Thinking and Emotion: Affective Modulation of Cognitive Processing Modes

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Abstract In this chapter, we review empirical findings showing that positive and negative affective states are accompanied by qualitatively different information-processing modes. Specifically, positive moods and emotions appear to be associated with a more flexible processing mode as indicated by a broadened scope of attention, activation of weak or unusual associations, and facilitated switching between cognitive sets. We interpret these findings within a general theoretical framework according to which different modes of thinking serve complementary or even antagonistic adaptive functions in the planning and control of goal-directed action. In contrast to the widespread view that positive affect has exclusively beneficial consequences such as increased creativity and flexibility, we argue that different emotions and moods and the processing modes associated with them incur complementary costs and benefits. Thus, consistent with recent findings, positive and negative affect have advantages and disadvantages depending on the processing requirements of the to-be-performed task.

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1 Introduction

Our thinking is deeply influenced by our emotions and moods.[1] For instance, it is a familiar experience that in a positive mood one has the impression that one's life is full of opportunities; one comes up with a multitude of new ideas; and when thinking of the past primarily all the good things one has experienced come to mind. In contrast, in a sad or depressed mood one's attention appears to be focused in a rigid and narrow manner on a single negative topic, and one's mind is occupied with ruminations about past failures, negative experiences, or dismal prospects. As these examples illustrate, different moods – and in general emotional states – can influence thought processes in two principle ways: First, emotions and moods influence the contents of thought, i.e., *what* we focus our attention on, retrieve from memory, and reflect upon. Secondly, moods and emotions modulate the mode of thought, i.e., *how* we think, decide, and process information. As regards the first type of affective influence, since Bower's (1981) influential article on mood-congruency effects, a large empirical literature has accumulated showing that positive or negative moods facilitate the encoding and retrieval of memory contents with an affective valence that is congruent with one's current mood (although exceptions to this general effect have been reported and a number of boundary conditions for mood-congruency effects have since been identified; for reviews see Blaney 1986; Goschke 1996).

In this chapter, we focus instead on the second type of affective influences on thought processes, that is, we provide a selective review of evidence indicating that moods and emotions are associated with qualitatively different modes of thought and information-processing. Although the affective modulation of different modes of cognitive processing has been investigated less extensively than content-specific (e.g., mood-congruency) effects, there is now convincing evidence that emotions and moods do systematically influence the way we think and process information in various domains, including creative problem-solving, activation of semantic associations, selective attention, and cognitive control (for reviews see Ashby et al. 1999; Davidson et al. 2000; Erk and Walter 2000; Fiedler 2001; Forgas 2000; Fredrickson 2001; Isen 1999, 2004; Kuhl 1983, 2000; Martin and Clore 2001).

[1] In this chapter, we use the term *emotion* to denote psycho-physiological response patterns, which rest on more or less complex evaluations of events or actions in the light of an organism's needs, motives, and goals; which are accompanied by changes in the peripheral nervous system (e.g., increased arousal); which are controlled by specific brain circuits (e.g., the amygdale in the case of fear); which motivate the organisms toward particular categories of action (e.g., fight or flight); which are often accompanied by specific facial and postural expressions; and which are usually (but not always) associated with a specific qualitative subjective experience. In contrast, we use the term *mood* to denote more enduring, mild emotional states, which are not necessarily directed towards or caused by a particular object or event, need not be in the focus of attention, and have a non-focal ("colorizing") experiential quality. Finally, we will use the terms *affect* or *affective state* as generic summary terms subsuming both moods and emotions in the more narrow sense as defined above.

Our review will be guided by the theoretical idea that different modes of thinking (e.g. analytic vs. holistic; explicit vs. intuitive; focused vs. divergent) serve different and sometimes antagonistic adaptive functions in the planning and control of goal-directed action. As a direct consequence of this assumption, we assume that different emotions and moods and the processing modes associated with them incur complementary costs and benefits. Thus, in contrast to the widespread view that positive affect has primarily beneficial consequences like, for instance, increased creativity and cognitive flexibility, we assume that positive affect (like any emotional state) can have both advantages and disadvantages, depending on the processing requirements of the to-be-performed task.

2 Antagonistic Adaptive Functions and Complementary Modes of Thinking

Our central assumption that different modes of thinking serve complementary adaptive functions derives from a general theoretical framework, according to which organisms in a changing and uncertain world face antagonistic adaptive challenges or "*control dilemmas*" (Dreisbach and Goschke 2004; Goschke 1996, 2000, 2003). These control dilemmas afford a dynamic and context-sensitive balance between complementary modes of thought and action.

As an example, consider the *selection-monitoring dilemma*: On the one hand, agents must focus their attention selectively on task-relevant information and suppress distracting stimuli in order to prevent crosstalk and interference. On the other hand, however, it is equally important for an agent to monitor the environment for potentially significant information, even if this information is not relevant for the ongoing task. It would hardly be adaptive to focus attention so exclusively on a current goal (e.g., writing a chapter on emotion and thinking) that task-irrelevant information (e.g., the smell of smoke indicating a fire) is ignored completely. Thus, focusing attention vs. monitoring for potentially significant information incur complementary benefits and costs: while a narrow scope of attention and the suppression of distracting information reduces interference, it increases the risk to oversee potentially significant stimuli. Conversely, whereas a less focused, more distributed scope of attention increases the likelihood to detect potentially significant stimuli, it incurs a cost in terms of increased distractibility (cf. Dreisbach and Goschke 2004).

A second example is the *exploration–exploitation dilemma*: On the one hand, it is adaptive for organisms to rely on well-established routines and to select actions on the basis of acquired knowledge about reward contingencies and action outcomes. On the other hand, it is equally important to explore novel actions, which may lead to yet unknown, but potentially even better outcomes (cf. Aston-John and Cohen 2005; Doya 2008; Goschke 1996; Sutton and Barto 1998). Exploitation and exploration incur complementary benefits and costs: Whereas an exclusive reliance on the exploitation of learnt contingencies prevents an organism from finding even more rewarding actions, an excessive tendency to explore novel actions leads to erratic behavior that is insufficiently constrained by prior experience. In more general terms, this dilemma can also be phrased in terms of the question how an agent decides in the face of uncertainty whether to interpret novel experiences in the light of preexisting beliefs (assimilation), or whether to revise beliefs in the light of new experiences (accommodation) (Piaget 1975).

To the degree that emotions and moods alter the balance between complementary modes of thinking and information-processing, a particular emotional state should likewise be associated with complementary costs and benefits. Thus any affective state (and the associated processing mode) should lead to advantages in certain tasks, but at the same time impair performance in other tasks, depending on whether the processing requirements of the task fit with the prevailing processing mode promoted by the current emotion.

3 Theoretical Views on the Affective Modulation of Cognitive Processes

Several theories of the affective modulation of cognition contain the assumption that positive and negative moods or emotions are associated with qualitatively different processing styles. In particular, most theories agree that a positive mood is associated with a more flexible processing style, that is characterized by the activation of widespread associative relations, a broadened focus of attention, and an increased readiness to explore new ideas and opportunities for alternative thoughts and actions (e.g., Bolte, Goschke, & Kuhl 2003; Dreisbach and Goschke 2004; Fiedler 2001; Fredrickson 2001; Fredrickson and Joiner 2002; Goschke 1996; Isen 1999; Kuhl 2000). For instance, Alice Isen has pursued an extended research program on the effects of positive mood on cognition that rests on the hypothesis that positive compared to neutral or negative affect promotes a more flexible cognitive organization (for reviews see Isen 1999, 2004). In a similar vein, Fredrickson (2001) has developed a “broaden-and-build theory” according to which positive emotions or moods are associated with an expanded focus of attention and an increased tendency to explore new ideas or action alternatives, which renders cognitive processing more flexible, explorative, and creative. In contrast, negative emotions or moods are assumed to induce a narrow focusing of attention and restrict the variety of alternative thoughts that come to mind. According to Fredrickson, negative emotions evolved in order to support specific-action tendencies and to prepare the organism for adaptive action (for example, attack in the case of anger, or escape in the case of fear). In contrast, the adaptive function of positive emotions like joy or contentment is not seen in promoting specific behavioral tendencies, but rather in expanding the repertoire of thought and possible actions.

Fiedler (2001), in his theory of mood-cognition interactions, also distinguishes between two complementary information-processing functions: *information conservation* and *active generation*. The first function consists in the encoding and conservation of given input information, whereas the second function consists in the active generation of new information based on prior knowledge, as, for instance, in the development of new ideas during creative thinking. Fiedler distinguishes between different cognitive sets in appetitive and aversive situations: whereas appetitive settings encourage exploration, creativity, and the generation of new ideas, in aversive settings the organism must be attentive to potentially threatening stimuli and avoid making mistakes. Therefore a negative mood (that is typically associated with aversive settings) is assumed to support the conservative function (i.e., focusing on stimulus details or factual information), whereas a positive mood supports active generation (i.e., making new inferences and engaging in creative thought).

From a related perspective, Bless (2001) proposed a mood-and general-knowledge model, according to which individuals in benign situations rely on their general knowledge structures, whereas in problematic situations attention is focused on specific details. Bless assumes that these different information-processing modes are adaptive to the individual. Because problematic situations are usually deviations from routine situations individuals would be poorly advised to rely on the knowledge they usually apply and should better focus on the specifics of the current situation. In contrast, in benign situations less attention must be paid to specific details. Here it is adaptive to save processing resources allocated to the specifics of the situation and to direct resources toward other tasks or to generate and test new ideas (see also Schwarz 2001).

A particularly elaborated theory of the affective modulation of complementary cognitive systems and processing modes has been developed by Kuhl (2001). A central assumption of Kuhl's personality systems interactions theory ("PSI theory") consists in several affect modulation hypotheses, which specify how affective states modulate the relative balance and interaction between cognitive systems, which mediate qualitatively different aspects of information-processing and action control. More specifically, Kuhl assumes that an increase in negative affect promotes an analytic processing mode in which attention is focused on isolated details of the current stimulus situation, whereas the down-regulation of negative affect promotes a holistic processing mode, that is characterized by access to stored experiential knowledge (including personal preferences and implicit motives) and facilitates the integration of isolated pieces of information into a widespread network of coherent memory representations.

4 Selective Review of Evidence for the Affective Modulation of Complementary Modes of Thinking

Despite differences in specific assumptions, most of the mentioned theories agree that positive affective states are accompanied by increased cognitive flexibility as indicated by a broadened scope of attention, the activation of weak or unusual associations, and an increased readiness to explore new thoughts and actions. This assumption is supported by a growing body of empirical evidence on effects of positive and negative affect on the mode of information-processing. In this section we selectively review studies on the affective modulation of thought processes in four domains:

(1) Creative problem-solving and generative thought
(2) Activation of semantic associations
(3) Selective attention
(4) Cognitive control

4.1 Affective Modulation of Creative Problem Solving and Generative Thought

In an early study, Isen et al. (1987) investigated the effects of experimentally induced mood states on creative problem solving. One of the tasks they used was Duncker's (1945) candle task, in which participants received a box of matches, pushpins, and a candle. The task was to fix the candle on the wall with these implements such that no wax would drop on the floor (the solution is to empty the box of matches and pin it on the wall with the pushpins, such that it serves as a candleholder). Participants, in whom a positive mood had been induced by seeing a few minutes of a comedy film, came up with the solution within the specified time almost four times as often as participants in a negative or neutral mood.

More recent studies have obtained similar results and provide converging evidence that a positive mood reduces functional fixedness in solving insight problems. For instance, Gasper (2003) had participants in happy, sad, and neutral moods perform a classic problem-solving task designed to investigate the perseveration and breaking of mental sets (Luchins 1942). In this task, participants initially complete a series of similar problems, which can be solved only by using a relatively complex strategy and which serve to establish a stable mental set. In a subsequent phase of the experiment, problems are presented that can be solved by using either the established strategy or an obvious and much simpler strategy. In Gasper's experiment, participants in a sad mood relied on the established mental set until they received feedback that their strategy may be problematic, whereas participants in a positive mood were more likely to abandon the established mental set on their own.

As already mentioned, Fredrickson (2001) in her broaden-and-build theory assumes that positive affect increases the tendency to explore new ideas or action alternatives. Consistent with this assumption, Fredrickson and Branigan (2005) found that a positive mood enlarged the thought-action repertoires that participants generated. After participants had watched emotion-eliciting videos, they were asked to indicate all of the action urges they had at that moment. Participants in a positive mood generated a greater number of action-urges than people in a negative or neutral mood.

Consistent with this finding, it has been found that participants in a positive mood (induced by having participants read funny short stories) performed better than participants in a neutral mood on a fluency test, in which they had to produce as many novel uses for a given object (e.g., a cup) as possible (Phillips et al. 2002, Experiment 2). There was no reliable effect of positive mood on a superficially similar letter fluency task (producing as many words beginning with the letter A), although a correlational analysis revealed that the more positively participants rated their mood at the end of the experiment, the more words did they produce in the letter fluency task.

In summary, the studies reviewed in this section indicate that a positive mood improves performance in creative problem solving tasks by reducing functional fixedness, facilitating the breaking of mental sets, and by enlarging the thought-action repertoires that participants generate.

4.2 Affective Modulation of Semantic Associations

Several studies have examined the effects of positive mood on the activation and retrieval of semantic associations. In an early study, Isen et al. (1985) showed that participants in a positive mood gave more unusual first-associates to neutral words than did subjects in neutral mood or subjects who received no mood induction. In a further experiment, in which word type (positive, neutral, or negative) was a second independent variable along with induced mood, participants produced associates to positive words that were more unusual and diverse than were those to other words. Thus positive mood as well as processing words with a positive emotional valence promoted the activation and retrieval of more unusual associates.

In a further study, Isen et al. (1987) used the Remote Associates Test (Mednick and Mednick 1967), in which participants are presented three clue words and have to find a common associate (e.g., *mower* – *atomic* – *foreign* with the associated solution word *power*). Participants in whom a positive mood had been induced came up with more solution words compared to participants in a neutral mood. A condition in which a negative mood was induced and two additional control conditions in which participants engaged in physical exercise (intended to increase unspecific arousal) failed to produce comparable improvements in creative performance. This finding was recently replicated by Rowe et al. (2007), who also found that participants in a positive mood (induced by listening to pieces of music) performed reliably better in the Remote Associates Test than participants in a negative or neutral mood. The authors interpreted this as evidence that a positive affect induces a more open and exploratory mode of attention to both internal and external sources of information and thereby facilitates access to distantly related associates in memory.

Bolte et al. (2003) showed in addition that a positive (happy) mood facilitates not only the explicit retrieval of remote associates from memory, but also improves the ability to make *intuitive* judgments about the semantic coherence of word triads, even if participants do not consciously retrieve the associated solution word. Participants were presented three clue-words which were either coherent in the sense that all three words were weakly associated with a common fourth concept, or which were incoherent, i.e., there was no common associate. Participants in a neutral mood discriminated coherent and incoherent triads reliably better than chance level even if they did not consciously retrieve the solution word. The induction of a positive mood reliably improved intuitive coherence judgments, whereas participants in a negative mood performed at chance level. The authors concluded that positive mood potentiates spread of activation from the three clue words to the remote associate in memory, which gives rise to an intuitive impression of semantic coherence, even if the common associate is not accessible to consciousness. By contrast, a negative (sad) mood obviously restricted the spread of activation to close associates and dominant word meanings, thereby impairing the ability to intuitively judge the semantic coherence of the word triads. Consistent with this interpretation, Baumann and Kuhl (2002) found that individuals with a reduced ability to down-regulate negative affect (so-called state-oriented individuals) performed worse on the intuitive coherence task when being in a sad mood, compared to participants who tend to down-regulate negative emotions (so-called action-oriented individuals).

Further evidence that positive affect facilitates the processing of distantly related semantic concepts stems from an event-related potential (ERP) study by Federmeier et al. (2001). Participants read sentences which ended either with a highly expected word, an unexpected word from an expected semantic category, or an unexpected word from a different category. For participants in a neutral mood, amplitudes of the N400 component of the ERP, which is sensitive to the degree of semantic deviations (Federmeier and Kutas 1999) were smallest for expected items from an expected category. Moreover, N400 amplitudes were smaller for unexpected items from an expected category than for words from unexpected category. By contrast, for participants in a positive mood N400 amplitudes did not differ in response to the two types of unexpected items. The authors concluded that a positive mood facilitated the processing of unexpected, but distantly related items.

This conclusion fits with an earlier result of Isen and Daubman (1984) who had participants classify exemplars, which differed in their typicality with respect to a given category, as members of the category. Participants in a positive mood, induced by means of seeing a few minutes of a comedy film, showed a stronger tendency to classify less typical exemplars as members of a category than participants who saw a short film about mathematics (neutral mood) or a film about concentration camps (negative mood). In two further studies, in which participants had to group different exemplars to categories, participants in positive mood used fewer categories to sort the exemplars than participants in neutral or negative mood, indicating that a positive mood promotes an over-inclusive mode of categorization.

In conclusion, there is converging evidence that a positive mood facilitates access to weak or remote associates in memory, improves intuitive judgments in a semantic coherence task, and increases the tendency to view distant or untypical exemplars as members of a semantic category. Although different processes may underlie the effects of positive mood in the different tasks discussed so far, it is a plausible hypothesis that many of the discussed findings reflect a common underlying mechanism, namely the activation of widespread associative networks including weak, unusual, or remote associates. That is, the fact that positive mood induces a broadened scope of semantic associations may not only account for improved performance in tasks requiring activation or retrieval of remote associates, but also for the increased rate of solutions in insight problems, which require one to break habitual cognitive sets and to recognize novel or unusual relations between familiar elements. By contrast, a negative (especially a sad) mood appears to induce a more analytic and focused style of processing, which is characterized by a more restricted spread of activation to close associates in memory, thereby impairing performance on remote associate tasks as well as on insight problems.

4.3 Affective Modulation of the Scope of Selective Attention

The studies reviewed so far may give the impression that a positive mood has in most cases beneficial consequences like increased creativity and cognitive flexibility. However, in the introduction we proposed that different modes of thinking (e.g., focused vs. divergent) serve complementary adaptive functions and that different emotions and moods, by inducing qualitatively different processing modes, will have both advantages and disadvantages, depending on the processing requirements of to-be-performed task. More specifically, we expect that positive affect should impair performance when a more focused style of processing or a narrow scope of attention is required by a given task. In this and the next section we review recent studies on the affective modulation of selective attention and cognitive control processes, which indicate that positive affect can also incur a performance cost in tasks requiring focused attention or inhibition of distracting information.

It has long been assumed that positive affect is associated with a broadening of the scope of attention, whereas negative affect (especially when associated with high arousal) leads to a narrowed focus of attention (e.g., Easterbrook 1959). This assumption fits with everyday observations like the so-called "Weapon focus," which denotes the fact that victims of a violent assault often show an improved memory for central details of the event (e.g., the weapon used), but cannot remember other aspects of the experience, indicating an extreme narrowing of the focus of attention. Consistent with these observations, laboratory experiments have shown that negative affect elicited by aversive pictures (e.g., of a traffic accident) induces a narrow focus of attention on central details of the scene at the cost of peripheral aspects (e.g., Christianson and Loftus 1991).

On the other hand, there is evidence that positive affect has the opposite effect of broadening the focus of attention. For instance, in some studies the effects of positive mood on the processing of global or holistic vs. analytic details of visual stimuli were examined. Gasper and Clore (2002) asked participants to indicate which of two stimuli was more similar to a reference stimulus. Stimuli resembled each other either with respect to their global shape or with respect to the local elements from which they were composed. For instance, a large square made out of four small triangles resembled a large square made out of small squares with respect to global shape, whereas a large triangle made out of small triangles resembled a large square made out of small triangles on the level of local elements. As predicted, individuals in a sad mood were less likely than those in a positive mood to classify figures on the basis of global features. Likewise, Fredrickson and Branigan (2005) reported that participants, in whom a positive mood had been induced by having them view video clips eliciting amusement or contentment, showed a stronger bias than participants in neutral or negative moods to judge the similarity between visual stimuli on the basis of their global resemblance.

Direct evidence that a broadened scope of attention induced by positive affect may incur performance costs due to reduced attentional selectivity has recently been reported by Rowe et al. (2007). They induced a happy or a sad mood by having participants listen to selected pieces of music, whereas a neutral mood was induced by having participants read factual statements about Canada. After the mood induction, participants performed the Remote Associates Test (described above) and a visual selective attention task, the Eriksen flanker task (Eriksen and Eriksen 1974). In the flanker task participants had to respond to a central target stimulus (e.g., a letter) and ignore irrelevant flanking distracters. When target and distracters are mapped to incompatible responses, responses are usually slowed, indicating a failure of selective attention and an unwanted influence of the to-be-ignored flankers. As expected, participants in a positive mood showed a greater flanker interference effect relative to participants in sad or neutral moods, which was due to a disproportionate slowing to incompatible flankers under positive mood. Thus positive mood obviously broadened the scope of visuospatial attention, thereby increasing the (unwanted) processing of distracting flanker stimuli. Interestingly, as already reported above, in this study positive mood improved participants' performance in the Remote Associates Test, and within the positive mood group a significant correlation was found between the slowed response times associated with flanker incompatibility and the number of correctly identified remote associates. This indicates that enhanced access to remote associates was correlated with impaired visual selective attention and nicely demonstrates within one study, that the broadened scope of attention induced by positive mood can incur both costs and benefits, depending on the particular task requirements.

4.4 Affective Modulation of Cognitive Control

Further evidence for complementary costs and benefits of positive affect stems from recent studies of the affective modulation of cognitive control processes. Cognitive control is a summary term denoting mechanisms which serve the maintenance of goals in the face of distraction, the inhibition of task-irrelevant stimuli or prepotent, but inadequate responses, and the flexible reconfiguration of behavioral dispositions in response to changing goals or task demands (cf. Goschke 2003, 2007; Miller and Cohen 2001).

Initial studies of the affective modulation of cognitive control yielded mixed results. While some researchers found that a positive mood impaired performance on tasks requiring executive control like the Tower of London task (Oaksford et al. 1996) or when participants had to switch between different tasks (Phillips et al. 2002), others found that phasic increases in positive affect induced by positive emotional words reduced interference in the Stroop task (Kuhl and Kazén 1999). Moreover, Gray (2001) found that affective states either impaired or improved performance in a working memory task depending on whether the task involved spatial or verbal information. These inconsistencies may at least in part be due to the fact that different "executive" tasks involve different or even antagonistic requirements, as, for instance, the maintenance and shielding of a current task-set versus the flexible switching between task-sets. As we noted above, whether positive affect impairs or improves performance in tasks requiring cognitive control should critically depend on the specific control demands imposed by a particular task.

This hypothesis was directly tested by Dreisbach and Goschke (2004) who investigated differential effects of positive affect on complementary cognitive control functions. Specifically, these authors predicted that positive affect reduces perseveration and facilitates flexible switching of cognitive sets, but at the same time incurs a cost due to increased distractibility. To test this hypothesis, the authors used a task in which participants were first trained to respond to target stimuli appearing in a prespecified color (e.g., red), while ignoring distracter stimuli in a different color (e.g., green). After a block of 40 trials, participants were transferred to one of two switch conditions. In one condition, after the switch they had to respond to stimuli in a new color that had not appeared before (e.g., blue), while all the distracters appeared in the previous target color (i.e., red). In this condition, increased flexibility should facilitate switching to novel stimuli, as indicated by *decreased* switch costs (the authors termed this condition the *perseveration condition*, because switch costs primarily reflect the degree to which the previously relevant cognitive set perseverates). In the second switch condition, participants had to respond to stimuli in the previously to-be-ignored color (i.e., green), while all the distracters appeared in a new color (i.e., blue). In this condition, increased flexibility or a broadened scope of attention should bias participants' attention toward the novel distracters, thereby producing *increased* switch costs (one may term this condition the *distractibility condition*, because switch costs reflect the tendency to focus attention on novel distracters). To induce phasic affective responses, in different blocks either positive, neutral, or negative affective pictures from the International Affective Picture System (IAPS), Lang et al. (1998) were presented briefly before each imperative stimulus. Consistent with the authors' predictions, the presentation of positive pictures had opposite effects in the two switching conditions: Whereas the presentation of positive affective pictures almost completely *eliminated* the switch cost in the perseveration condition, it reliably *increased* the switch cost in the distractibility condition. This dissociation is consistent with the hypothesis that phasic increases in positive affect increase cognitive flexibility, albeit at the cost of increased distractibility. Importantly, the pattern of findings could not be accounted for by the higher arousal potential of the positive compared to neutral pictures, because negative emotional pictures which matched the arousal potential of positive pictures did not differ in their effects from neutral pictures.

5 Conclusions and Open Questions

The findings reviewed in this chapter show that induced tonic moods as well as phasic emotions exert strong influences on the prevailing mode of cognitive processing. In particular, in line with the theories outlined in the introduction, there is converging evidence that positive affect is associated with a more flexible processing style that is characterized by the activation of widespread networks of weak or remote associates in memory, a broadened scope of attention, and an increased readiness to explore new ideas and opportunities for alternative actions. The mode of thinking induced by positive affect usually improves performance in tasks requiring a more global or "holistic" style of information processing, such as the remote associates task (requiring the activation of widespread associative networks), insight problems (requiring the breaking of habitual cognitive sets and the detection of novel or unusual relations among cognitive elements), or fluency tasks (requiring the generation of a wide variety of alternative action options). However, as predicted by our complementary processing modes framework, positive affect can also incur performance costs in selective attention and cognitive control tasks, when the tasks require a more focused style of processing or the inhibition of distracting sources of information.

This conclusion fits with the general assumption outlined in the introduction, that different processing modes serve complementary adaptive function in the control of action. Accordingly, many theorists implicitly or explicitly rely on evolutionary considerations when justifying specific hypotheses concerning the affective modulation of cognitive processes. As described in the introduction, it is frequently assumed that negative emotions evolved to prepare the organism for specific adaptive action in response to danger, threat, or challenged goal pursuit. Accordingly, it appears plausible to assume that negative emotional states are associated with a "conservative" mode of processing (Fiedler 2001) and a focusing on details of potentially threatening stimuli (Bless 2001; Fredrickson 2001). Conversely, positive emotions are usually interpreted as signals that goal pursuit runs smoothly and there are no immediate or anticipated threats that one must cope with. Thus it appears plausible that positive emotional states promote an exploratory mode characterized by creative thought, new inferences, and the generation of unusual ideas, which may serve to expand the repertoire of thoughts and possible actions (Fiedler 2001; Fredrickson 2001; Goschke 1996; Kuhl 1983, 2001). However, as is the case for most evolutionary accounts, one should be aware of the fact, that such hypotheses are plausible post-hoc accounts of the adaptive function of mental processing modes, which may be difficult to test in a strict experimental sense.

Another influential interpretation for affective influences on cognitive processing modes (that is not incompatible with an evolutionary-functional analysis) rests on the assumption that emotions and moods serve an informational function in that they indicate whether a situation is benign or problematic, thereby tuning cognitive strategies to meet the respective situational requirements (e.g., Schwarz 2001). For instance, if positive moods or emotions signal the absence of problems or obstacles, it may inform the organism that there is no risk in engaging in a more intuitive, exploratory, or creative mode of thought. By contrast, negative moods or emotions usually indicate the presence of conflicts, problems, or dangers, and may thus signal that a more analytic problem-solving mode of processing is required. Thus effects of moods and emotions on, for instance, the activation of remote associates or creative problem-solving may reflect the informational function of affective states. It is an open question, however, whether the informational content of affective states in general or moods in particular influences cognitive processes primarily by way of a deliberate strategy change, or whether moods and emotions can also modulate cognitive processing modes in a more automatic way. Likewise, it is an open question whether moods and emotions influence cognitive processes or judgments only when they are experienced as relevant sources of information in an ongoing task (e.g., Schwarz and Clore 1983; Schwarz 1990; Schwarz and Bless 1991; Schwarz et al. 1991), or whether they influence cognitive processing modes also in a more direct way, that is, independently from whether or not a current mood or emotion is attributed to a specific cognitive source.

In closing our review we would like to point to three further open questions for future research. First, in this chapter we have neglected differences between specific emotions (e.g., anger, fear, disgust, sadness). Different emotions most likely developed as evolutionary answers to specific adaptive challenges (Panksepp 1982; LeDoux 1996) and it is therefore very likely that different emotions like fear and anger – even though they may share a similar valence – are associated with qualitatively different processing modes (Dörner 1999). Thus to speak simply of positive and negative emotions or moods is clearly an oversimplification. Closely related to this point is the requirement to distinguish more systematically between the effects of tonic moods and phasic emotions. Although in most of the studies reviewed here, positive mood had similar effects as the induction of phasic increases in positive emotions (even if such phasic emotional responses were not accompanied by enduring mood changes), it is an important empirical question under which conditions moods and emotions differ in their effects on cognitive processes.

A second question concerns the observation that in many studies using tonic mood induction techniques in nonclinical subject populations, induced positive moods had stronger effects on cognitive processes than negative moods. One possible explanation is that negative mood induction methods (e.g., listening to sad music) may not result in equally strong or unambiguous mood changes, or that participants use “mood-repair” strategies to counter-regulate negative affective states (Isen et al. 1987). Moreover, many of the cognitive tasks typically used to examine effects of mood on cognition are relatively demanding and boring for the participants and will thus often elicit a negative change of participants’ mood independently from the intended mood induction.

A third – and theoretically most important – question is which psychological processes and neurobiological mechanisms underlie the effects of emotions and moods on cognitive processing modes. At present, relatively little is known about the specific mechanisms by which affective states exert their modulating influence on cognitive processing modes. On a psychological level, one promising hypothesis holds that affective states influence the settings of global *parameters* of the cognitive system, which regulate the *mode* of information-processing independently from the processed contents (Dörner 1999; Doya 2008; Erk and Walter 2000). An example of such a global processing parameter is the *signal-to-noise ratio*, which regulates the degree to which the cognitive system engages in exploratory behavior; another example is the *scope of attention*, which regulates the degree to which attention is focused or distributed; a third example is the *switching or updating threshold*, which regulates how easily the current content of working memory is updated vs. how strongly this content is shielded from distraction. It is an interesting hypothesis for future research that different affective states are associated with specific pattern or configurations of such processing parameters (for an elaborate version of this hypothesis and computational models based on it see Dörner 1999; Dörner et al. 2002). On a neurobiological level, there is evidence that some of the effects of affective states on the setting of global processing parameters may be mediated by the action of specific neuromodulatory systems. For instance, Ashby et al. (2002, 1999) have hypothesized that some of the effects of positive affect on cognitive processes are mediated by increased levels of brain dopamine (DA) in frontal cortical areas, notably the anterior cingulate cortex (ACC). Increased DA levels in the ACC are assumed to enhance the ability to overcome dominant responses and to facilitate flexible switching of cognitive sets. There is indeed increasing evidence from neurobiological and neuroimaging research that neuromodulators like dopamine, serotonin, and norephinephrine influence prefrontal cortical functions involved in thinking and planning, the maintenance vs. updating of information in working memory, and the regulation of focused vs. distributed modes of attention (e.g., Braver and Cohen 2000; Cools 2008; Dreisbach et al. 2005; Müller et al. 2007; Roberts 2008). While a discussion of these findings is beyond the scope of this chapter, it will be a major goal for future research to relate behavioral studies on the affective modulation of cognitive processing modes more closely to underlying neuromodulatory systems and their effects of neural systems involved in thinking and cognitive control.

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