning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

Interestingly, such a tradeoff could potentially account for the observation of a more outward (or alternatively, less inward) looking in happy mood, with effects visible on complex internal processes such as mind wandering for example (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 working memory processes. Hence, positive mood could influence prefrontal dopaminergic signaling,

which in turn could affect either specific working memory functions or dedicated cognitive control processes that all heavily depend on prefrontal cortex's integrity (see Figure 3). Moreover, this would allow to maintain 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 Figure 3) and whether this effect might then account for the changes in the size of the attentional's focus as well as the monitoring of response errors associated with this specific mood state, as reviewed here above.

Remarkably, both research lines outlined here above reveal that positive mood provides the organism with a powerful information signal (Schwarz & Clore, 2003; Mitchell & Phillips, 2007) that allows to promote exploration (i.e., to tip the balance towards external attention, which can lead to a broadening of attention) as well as to evaluate 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 either to benefits or costs during information processing. Thus, broadening attention could turn out to be advantageous in specific circumstances (such as exploration of new contingencies or possible rewards in the environment), but not other ones (such as exploitation of prior knowledge). Likewise, it could be beneficial to lower internal error monitoring in specific conditions (such as associative thinking or creativity), while it may probably be detrimental to performance in other cases (when logic or reasoning prevails).

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