How positive affect modulates cognitive control:
New insights into the specificity of positive affect effects

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Preface

It is part of our everyday experience that affect modulates cognition. For example, a typical workday at the office can change significantly depending on the current mood state. Imagine the following scenario: an administration secretary oversleeps, it is raining non-stop and on top of everything, he misses his bus. This will probably worsen his current mood significantly. In a negative mood, he will most likely try to avoid further annoyance and therefore most thoroughly attend to his daily tasks and carefully plan his workday at the office to prevent errors and other possible problems. In contrast, if he had woken up on time with his favorite song playing on the radio and the sun shining from a bright blue sky, the administration secretary most likely would have been in an especially bright mood. In a positive mood state, everything seems to be easier than on a regular day. Therefore, it can be assumed that he would just enjoy the moment without thinking about later, which can be advantageous, when an unexpected change of plans occurs. But he may be less efficient than usual in completing the regular tasks of a routine workday, because he most likely will be more susceptible to irrelevant distractions. Such everyday examples illustrate how important it is to investigate cognitive processes not only in isolation but also to consider affective modulations thereof.

The main aim of the present thesis is to further investigate a special topic in the field of cognition-emotion interactions, namely the relationship of positive affect and cognitive control. The following introduction will present relevant theoretical concepts as well as empirical results, and point out open questions in this research area. Subsequent parts of the thesis will present original research to address some of these open questions. The thesis will close with a general discussion and final conclusions about the modulation of cognitive control by positive affect.

Content

Abstract

Converging evidence suggests that positive affect modulates cognitive control by increasing cognitive flexibility. The present thesis is aimed to shed further light on this relationship between positive affect and cognitive control by investigating possible influences of arousal (Part I), dissociating between proactive and reactive control (Part II), and testing an increased novelty bias under positive affect (Part III).

Arousal differences between positive affective states were manipulated by inducing affect via pictures from the International Affective Picture System. Furthermore, different paradigms including informative cues, non-informative cues, or no cues at all were used to dissociate between proactive and reactive control, because only in situations with informative cues performance can be optimized by using a proactive control strategy. Finally, an experiment using a Stroop-like word-picture interference task with familiar and new distractors was run to gather evidence for an increased novelty bias under positive affect.

Results showed very specific influences of positive affect on cognitive control, thereby exceeding the existing literature: Specifically positive affect with low arousal as compared to positive affect with high arousal was found to reduce proactive control. In contrast, the present data showed no evidence for an affective modulation of reactive control. Moreover, Part III of the present thesis succeeded in presenting first empirical evidence for an increased novelty bias under positive affect with low arousal. All results will be discussed with respect to the existing literature on positive affect and cognitive control.

CHAPTER 1 Background

1.1. Emotions, core affect and the circumplex model of affect

1.1.1. What is an emotion?

For a feasible investigation of affective modulations of cognitive processes it is first of all necessary to determine what is meant by terms like affect or emotion. At first sight, a generally accepted definition for the term emotion should not be a problem, because the topic of emotion is of utmost importance in everyday life and, therefore, has indeed a long history in psychological science. For example, in 1884 William James already published an article entitled “What is an emotion?” (p. 188). However, sixty-five years and even a hundred years later typical answers to this question still were statements like “the word ‘emotion’ is used to designate at least three or four different kinds of things” (Ryle, 1949/1966, p. 83) and “Everyone knows what an emotion is, until asked to give a definition” (Fehr & Russell, 1984, p. 464).

While psychologists in the last decades no longer disapprove emotions as fictional – as has been done in behaviorism (e.g., Skinner, 1978) –, a unique definition is nonetheless still a work in progress. In a review on a hundred years of emotion research, Gendron and Feldman Barrett (2009) identified three coexisting lines of emotion theories, namely basic emotion, appraisal, and psychological constructionist traditions. Inspired by Charles Darwin’s classical work “The expression of the emotions in man and animals” (1972), basic emotion theorists (e.g., Ekman, 1992) suggest that there is a certain number of distinct and unreducible basic emotions. Each basic emotion is characterized by a specific response pattern of, for example, expressive behavior or physiological changes, which are assumed to be a consequence of a fixed biological basis. These characteristic response patterns are, furthermore, supposed to be adaptive reactions that are automatically triggered by appropriate objects or events in the environment. Appraisal theories (e.g., Arnold, 1960a, 1960b), in contrast, reject the idea of a reflex-like emotion elicitation by specific external triggers. They suggest, instead, that there is first an – not necessarily consciously aware – interpretation of an object or event, whereupon the outcome of this appraisal determines what kind of emotion is elicited or whether an emotion results at all. In this way, appraisal theories are able to explain the inter-individual variety of emotional experiences by different people in the same situation. Psychological constructionists theories (e.g., Russell, 2003), moreover, assume that emotions – like all psychological states – are constructed from more basic “ingredients” or primitives that are not necessarily specific to emotions (e.g., arousal). The interplay of those basic components, like perceptions of current internal body state, processing and evaluation of the external environment, or actions, can result in a psychological compound that is experienced as an emotion. Thus, psychological constructionists consider emotions not as special entities but merely as characteristic patterns that are conventionally labeled with an emotional term. Following this point of view, emotion research should focus less on the psychological compound emotion but rather investigate its basic “ingredients” and their interplay.

How challenging a unique definition of the term emotion obviously is can also be seen in a review by Kleinginna and Kleinginna (1981): The authors collected 92 different definitions from the literature on emotions, and classified these based on their theoretical emphasis into 11 categories like, for example, cognitive or physiological. Compared to former reviews on definitions of emotion (Fantino, 1973; Plutchik, 1980) the authors found that there is an increasing number of definitions that emphasize the multi-component nature of emotions as well as a stronger focus on affective and cognitive components of emotion. In their conclusion, Kleinginna and Kleinginna proposed a working definition of emotion themselves with emphasis on the complexity of emotions including affective experiences, cognitive processes, physiological adjustments, and behavioral tendencies. More recently, Carroll Izard (2010) conducted a survey amongst distinguished emotion researchers on the term emotion and came to the conclusion that – although there is moderate to high agreement on assumed structure and functions of emotion – there is still no generally accepted unique definition of emotion. Taken together, there has been a lot of interest in the research of emotion throughout the history of psychological science, but there is still a lack of agreement on the theoretical basis. Therefore, even present textbooks of psychology still give working definitions for the term emotion only (e.g., Goschke & Dreisbach, 2011).

1.1.2. The Circumplex model of affect

A promising solution to this dilemma seems to be Russell’s circumplex model of affect (1980) – a psychological constructionist theory according to the classification of Gendron and Feldman Barrett (2009) –, which over the years has repeatedly proven to be a valid and reliable model with a strong empirical basis and high integrative value (Feldman Barrett & Bliss-Moreau, 2009; Posner, Russell, & Peterson, 2005; Russell, 2003; Russell &

Feldman Barrett, 1999; Yik, Russell, & Feldman Barrett, 1999; Yik, Russell, & Steiger, 2011). Russell (1980) showed - for self-reported affect and with different scalings of affective words – that affect is best described not in terms of distinct categories – like anxiety or anger – but as a linear combination of two independent basic dimensions, namely, *valence* and *arousal*. Because all combinations of valence and arousal are possible – with some of them nameable with affect words like, for example, happy –, the affective space can be represented as a circumplex within a two-dimensional space (see Figure 1.1): In Russell's model, the horizontal axis comprises valence ranging from negative to positive (unpleasant - pleasant), whereas the vertical axis comprises arousal ranging from low to high (deactivation - activation). The structure of affect is thus assumed to be a continuum, so that similar affective states like being calm or relaxed – both rather positive in valence, and low in arousal – are neighbors in the circumplex whereas oppositional affective states like happy and sad – both moderate in arousal, but one positive and one negative in valence – are approximately 180° apart.

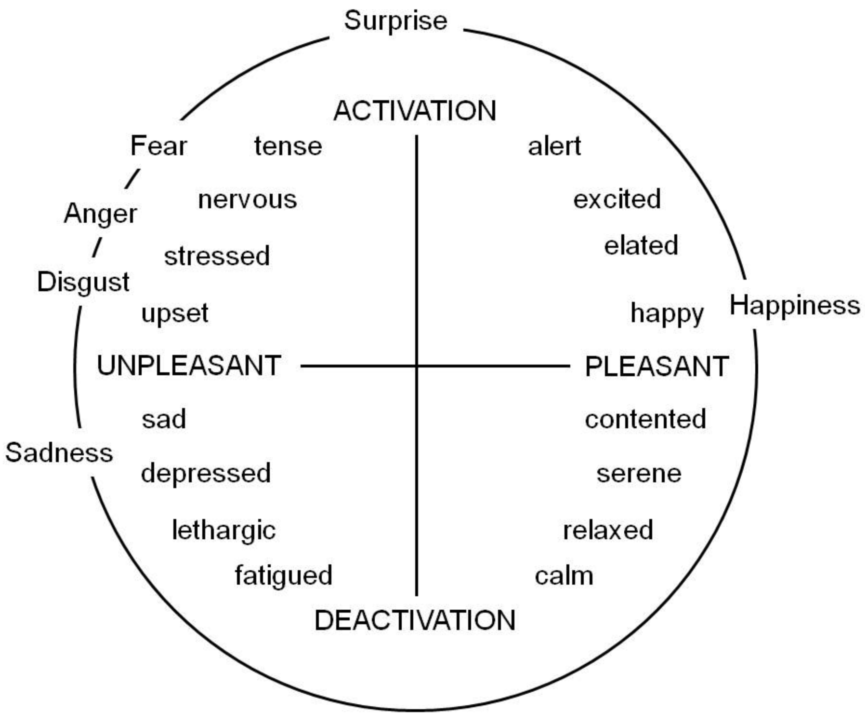

Figure 1.1. The Circumplex model of affect. The inner circle represents core affect: Two independent dimensions valence (x-axis) and arousal (y-axis) define a Cartesian space, in which specific affective states (i.e., any combinations of valence and arousal) form a circumplex. The outer circle shows the typical position of several prototypical emotional episodes. Adapted from "Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant," by J. A. Russell & L. Feldman Barrett, 1999, *Journal of Personality and Social Psychology*, *76*, p. 808. Copyright 1999 by the American Psychological Association.

What further strengthens the assumption of a two-dimensional affective space is the fact, that there are several alternative dimensional models of affect besides the circumplex model (e.g., Larsen & Diener, 1992; Thayer, 1996; Watson & Tellegen, 1985), which also propose two – not necessarily identical – underlying dimensions. All these models have been shown to be integrable with Russell's circumplex model into a single model by a simple rotation of the postulated axes (Russell & Feldman Barrett, 1999; Yik et al., 1999; Yik et al., 2011). The suggestion of valence and arousal – and not, for example, two orthogonal dimensions of activation (cf., Thayer, 1996) – as basic dimensions is supported by a broad theoretical and empirical basis. For example, Reisenzein (1994) argued that people can naturally apply these dimensions, when rating their own affect, while other rotations lack this intuitive advantage. This seems to be true not only for self-ratings of affect, but also for judgments of emotions in other persons: For example, facial affective expressions and affect in vocal tone can both be characterized as a combination of valence and arousal (e.g., Green & Cliff, 1975). Furthermore, physiological measures support the assumed structure of core affect: For example, skin conductance and heart rate acceleration systematically vary with subjective ratings of arousal, whereas facial electromyographic measures of corrugator and zygomatic activity – muscle groups associated with frowning and smiling, respectively – are correlated with subjective ratings of valence (Lang, Greenwald, Bradley, & Hamm, 1993). Moreover, neuroimaging results suggest that there are distinct neural networks associated with the valence and arousal dimensions: Posner, Russell and Bradley (2005), for example, suggest the mesolimbic dopamine system as a candidate for a neural correlate of the valence dimension, whereas activity in the reticular formation is supposed to mediate arousal. Also a recent fMRI study (Colibazzi et al., 2010) found evidence for distinct valence and arousal networks: Valence was associated with activity in a neural system including the dorsolateral prefrontal cortex, parts of the cingulate cortex and midbrain areas, whereas arousal was associated with activity in a system including the thalamus, the amygdala, the hippocampus, and premotor cortex (see also Anders, Lotze, Erb, Grodd, & Birbaumer, 2004; Lewis, Critchley, Rotshtein, & Dolan, 2007).

1.1.3. Core affect vs. emotional episodes

A common critique on the circumplex model of affect is, however, that some subjectively very different affective feelings, like anxiety and anger, are direct neighbors in the circumplex due to a rather similar – and therefore hardly distinguishable – combination of valence and arousal levels. That is, Russell's model is being criticized as being insufficient to represent the entire spectrum of affective experiences. Russell dissolves this at first sight profound caveat by differentiating *core affect* from *emotional episodes* (Russell, 2003; Russell & Feldman Barrett, 1999). The circumplex model of affect is primarily a representation of the structure of core affect, which is defined as a "neurophysiological state that is consciously accessible as a simple, nonreflective feeling that is an integral blend of hedonic (pleasure–displeasure) and arousal (sleepy–activated) values" (Russell, 2003, p. 147). Fear or anger, on the other hand, – that is, terms that are typically referred to as emotions in everyday language – exceed this most elementary affective experience of feeling good or bad and calm or excited. Core affect is supposed to vary over time in a free-floating manner and is not necessarily conscious or directed at anything. Specific emotions like fear or anger, in contrast, endure a certain time, are always directed at a specific object (e.g., being afraid of sth., being angry at so.), and include an appraisal of and attributions to that object. So, it is core affect plus other specific components that result in the subjective experience of being afraid or angry. In Russell's framework, such a complex of interrelated components is called an emotional episode (see Figure 2). With this differentiation, Russell follows early psychological constructionists ideas that can be found already in Wilhem Wundt's classic book "Outlines of psychology" (1897). Wundt assumed that at any given moment there is a psychologically irreducible "simple feeling" – which differs from moment to moment in valence, arousal and intensity levels – and that this simple feeling is only one element amongst others composing an emotion. Thus, an emotion is a psychological compound, for which this "simple feeling" (core affect) is a necessary but not sufficient ingredient. Like Wundt, Russell furthermore assumes that these psychological compounds, that he calls emotional episodes, can be classified into categories. Moreover, he argues that there is a prototypical cognitive structure for each emotional category, that is, a definition of the typical components and their temporal and causal relations within the emotional episode (Russell, 2003; Russell & Feldman Barrett, 1999). However, prototypical emotional episodes – that is, events that perfectly match a specific emotional prototype like fleeing from a wild animal in fear – are quite rare in real life, while non-typical emotional episodes – that is, events with one or more components altered or missing, but with sufficient fit to the prototype for being classifiable – are more common. The integration of core affect and the situational context into a specific emotional episode is assumed to take place in the prefrontal cortex (Posner et al., 2005).

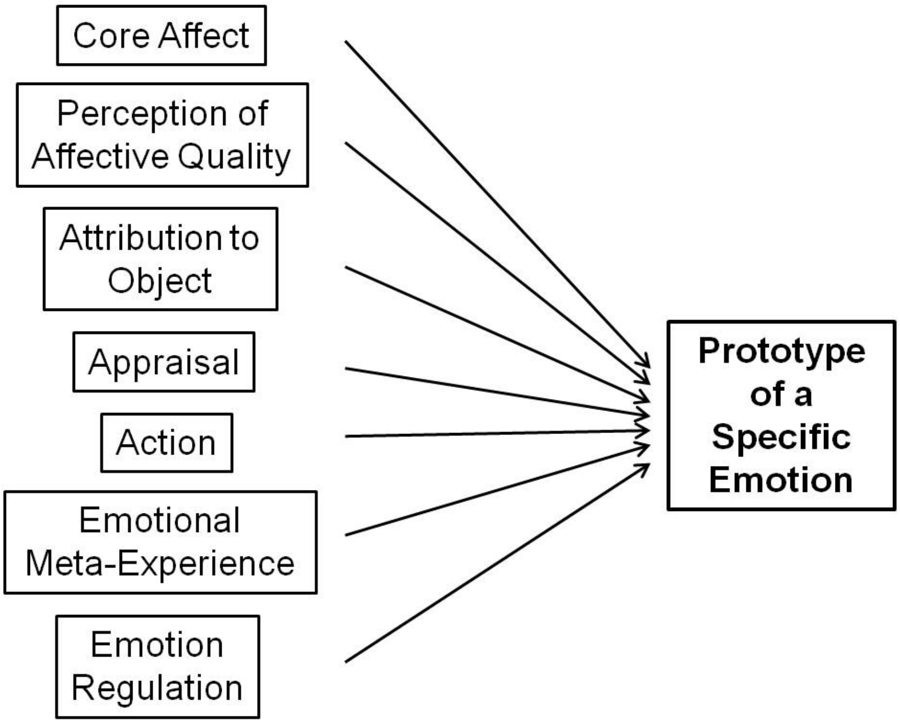

Figure 1.2. Psychological constructionists model of an emotional episode: A typical pattern of components, that matches a certain cognitive prototype, results in the subjective feeling of a specific emotion. Adapted from "Core affect and the psychological construction of emotion," by J. A. Russell, 2003, *Psychological Review*, *110*, p. 152. Copyright 2003 by the American Psychological Association.

Taken together, core affect is a unified state of feeling good or bad with some degree of arousal that can be represented as a circumplex in a two-dimensional space. Even though some clearly distinguishable affective feelings, like being afraid or angry, are very similar in core affect (direct neighbors in the circumplex), they can be differentiated based on other components besides core affect that are part of the more complex structure of an emotional episode. Emotional episodes can be classified into categories, like fear or happiness, based on their similarity to the prototypical emotional episode of a given category. In this way, also basic emotion theories (e.g., Ekman, 1992; Panksepp, 1998; Plutchik, 1980) can be reconciled with the circumplex model of affect to some extent. The idea of prototypical emotional episodes with specific concepts of typical components and their temporal and causal interrelations is similar to the concept of basic emotions, which are assumed to have characteristic response patterns. The integration of basic emotion theories into the circumplex model of affect is a promising solution for overcoming some shortcomings of that theory. For example, a basic assumption of basic emotions theory is that each emotion is associated with a unique neural pathway. With respect to affective neuroscience results (e.g., see the review by Davidson & Irwin, 1999 or the meta-analysis by Lindquist, Wager, Kober, Bliss-Moreau,

& Feldman Barrett, 2012) this is no longer tenable. There seems to be an interconnected network of brain regions (including, e.g., ventromedial and dorsolateral prefrontal cortex, amygdala, ventral striatum, anterior cingulate and insular cortex) involved in emotional responding that seems to respond differently to positive or negative affect, but there is still no proof of specialized circuits for single specific emotions. These findings are, however, in line with Russell's differentiation of core affect and prototypical emotional episodes, which includes no assumption of unique neural pathways for every emotion prototype. Furthermore, basic emotion theories claim a discrete set of basic emotions, but there is still no consensus on the definitive number of specific emotions. For example, Panksepp (1998) assumes four basic emotions whereas Plutchik (1980) suggests eight. Russell's circumplex model is able to include as many prototypical emotional episodes as there are reasonable prototypes. Some examples of prototypical emotional episodes are included in Figure 1 in the outer ring of the circumplex.

1.1.4. Interim Summary

Overall, Russell's circumplex model of affect seems to be a very useful and fruitful description of the structure of affect that appears to be well suited to represent the entire spectrum of affective experiences. It is able to integrate differential emotion theory traditions (cf., review by Gendron and Feldman Barrett, 2009) into a single conceptual framework that is supported by affective neuroscience results and empirical studies. Therefore, the present thesis adopts the concept of affect as a combination of the basic dimensions valence and arousal as suggested in the circumplex model of affect.

1.2. Cognitive control

Cognitive control, like emotion, is another term widely-used in the psychological literature, but not always with the same meaning. Thus, like in the previous chapter, a short review is initially given on the history of cognitive control in psychology followed by a description of a current perspective on the topic as well as a definition of the concept of cognitive control that is applied in the present thesis.

1.2.1. Defining cognitive control

More than a hundred years ago, the idea of a dual process system that differentiates automatic (synonymously often called stimulus-driven or involuntary) from controlled (synonymously often called goal-driven, voluntary, or executive) processes can already be found in William James's classical book "The Principles of Psychology" (1890). The works of Schneider and Shiffrin (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977) – from a present-day perspective classical works themselves – give a more detailed description of these two types of processing: Automatic processes are assumed to be effortless, fast, unconscious, and difficult to modify. Furthermore they are supposed to be triggered by specific stimuli in a reflexive manner and to work in parallel without interfering with other concurrent processes. Controlled processes, in contrast, are assumed to be conscious and intentional, to rely on limited processing capacity, and to work in a serial manner. Therefore, they are slower and prone to interference, but enable more flexibility in behavior. Empirical research over the last decades has shown, however, that human cognition is not reducible to a simple distinction of automatic versus controlled processes, but that there is a more complex interplay of both kinds of processes. For example, automatic processing seems to be triggered in a truly reflexive, stimulus-driven manner but only under certain conditions, namely when the trigger stimulus includes features that are important for the currently active goal or intention (e.g., Remington, Folk, & Mc Lean, 2001). Moreover, in certain situations controlled processes can be activated automatically and without consciousness, for example, by subliminal stimuli (e.g., Neumann & Klotz, 1994). According to Hommel (2007) the association of control and consciousness, furthermore, lacks a substantiated theoretical basis. He criticizes that the association is often found in the literature but seldom explained, and mostly stems from mere beliefs about a natural connection of control and consciousness. This sometimes culminates in the usage of the combined term "conscious control" without definition or justification. To achieve progress in the understanding of cognitive control processes, however, it is necessary that researchers use well-defined theoretical concepts, so that empirical studies from different researchers can be compared and used to draw general conclusions.

The present thesis follows the idea of cognitive control as a basis for adaptive action (cf., Goschke, 2003). In this framework, processes are considered controlled only under specific conditions, namely when completely new stimulus-response connections have to be established, or when the representation of a current intention requires active maintenance because competing pre-dominant, but inadequate, response tendencies have to be overcome (see also Miller & Cohen, 2001). Cognitive control thereby faces two antagonistic challenges:

On the one hand, goals and intentions have to be maintained over time and shielded against irrelevant distractions. On the other hand, adaptive behavior must be flexible enough to switch goals according to internal needs or relevant changes in the environment. So, there is a control dilemma between stable maintenance and flexibility with a trade-off between the two antagonistic demands: Stability protects current intentions from competing action tendencies, but unrestricted stability results in perseverative, inflexible behavior. Flexibility, on the other hand, enables, for example, adaptive behavior in new situations, but is accompanied by increased distractibility. In a complex, constantly changing environment, adaptive action thus needs a context-dependent, dynamic balance between maintenance and flexibility. This leads to the question, how to accomplish this dynamic adjustment. The intuitive answer that, of course, "the person" is in control is just as problematic and unjustified as an unfounded association of control and consciousness. Alternatively, the idea of a central executive in the cognitive system arose analogous to the central processing unit of a computer system (e.g., Norman & Shallice, 1986; Baddeley, 1986; 2000), that is, a single control unit is assumed to monitor and regulate lower level processes in a top-down manner. For example, in Baddeley's working memory model (1986; 2000) a central executive system is assumed to control and regulate three subsystems, namely the phonological loop – for maintenance of verbal information –, the visuospatial sketchpad – for maintenance of visual and spatial information –, and the episodic buffer – a limited capacity short time storage for integration of information from short- and long-term memory and different modalities. But the concept of a central executive cannot really explain cognitive control either, because it still gives no explanation about how this central executive knows when to exert control. This "homunculus problem" is sorted out in theories of a self-regulating control system (e.g., Miller & Cohen, 2001; Cohen, Aston-Jones, & Gilzenrat, 2004), that is implemented in a self-organized neural system.

1.2.2. A self-regulatory system for adaptive cognitive control

The primary assumption for such a self-regulatory control system is that the prefrontal cortex (PFC) plays an essential role for cognitive control. Cognitive control requires active maintenance of task-relevant representations, shielding of these representations against distraction, plasticity to establish new representations, flexibility for updating representations in case of significant changes of the situation, integration of information from different sources, and modulation of ongoing processes in accordance with the current goal or intention. The PFC has been shown to be suitable for all these functions (see Miller & Cohen, 2001 for a review): (1) There is empirical evidence that the PFC is essential for establishing new stimulus-response representations and that PFC activity dynamically changes in accordance with current task rules. For example, it has been shown that patients with PFC lesions are impaired in learning new, arbitrary task rules (Petrides, 1990), and that PFC activity systematically varies, when alternating between different tasks (Asaad, Rainer, & Miller, 2000). (2) The PFC is not only suitable for establishing new task rules and adapting to changes of tasks, there is also evidence that current task representations are actively maintained and shielded against distraction in the PFC (e.g., Courtney, Ungerleider, Keil, & Haxby, 1997; Miller, Erickson, & Desimone, 1996), whereas distractors easily disrupt sustained activity in other areas of the brain (e.g., Costantinidis & Steinmetz, 1996). (3) The PFC has strong afferent and efferent connections with diverse cortical and sub-cortical structures (e.g., Barbas & Zikopoulos, 2007; Fuster, 1989). For example, the PFC receives widespread input from multiple sensory areas (e.g., Jones & Powell, 1970; Pandya & Barnes, 1987), has output to the motor system (e.g., Lu & Preston, 1994) and further neocortical areas (e.g., Pandya & Barnes, 1987), direct and indirect connections with medial temporal structures associated with memory and affect like the hippocampus or the amygdala (e.g., Barbas & DeOlmos, 1990; Goldman-Rakic & Selemon, 1984), and a high interconnectivity between its own subdivisions (e.g., Pandya & Barnes, 1987). This enables both the integration of information from different sources and the top-down modulation of various processes. Taken together, the PFC seems suitable to meet both demands of cognitive control, stability and flexibility, but a self-regulatory control theory still needs to explain how an adaptive, context-dependent adjustment of these antagonistic demands is achieved in a self-organized manner.

Converging evidence and computational modeling suggest that updating of representations in PFC is mediated by a dopaminergic adaptive gating mechanism (see Braver & Cohen, 2000; Cohen et al., 2004; Miller & Cohen, 2001 for an overview). Without a gating signal, an active representation in the PFC is maintained and shielded against task-irrelevant input. The detection of behaviorally salient events – especially unpredicted rewards – leads, however, to bursts of activity in midbrain dopamine (DA) neurons in the ventral tegmental area (VTA), which project widely into the PFC (Mirenowicz & Schultz, 1996). These DA bursts are assumed to work as a gating signal that allows input of relevant new information into the PFC, and thereby enables adaptive updating of active representations in the PFC. This gating signal is furthermore modulated by learning mechanisms (Schultz, 1997). DA neurons in the VTA initially fire, when a novel stimulus appears or an unpredicted reward occurs.

However, when a stimulus is repeatedly paired with the same reward, DA neurons no longer fire in response to the reward itself but to the reward predicting stimulus. Further learning is accomplished by systematic adjustments in DA activity to prediction errors: DA activity decreases with delays or absence of a predicted reward, and increases with unexpected fast rewards or rises in rewards (e.g., D'Ardenne, Mc Clure, Nystrom, & Cohen, 2008). So, the midbrain DA system learns and gates at the same time, and thereby can optimize itself. That is, a novel stimulus initially elicits an exploratory gating signal from the VTA into the PFC, which causes an update of current representations in the PFC. If this new representation leads to a behavior, which results in a reward or success, reinforcement learning strengthens midbrain DA activity associated with this new stimulus. Thus, a future encounter with this stimulus will more easily again elicit a gating signal, which reactivates the PFC representations and the associated behavior. If this behavior still leads to a reward, the reinforcement of associations with this stimulus in VTA will continue. In contrast, if a novel stimulus is followed by non-rewarded or unsuccessful behavior, associations to this stimulus will be diminished, and the probability, that the same stimulus will again elicit a gating signal decreases. Taken together, the system is able to regulate adaptive updating on its own (cf., Braver & Cohen, 2000; Cohen et al., 2004; Miller & Cohen, 2001). However, a theory of a self-regulating control system not only needs to explain how an adaptive balance between stability and flexibility is established, it also should be able to explain how the system “knows” when cognitive control is needed in the first place, and how much control is necessary for achieving a certain goal.

The conflict monitoring hypothesis (Botvinick, 2007; Botvinick, Braver, Barch, & Carter, 2001; van Veen & Carter, 2006) assumes that conflict is a natural signal of the need for control. For example, in the Stroop task (Stroop, 1935) – a classical conflict task, in which subjects have to name the ink color of printed color words – an incongruent Stroop stimulus (e.g., the word BLUE written in red ink) causes a conflict between the pre-dominant, but irrelevant, word meaning and the ink color. Therefore, cognitive control is needed to overcome the relatively stronger process of reading in favor of the weaker color naming process. The conflict monitoring hypothesis suggests that the anterior cingulate cortex (ACC) detects such conflicts, and signals the demand for control to the PFC. In consequence, activity of representations in the PFC is increased, so that task-relevant processing is strengthened. This hypothesis received behavioral and neuro-imaging support from several studies on sequential conflict adaption effects (e.g., Egner & Hirsch, 2005; Kerns, 2006; Kerns et al., 2004): A conflicting stimulus – for example, an incongruent Stroop stimulus – activates the

ACC, and is, furthermore, associated with performance impairments compared to a non-conflict stimulus, because the conflict has to be resolved in order to accomplish a correct response. In addition, PFC activity also increases with the consequence that subsequent conflicting stimuli cause less interference, because task-relevant representations are strengthened and conflict resolution is facilitated. So in sum, the ACC appears to monitor conflicts and signal the demand for control, while the PFC seems to be responsible for implementing control. While some theorists assume that the ACC directly influences the PFC, an alternative theory (Cohen et al., 2004) suggests that control adjustment is mediated and further modulated by activity of the locus coeruleus (LC). The LC is a norepinephrine (NE) releasing nucleus in the brainstem with widespread projections throughout the brain (see e.g, Berridge & Waterhouse, 2003), which enhance the contrast of current activity patterns in the brain. That is, already activated pathways are further activated and inhibited pathways are further suppressed, which is exactly the mechanism needed within the PFC for an adaptive adjustments of control.

Cohen et al. (2004) suggest that it is a phasic release of NE that mediates conflict detection in the ACC and control adjustment in the PFC, but furthermore assume that there is also a tonic mode of LC activity involved in the adaptive regulation of cognitive control (cf., Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b) . This is based on the assumption, that the conflict detection-control enhancement-loop is only adaptive up to a certain point. For demonstration, imagine a visual discrimination task, in which the subject has to decide whether two lines have the same orientation: This task is rather easy, when one line is oriented horizontally and the other line vertically, but task difficulty and conflict increases with decreasing angular difference of the lines. Increasing cognitive control can stabilize performance accuracy only until the angular difference is no longer recognizable. At this point, further enhancement of control makes no longer sense, so that control should be disengaged from this task, and a search for more promising alternative tasks should be initiated instead. That is, a self-regulating control system needs to achieve an adaptive balance between exploitation – optimizing current task performance – and exploration – disengagement from the current task, when it is no longer advantageous, and search for alternatives –, which is assumed to be mediated by shifts between phasic and tonic release of NE from the LC (Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b). In phasic mode, there is only moderate tonic LC activity but there are phasic bursts of NE selectively to target but not to distractor stimuli, which optimize performance in the current task (e.g., Aston-Jones, Rajkowski, Kubiak, & Alexinsky, 1994). In tonic LC mode, on the other hand, there is a higher level of tonic activity and no phasic responses to target stimuli, which impairs performance with slower reactions to targets and more false alarms to distractors (e.g., Usher, Cohen, Servan-Schreiber, Rajkowski, & Aston-Jones, 1999). At first sight, the tonic mode seems to lack an adaptive value, because it makes the system more responsive to task-irrelevant stimuli. However, it becomes adaptive in situations like the scenario described previously, when exploitation of the current task is no longer advantageous. By increasing responsiveness to all kind of stimuli in the environment, the tonic mode enables the exploration of promising new behaviors. In sum, the phasic LC mode helps in optimizing performance within a task, while the tonic mode helps in optimizing performance across tasks. As a final step for a self-optimizing and self-regulating adaptive control system it needs to be explained how the system comes to know whether to exploit or to explore. Cohen et al. (2004) assume that the conflict monitoring mechanism in the ACC can provide this information, given the additional assumption that the ACC is sensitive to conflict in different time frames. That is, in situations with only transient increases in conflict – for example, when being confronted with a moderate percentage of incongruent Stroop trials amongst congruent Stroop trials – detection of conflict increases control by activating phasic LC mode. In situations with constantly high conflict – for example, when being confronted with perceptually undistinguishable stimuli in a visual discrimination task –, however, transient changes in conflict no longer matter, and control should instead be withdrawn, which is associated with a shift into tonic LC mode. This mechanism is furthermore assumed to be sensitive to reward. When current performance – irrespective of conflict – is no longer associated with reward, LC is also driven into tonic mode (see also Mc Clure, Gilzenrat, & Cohen, 2006).

Taken together, cognitive control is assumed to rely on representations in the PFC that lead to a modulation of ongoing processing in a top-down, goal-directed manner. PFC representations are furthermore suggested to be self-optimized and regulated by several mechanisms, including the VTA-DA system for adaptive updating of representations, the ACC conflict monitoring system for assessing the demand for control, and the LC-NE system for adjusting PFC representations in accordance with the current demands (cf., Cohen et al., 2004). The complete neural system for adaptive regulation of control is illustrated in Figure 3.

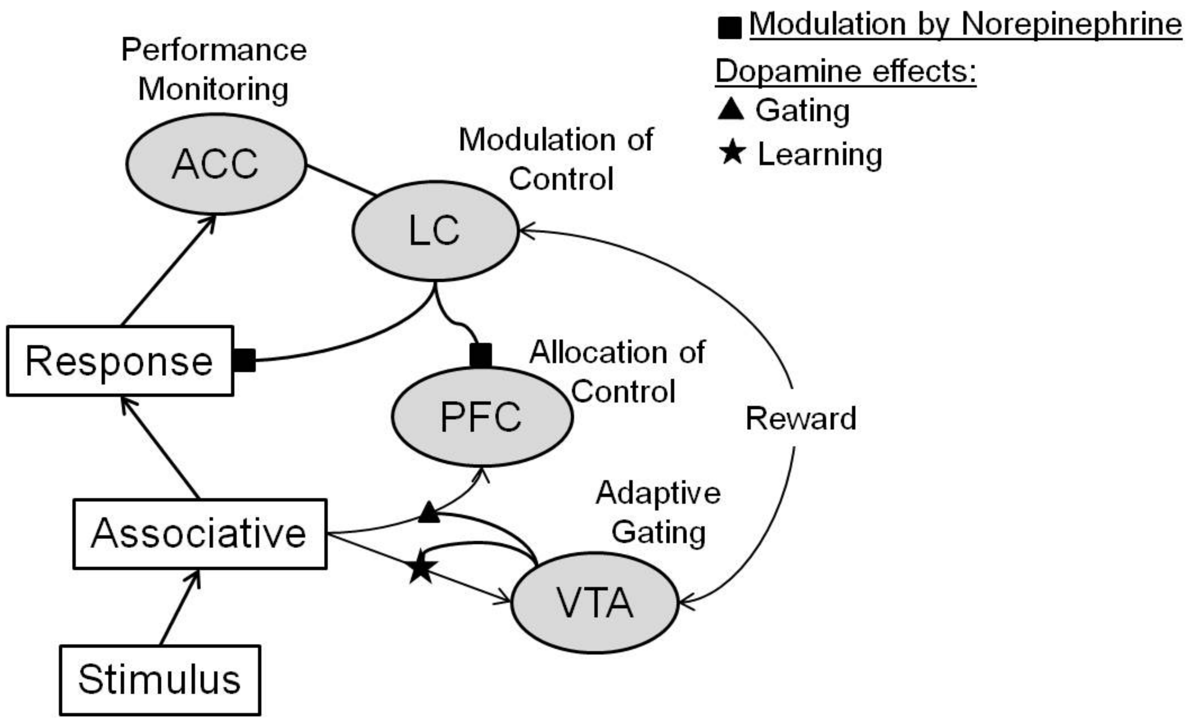

Figure 1.3. Neural model of a self-regulatory system for adaptive cognitive control. In a self-organized manner this system is able to adaptively maintain or update control representations in PFC, to learn how to do so, to determine the need for control, and to regulate the degree of control. Adapted from “A system-level perspective on attention and cognitive control. Guided activation, adaptive gating, conflict monitoring, and exploitation versus exploration,” by J. D. Cohen, G. Aston-Jones, & M. S. Gilzenrat, 2004, in M. I. Posner (Ed.), *Cognitive neuroscience of attention*, p. 84, New York: Guilford Press. Copyright 2004 by the Guilford Press.

1.2.3. The dual mechanism of control framework

Braver and colleagues (Braver, 2012; Braver, Gray, & Burgess, 2007) recently suggested the dual mechanisms of control (DMC) framework to explain variations in cognitive control – inter-individual, intra-individual, and between groups. Therein, cognitive control is differentiated into two distinct modes, namely, proactive and reactive control. Proactive control means that task-relevant context information is actively maintained and used to optimize *in advance* attentional, perceptional and motor systems for an upcoming demanding event. Reactive control, in contrast, is assumed to be activated *transiently* in a just-in-time manner as soon as a high interference event is detected. Thus, proactive control works as an ‘early selection’ mechanism to prevent interference before it occurs, whereas reactive control works as a ‘late correction’ mechanism to resolve interference after its onset. Furthermore, both are associated with different neuronal mechanisms: Proactive control is assumed to rely on the active maintenance of task-relevant representations in the PFC, which are regulated by the adaptive DA gating mechanism explained above (cf., Braver & Cohen, 2000; Cohen et al., 2004; Miller & Cohen, 2001). These maintained representations are robust against task-irrelevant distractions and bias ongoing processing for optimal performance in a top-down manner. Under reactive control, on the other hand, PFC representations are assumed to be activated only transiently in a bottom-up manner after detection of a demanding event. This is assumed to be mediated by activity in additional areas besides the PFC, for example, the long-term memory system in medial temporal lobe or the ACC conflict monitoring mechanism (cf., Botvinick, 2007; Botvinick et al., 2001; van Veen & Carter, 2006).

The DMC framework furthermore suggests that there is a computational trade-off between these two control modes, so that in a given situation there is always a bias in favor of one control strategy over the other as a function of intra-individual, inter-individual and/or between-groups factors. For example, proactive control is only possible in situations, where predictive context information – for example, informative cues – is present, so that in advance preparation is enabled in the first place. Reactive control, in contrast, is not dependent on such in advance information and is therefore applicable to a wider range of situations. Furthermore, proactive control requires active maintenance of task-relevant information, which enables to optimize performance in this task and to reduce distractions by task-irrelevant sources, which is, however, resource-demanding. Thus, with longer intervals between maintenance initiation and utilization of the activated representation a shift towards a reactive control strategy is more likely, because it only requires a transient, less resource-demanding activation of PFC representations. These transient representations, however, are less robust against distraction and can also be activated by salient but task-irrelevant trigger stimuli. Thus in sum, Braver's DMC framework can be understood as the neuronal implementation of the stability-flexibility framework suggested by Goschke (2003). Like Goschke, Braver also assumes that adaptive action is associated with dynamic shifts between the two control modes in accordance with a constantly changing environment. Importantly, not only external changes are assumed to influence which control strategy will be favored over the other, but also intra-individual changes are associated with strategy shifts. For example, healthy aging is accompanied by impairments in DA and PFC functioning, which result in a general preference for reactive control (Braver et al., 2001). Importantly for the present thesis, affect is another factor assumed to influence the balance between proactive and reactive control.

1.3. Positive affect and cognitive control

A meta-analysis of over 150 neuroimaging studies came to the conclusion that affect is associated with activity in a broadly distributed system, including orbitofrontal cortex, anterior insula, amygdala, ACC, ventral medial PFC, thalamus, hypothalamus, ventral striatum, and midbrain and brainstem areas (Wager et al., 2008). Several of these areas are also associated with the self-regulatory cognitive control system described in the previous chapter (cf., Cohen et al., 2004), which is one reason why currently more and more researchers reject the idea of distinct affective and cognitive systems, and instead suggest strong interactions of or even integration of affect and cognition not only in the brain but consequently also in behavior (cf., Duncan & Feldman Barrett, 2007; Gray, 2004; Feldman Barrett & Bliss-Moreau, 2009; Pessoa, 2008; Storbeck & Clore, 2007). Therefore, affective modulation of cognitive control has become a special research topic with more and more interest over the last few years. Regarding positive affect in particular, research was especially influenced by the neuropsychological theory proposed by Ashby and colleagues (Ashby, Isen, & Turken, 1999; Ashby, Valentin, & Turken, 2002).

1.3.1. The neuropsychological theory of positive affect

The neuropsychological theory of positive affect (Ashby et al., 1999; Ashby et al., 2002) is based on two basic assumptions: (1) Positive affect is associated with moderate increases in brain DA levels, which, however, are not assumed to mediate the pleasant feelings. (2) Some cognitive effects of positive affect are due to these increased levels of DA. The proposed link between DA activity and positive affect is based on several sources: For example, unexpected rewards are known to induce positive affect and to elicit DA release (e.g., Schultz, 1992). Furthermore, DA agonists – that is, drugs that enhance DA activity – induce positive affect (e.g., Beatty, 1995), whereas DA antagonists – drugs that inhibit DA activity – flatten affect (e.g., Hyman & Nestler, 1993). Moreover, positive affect and DA release are both associated with elevated motor activity (e.g., Strickland, Hale, & Anderson, 1975). For the cognitive effects of positive affect, Ashby et al. (Ashby et al., 1999) postulate that specifically DA input from the VTA into the PFC and the ACC are important. More precisely, they suggest that moderate increases of DA release into the PFC facilitate working memory, while projections into the ACC are supposed to facilitate switching between or the selection of cognitive sets, which might be furthermore mediated by the PFC and the basal ganglia. The first assumption is based on studies showing, for example, that DA agonists can improve performance in a delayed matching task (Müller, von Cramon, & Pollmann, 1998), whereas blocking DA projections into the PFC with DA antagonists impairs performance in delayed response tasks (Sawaguchi & Goldman-Rakic, 1991; Sawaguchi & Goldman-Rakic, 1994). Furthermore, this facilitatory effect of dopamine seems to be dose-dependent and optimal at an intermediate level (Sawaguchi & Goldman-Rakic, 1994; Williams & Goldman-Rakic, 1995). The proposed association of DA and cognitive set shifting is based on studies showing, for example, that DA antagonists specifically impair performance in tasks requiring cognitive set shifting (Berger et al., 1989), and that patients with Parkinson's disease, which is associated with degenerations particularly in the DA system, have specific deficits in cognitive set shifting tasks (Cools, van den Bercken, Horstink, van Spaendonck, & Berger, 1984). In sum, the neuropsychological theory of positive affect led to the hypothesis that positive affect – mediated via mild increases in DA release – increases cognitive flexibility, which could, for example, explain the benefits in creative problem solving found in association with positive affect (e.g., Estrada, Isen, & Young, 1994; Isen, Daubman, & Nowicki, 1987; Isen, Johnson, Mertz, & Robinson, 1985): Positive affect compared to neutral affect – induced via different procedures like giving an unexpected gift, watching a funny film clip or reading positive words – increased, for example, the probability to solve Duncker's candle problem (1945), which requires cognitive flexibility to overcome functional fixedness. Positive affect was, furthermore, associated with more correct solutions in the Remote Associates Test (Mednick, 1962; Mednick, Mednick, & Mednick, 1964), in which participants have to find a word that is remotely related to three given probe words, as well as with more unusual first associates for positive and neutral, but not negative words in a free association task.

The publication of the neuropsychological theory (Ashby et al., 1999) inspired several further studies investigating the relationship of positive affect and cognitive flexibility, which showed converging evidence that positive affect enhances flexibility in form of an increased ability to overcome predominant but task-irrelevant responses tendencies. For example, Dreisbach and Goschke (2004) manipulated affect via IAPS pictures preceding every trial in a cognitive set-switching paradigm. In this paradigm, participants had to categorize a target presented in one color, while ignoring a simultaneously presented distractor in another color. Dreisbach and Goschke investigated two switching conditions of cognitive sets: After the switch, either the targets appeared in a new color, while the former target color became the distractor color (perseveration condition), or the distractors appeared in a new color, while the former distractor color became the target color (learned irrelevance condition). The authors found that mild positive affect compared to neutral affect reduced switch costs in the perseveration condition but increased switch costs in the learned irrelevance condition. No effects were found for a negative affect control group. They concluded that positive affect, on the one hand, helps to overcome a (predominant) cognitive set, but increases distractibility by new distracters, on the other hand. Thus, positive affect seems to modulate the balance between flexibility and stability of cognitive control (cf., Goschke, 2003) in favor of a more flexible but consequently also more distractible behavior. Further evidence for this conclusion can be found in a study by Dreisbach (2006) that shows that positive affect reduces maintenance capability. This study used the same affect manipulation as the previous study but this time in an AX Continuous Performance Task (AX-CPT) – a modified version of the Continuous Performance Test (Rosvold, Mirsky, Sarason, Bransome, JR., & Beck, 1956). In this paradigm, participants have to press a prespecified target-response key to the target "X" but only if it follows the cue "A". If X follows another letter (e.g., B) or A is followed by another letter than X (e.g. Y), the non-target response key has to be pressed. Critically, the cue A is highly informative about the occurrence of X (70 % frequency of AX trials, whereas the other trial types BX, AY, and BY occur with 10 % frequency each), likewise, the cue B is also very informative, as it unequivocally predicts a non-target response. Dreisbach (2006) found improved performance in AY trials, but worsened performance in BX and BY trials under positive affect. This result was interpreted as evidence for a reduced maintenance of the cue, because subjects in the positive group – compared to a neutral and a negative affect group – showed costs when a to be maintained goal had to be executed (BX and BY trials; less stability) and benefits when a to be maintained goal unexpectedly changed (AY trials; more flexibility).

A reference to the neuropsychological theory of positive affect can also be found in a study by Kazen and Kuhl (2005) that was furthermore motivated by the personality systems interactions theory (PSI; Kuhl, 2000). According to this framework, the selection of non-dominant response alternatives is facilitated under positive affect (inhibited under negative affect) only in situations when intention memory is loaded or extension memory is highly activated, which is suggested to be mediated by DA activity. Kazen and Kuhl manipulated affect via affective prime words preceding every trial and found a reduction of Stroop interference after positive words related to achievement needs, but not after positive words related to affiliation or power needs. Compared to neutral words, negative achievement words even increased the Stroop effect. Following the PSI theory, these results were interpreted as evidence that specifically positive affect facilitates currently active intentions in a loaded intention memory, which is accomplished, for example, by an achievement-related context. This study, thereby, extended and replicated a previous study (Kuhl & Kazen, 1999), which already showed a reduction of Stroop interference for the first of two consecutive Stroop tasks under positive affect. Having to complete two consecutive tasks in one trial is also assumed to load intention memory. Another study by Baumann and Kuhl (2005) found similar results with a different task: They used a shape detection task, wherein the target shape could be present on a global (dominant) or local (non-dominant) dimension and found that subjects responded faster to local targets after positive prime words compared to neutral or negative words. So, despite a general preference for global processing (Kimchi, 1992) – particularly under positive affect (e.g., Gasper & Clore, 2002) – positive prime words improved switching to the local dimension, whereas negative prime words increased response latency especially to local targets. With reference to the PSI theory, this result was interpreted as evidence that positive affect can facilitate the activation of extension memory, which results in enhanced cognitive flexibility in form of an increased ability to overcome predominant response tendencies.

A more recent study (van Wouwe, Band, & Ridderinkhof, 2011) is also referring to the neuropsychological theory of positive affect. Therein again an AX-CPT paradigm was used but affect this time was manipulated with emotional film clips – positive or neutral – prior to the actual experiment, and event related potentials (ERP) were recorded in addition to the assessment of behavioral data. In line with the Dreisbach (2006) study, they found improved behavioral performance in AY trials, that is, in trials on which a cue-induced response tendency had to be overcome, which also fits with the above reported results found by Kuhl and colleagues (Baumann & Kuhl, 2005; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999). However, unlike the Dreisbach study, the authors did not find impairments in BX and BY trials, where the cue unequivocally announced the non-target response. Based on these behavioral results and the supporting ERP data, van Wouwe and colleagues (2011) concluded that proactive control – which would be seen in a difference in cue usage –, did not differ between their positive and neutral group but that, instead, reactive control as soon as the target stimulus appeared was enhanced under positive affect.

Though all above reviewed studies are motivated by the neuropsychological theory by Ashby et al. (Ashby et al., 1999; Ashby et al., 2002) or interpret their behavioral (and ERP) results with reference to this theory, they, admittedly, can only indirectly support it. More direct evidence for the mediating role of DA for positive affect effects comes from studies investigating the relationship of individual differences in DA activity and cognitive control processes (Dreisbach et al., 2005; Müller et al., 2007; Tharp & Pickering, 2011). Those studies used the same cognitive set-switching paradigm that was already used in the study by Dreisbach and Goschke (2004), and measured differences in DA activity via individual differences in two indicators for central DA functioning, namely spontaneous eyeblink rate (EBR; cf. e.g., Elsworth et al., 1991) and a specific gene polymorphism (D_4 DA receptor gene exon III polymorphism [DRD4] 4/7 genotype; cf. e.g., Oak, Oldenhof, & van Tol, 2000). All three studies found that participants with higher central DA activity (high spontaneous EBR or DRD4 4/7 genotype) showed the same response pattern – with enhanced cognitive flexibility accompanied by increased distractibility – that was also found for participants under positive affect in the original Dreisbach and Goschke (2004) study, whereas participants with lower DA activity (low spontaneous EBR or the low activity DRD4 4/4 genotype) behaved like the neutral affect group. Taken together, there is converging evidence that specifically positive affect enhances cognitive flexibility, which seems to be mediated by the neurotransmitter DA.

1.3.2. The influence of arousal

With respect to the circumplex model of affect (Russell, 1980; Russell, 2003), it is however remarkable that none of these studies considered possible effects of different arousal levels. Though the studies by Dreisbach and Goschke (2004) and Dreisbach (2006) controlled for arousal by including a negative affect group with matched arousal levels to the positive affect group, they nonetheless did not investigate effects of different arousal levels. According to Russell's affect model valence *and* arousal are, however, inseparable components of core affect, meaning that any person at any given moment is always in a state of feeling good or bad with some degree of arousal (see also Chapter 1.1.2.). Furthermore, arousal is associated with activity in other neurotransmitter systems besides DA like NE, acetylcholine, serotonin, and histamine (Marrocco, Witte, & Davidson, 1994) with emphasis on the NE system (e.g., Grant, Aston-Jones, & Redmond, JR., 1988; Rasmussen, Morilak, & Jacobs, 1986). The LC-NE system, moreover, received special attention over the last decade because it not only mediates general arousal but moreover seems to modulate cognitive processing (e.g., Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b; Berridge & Waterhouse, 2003). More precisely, and as stated above, phasic and tonic LC mode are assumed to be a part of the self-regulatory cognitive control system (Cohen et al., 2004; see also Chapter 1.2.2.). Taken together, it is theoretically interesting and quite likely that this specific interaction of positive affect and cognitive control – namely, an enhancement of cognitive flexibility – is additionally modulated by arousal.

Only recently, first studies started to specifically investigate how valence *and* arousal influence cognitive control (Demanet, Liefooghe, & Verbruggen, 2011; Kuhbandner & Zehetleitner, 2011; van Steenbergen, Band, & Hommel, 2010). For example, Demanet et al. (2011) used three types of affective pictures preceding every trial as affect induction in a voluntary task-switching paradigm. In this paradigm, participants had to categorize a neutral stimulus either by identity (task 1) or by color (task 2), while using two fingers of one hand for responding to task 1 and two fingers of the other hand for task 2. Subjects were instructed to switch between tasks freely, but to try to perform each task about equally often. Affective picture types were neutral pictures with low arousal, positive pictures with high arousal and negative pictures with high arousal with the latter two matched for arousal levels. Influences of valence – by analyzing performance as a function of all three picture types – and arousal – by comparing high arousal, collapsed over negative and positive valence, with neutral picture trials – were investigated for global performance, task-switching performance, and the task-repetition bias. There was no difference in proportion of repetitions in association with valence or arousal. High arousal, however, increased switch costs with especially fast task-repetitions and higher error rates in task-switches following positive and negative as compared to neutral pictures. The authors interpreted this result in line with the adaption by binding account (Verguts & Notebaert, 2009), which suggests that arousal – via the LC-NE system – mediates control adaptation processes: Verguts and Notebaert assume that in any given trial binding processes – via Hebbian learning – strengthen current task representations. Furthermore, conflict detection is supposed to increase arousal, which is associated with a phasic NE signal. This NE signal is assumed to promote Hebbian learning, which consequently increases the binding of task-relevant representations. These strengthened task representations can explain why conflict is decreased in a subsequent conflict trial. In the voluntary task switching study by Demanet et al. (2011), the same mechanism is assumed to underlie the task-repetition benefit and increased switch costs under high arousal. Demanet et al., moreover, found that positive affect improved general task performance with faster overall RTs as compared to negative affect. RTs following neutral pictures were intermediate compared to positive and negative pictures, but did not differ significantly from either of them. Interestingly, valence did not influence switch costs, which was expected due to the hypothesis of increased flexibility under positive affect. However, the Dreisbach and Goschke study (2004) showed that it is crucial to look into specific switching conditions to detect the costs and benefits of positive affect in task switching. Furthermore, Demanet et al. suppose that methodological differences might contribute to the inconsistent results of both studies: In their study participants switched voluntarily and more than once per block, whereas in the study by Dreisbach and Goschke participants switched on instruction and only once in every block. Moreover, Demanet et al. directly investigated the influence of affect on switch costs in a given trial, whereas Dreisbach and Goschke compared mean performance in the last five trials before a switch with performance in the first five trials following a switch. Furthermore, Demanet et al. used a within-participants design with a mix of positive, neutral, and negative pictures in every block, whereas Dreisbach and Goschke compared different influences of affect in a between-groups design. Demanet et al., therefore, speculate that both studies might investigate cognitive control processes of different time scales and that mixing positive and negative affect might cause carry-over effects that cancel each other out. Another important difference between the two studies, which is, however, not mentioned in the discussion by Demanet et al., is the fact that though both studies controlled for arousal differences between positive and negative affect, they used affective pictures of different arousal levels with higher levels in the study by Demanet and colleagues. Thus, an alternative or additional explanation for these discrepant results might be that positive affect has different influences on cognitive control as a factor of low or high arousal levels. Both studies, however, cannot clarify this assumption because they did not manipulate different arousal levels within positive affect.

A completely orthogonal affect manipulation can be found in a study by Kuhbandner and Zehetleitner (2011). They did not use affective pictures but instead used a mood induction procedure including music and imagination prior to the actual experiment to elicit happiness (positive valence, high arousal), calmness (positive valence, low arousal), anxiety (negative valence, high arousal), and sadness (negative, low arousal). In their experiment, two components of cognitive control – amount of current control and strength of sequential control adaptation – were investigated with a visual pop-out distractor task. In this paradigm, participants had to detect and identify a pop-out target (e.g., tilted line amongst vertical lines), while on half of the trials a pop-out distractor was also present (e.g., a white line amongst grey lines), which causes interference. Amount of current control was measured by distracting mean RTs on trials without distractors (C) from mean RTs on trials with task-irrelevant distractors (I). Control adaption was operationalized by distracting mean interference on trials following trials with distracters (II – IC) from mean interference on trials following trials without distractors (CI – CC). The typical pattern of results for this kind of sequential analysis is that mean interference decreases in the current trial, if control was needed in the previous trial (I), reflecting sequential adaption of control demands (Gratton effect; Gratton, Coles, & Donchin, 1992), which is assumed to be mediated by ACC activity (e.g., Botvinick et al., 2001). Kuhbandner and Zehetleitner (2011) found that high arousal as compared to low arousal was associated with less current control (more interference), which they interpreted as a sign that high arousal increases distractibility by task-irrelevant pop-outs. Valence, on the other hand, did not influence current control but control adaptation: Stronger adaption was found for negative affect as compared to positive affect. The authors concluded that valence and arousal have dissociable effects on cognitive control processes, which may be a consequence of different neural bases (e.g., Colibazzi et al., 2010; see also Chapter 1.1.2.). In line with this study, van Steenbergen and colleagues (2010) also found stronger control adaption under negative affect in a classical flanker task (Eriksen & Eriksen, 1974) with a similar mood induction procedure like Kuhbandner and Zehetleitner. In their paradigm, a central target word was flanked by two distractor words on either side, which could be response-compatible or incompatible to the target. Participants had to categorize the central target only, so that response-incompatible flanker words resulted in interference, which had to be resolved by activating cognitive control. Sequential analysis of the flanker task normally also results in a typical Gratton effect. In contrast to Kuhbandner and Zehetleitner, van Steenbergen et al. (2010), however, did not find an influence of arousal on current control. Interference effects were comparable in all four mood groups. The valence influence on sequential control adaptation was interpreted as further evidence for the conflict as negative affective signal hypothesis (Botvinick, 2007; see also Dreisbach & Fischer, 2012a), which assumes that control adaptation happens to avoid future conflict and its negative affective consequences in particular. In line with emotion-congruency frameworks (cf., Rusting, 1998), it has already been shown that negative affect can facilitate conflict monitoring processes (Luu, Collins, & Tucker, 2000). Thus, van Steenbergen et al. (2010) interpreted their results as a sign that not only conflict registration but also sequential adaption may be facilitated by valence-congruent moods, that is, increased conflict adaptation effects under negative affective states.

1.3.3. Interim Summary

In sum, the reviewed theories and studies clearly show that positive affect modulates cognitive control. So far, the hypothesis of increased cognitive flexibility under positive affect, which is supposedly mediated by midbrain DA activity, gathered most empirical evidence. Contemporary neuroscientific theories and research as well as theories of affect, however, suggest that more factors might be important like, for example, arousal, which is associated with other neurotransmitters besides DA and activity in different brain areas. First studies addressing this issue already indicate additional influences of arousal.

1.4. Affect induction and the International Affective Picture System

1.4.1. Experimental affect induction procedures

The selective review of studies in the last chapter already showed that there is a variety of affect induction procedures used in affective science (see also Coan & Allen, 2007; Gerrards-Hesse, Spies, & Hesse, 1994; Martin, 1990). Different induction methods vary, for example, in the range of affective states that can be elicited, the intensity of induced affective reactions, the required administration time of the technique, or individual differences in susceptibility (Martin, 1990). Furthermore, this variety of affect induction procedures can be classified into different categories like imagination techniques (free or guided) or creation of an affective situation associated with, for example, success or frustration (Gerrards-Hesse et al., 1994). There are several kinds of affect induction methods that use simple exposure to affective stimuli. In this context, an affective stimulus can be any material (e.g., words, music, or events) that has the ability to influence a person's core affect (cf. Feldman Barrett & Bliss-Moreau, 2009). Most common are exposures to affective words, pictures, films or music. Affective film clips, for example, are able to elicit relatively intense affective reactions and are ecologically quite valid, because they are very complex and therefore more naturalistic than other kinds of affective stimuli (cf., Rottenberg, Ray, & Gross, 2007). To enable more comparable research (at least within English-speaking populations), a set of film clips, which has been shown to reliably elicit specific affective states, like amusement, fear or sadness, has been suggested for standardized usage in research (Gross & Levenson, 1995). A disadvantage of using film clips, however, is that affect induction is only possible prior to the actual experiment and not throughout the course of the experiment, which is accompanied by two problems: First, the application of within-participants designs is not possible – at least not on a trial by trial basis. Second, this procedure is accompanied by a great temporal heterogeneity in affective reactions with a strong affective activation directly after exposure, which is, however, fading over time. Thus, experiments using film clips for affect induction are rather time-limited.

A more classical common affect induction procedure is the Velten technique (Velten, JR., 1968). Therein participants read self-referred statements, which are associated with positive or negative affective states, and are furthermore instructed to try to feel the suggested affective states. This induction procedure, therefore, has greater demand characteristics than the above mentioned exposure techniques. Furthermore, for the Velten technique the same methodological concerns apply that were already discussed for affect induction via film clips. One of these concerns is addressed in another induction method that combines affective music with thoughts (cf., Eich, Ng, Macaulay, Percy, & Grebneva, 2007). In this procedure, participants are exposed to happy or sad music and furthermore instructed to concentrate on pleasant or unpleasant thoughts. During the actual experiment the music continues in the background to prolong the induced affective state. However, to establish an intense affective state in the first place most participants need about 15 minutes, which is rather long as compared to other affect induction methods. A complete discussion of the pros and cons of different affect induction procedures is beyond the scope of the present thesis. Thus, the remaining chapter will be restricted to a discussion of the affect induction method used in the following experiments of this thesis, which is short presentation of pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) preceding every trial. More exhaustive descriptions and discussions of common affect induction procedures can be found, for example, in the “Handbook of Emotion Elicitation and Assessment” (Coan & Allen, 2007) or the reviews by Martin (1990) or Gerrards-Hesse et al. (1994).

1.4.2. Affect induction via presentation of IAPS pictures

The IAPS contains a large set of color photographs from different categories like animals, sports or landscapes, which have been shown to reliably elicit specific affective reactions (e.g., Lang et al., 1993). Those pictures have been rated in several studies (cf., Bradley & Lang, 2007; Lang et al., 1999), so that researchers can select specific picture sets with respect to standardized valence and arousal levels. Those ratings proved to be highly reliable with high inter-rater reliability, high test-retest reliability as well as high internal-consistency reliability (Lang et al., 1999).

In comparison with alternative affect induction procedures, presenting IAPS pictures is associated with several advantages: (1) First of all, using pictures from a standardized system increases comparability and replicability across different studies in affective science, which is essential to permit progress in a research area. (2) Picture stimuli, on the one hand, are more complex and therefore more naturalistic than, for example, word stimuli, while, on the other hand, they are static, which makes them more controllable than dynamic stimuli like films. (3) Pictures are language-free, which makes them applicable across different cultures and throughout the lifespan, whereas using affective words, for example, is challenged by translation problems and the need of reading skills. (4) Affective pictures are effective almost instantaneously. Even very short presentation durations reliably elicit specific affective reactions (Codispoti, Bradley, & Lang, 2001; Codispoti, Mazzeti, & Bradley, 2009) with little difference to longer presentation durations: Typical affective reactions can be found already following a 25 ms exposure time or 80 ms, when pictures are directly followed by a mask. This enables much faster experimental procedures than other affect induction procedures. IAPS pictures, for example, can be presented shortly before every single trial without prolonging the experiment to an unreasonable extent. Furthermore, the instantaneous effect of IAPS pictures makes them also applicable in within-participants designs, which are not feasible with more time-consuming affect induction procedures like, for example, the Velten technique. (5) Repetitive exposure to pictures of the same valence is associated with maintained or even sensitized – but not habituated – affective reactions (Bradley, Cuthbert, & Lang, 1996; Smith, Bradley, & Lang, 2005). Therefore, presentation of positive or negative IAPS pictures preceding every trial seems better suited for investigating affective influences throughout the course of an experiment than induction procedures, which induce affect prior to the actual experiment. (6) Importantly for the present thesis, the standardized valence and arousal norms included in the IAPS enable the systematic investigation of both dimensions of affect. Though Lang and colleagues (Lang et al., 1999) tried to find pictures for the whole continuum of affective states, a few caveats are nonetheless associated with the IAPS affective space: Neutral affective pictures are restricted to rather low arousal levels. Positive and negative pictures show a trend for increasing arousal levels with more extreme valence levels, while this relationship is especially pronounced for negative stimuli (cf., Bradley & Lang, 2007; Lang et al., 1999). This pattern, however, might simply be a reflection of real world experiences, namely that emotional intense – and especially highly aversive – objects and events naturally go along with high arousal. For example, the fact that negative stimuli can be evaluated faster when they are high in arousal compared to low arousing negative stimuli (Robinson, Storbeck, Meier, & Kirkeby, 2004) strengthens this assumption of a natural relationship between negative affect and arousal. Furthermore, positive pictures with high arousal include the category of erotica, which are associated with gender differences and effects that are untypical for other highly arousing positive pictures (Most, Smith, Cooter, Levy, & Zald, 2007). These caveats should be taken account of when selecting IAPS picture sets for an experiment. But overall, the presentation of IAPS pictures seems a well suited affect induction method for investigating the research questions addressed in the present thesis, which will be introduced in the next chapter.

1.5. Scope of the present thesis

The main aim of this thesis is to further investigate how positive affect modulates cognitive control. One might argue that it is more important to investigate effects of negative affect, because results might be relevant for affective disorders like depression or anxiety disorder, but positive affect effects are no less important and seem to be especially relevant in association with everyday behavior. In a healthy person, affective state during a normal day is more likely to fluctuate from neutral to positive affect, for example, due to hearing a cheerful song on the radio or getting a surprise call from a good friend.

In the last years there has been a strong focus in research – inspired by the neuropsychological theory by Ashby and colleagues (Ashby et al., 1999; Ashby et al., 2002) – on the hypothesis that specifically positive affect – mediated via DA activity – increases cognitive flexibility (e.g., Baumann & Kuhl, 2005; Dreisbach, 2006; Dreisbach & Goschke, 2004; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999; van Wouwe et al., 2011). The majority of these studies included a negative affect control condition, and could indeed show a valence specific enhancement in cognitive flexibility under positive affect. This increase in flexibility seems to be accompanied by increased distractibility (Dreisbach & Goschke, 2004) and reduced maintenance capability (Dreisbach, 2006), which supports the stability-flexibility framework of cognitive control (cf. Goschke, 2003). With respect to the circumplex model of affect (Russell, 1980; Russell, 2003) research on specific affect effects should, however, also investigate influences of arousal, because both valence and arousal are inseparable components of affect. Furthermore, arousal is associated with activity of the neurotransmitter NE (e.g., Grant et al., 1988), which also has a modulatory effect on cognitive control according to current theories (cf., Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b; Cohen et al., 2004). A few recent studies (Demanet et al., 2011; Kuhbandner & Zehetleitner, 2011; van Steenbergen et al., 2010) already indicate that not only valence but also arousal influences cognitive control processes, but so far with rather mixed results. Therefore, the main aim of Part I of the present thesis is to further investigate, whether cognitive control is differently modulated by positive affect with low or high arousal levels.

According to the DMC framework (Braver, 2012; Braver et al., 2007) cognitive control can be differentiated into proactive and reactive control. With this framework in mind, two kinds of cognitive flexibility are feasible: The classical point of view, that is, flexibility in form of an increased ability to overcome pre-dominant response tendencies, corresponds to an increase in reactive control. But a reduction of proactive control can also be interpreted as increased flexibility, because less proactive control means that the behavior is less dependent on advance information. When classifying the existing literature, evidence for both kinds of flexibility can be found. For example, the results by Bauman & Kuhl (2005) could be interpreted as flexibility in form of increased reactive control, while the results by Dreisbach (2006) would fit with the interpretation of increased flexibility in terms of reduced proactive control. Therefore, Part II of the present thesis directly investigates, whether positive affect influences proactive or reactive control. Furthermore, the arousal effect examined in Part I will be replicated with different paradigms.

Favoring flexibility in the stability-flexibility balance of cognitive control is associated with a behavioral trade-off (cf., Goschke, 2003). Therefore, a comprehensive investigation of positive affect effects should not neglect the costs of an increase in cognitive flexibility. For example, Dreisbach and Goschke (2004) showed that increased flexibility under positive affect reduces perseveration, but at the same time enhances distractibility. The authors furthermore suggested that this increased distractibility is a consequence of an increased novelty bias under positive affect. That is, positive affect is assumed to promote susceptibility towards novel stimuli. This specific hypothesis has, however, not been directly addressed in an empirical investigation so far. Therefore, Part III of the present thesis is aimed to find evidence for an increased novelty bias under positive affect.

The final section of this thesis will give a general discussion on the influences of positive affect on cognitive control. Therein, results from the original research presented in

Parts I to III are discussed with respect to neuropsychological theories, theories on the functionality of positive affect, and current theories on cognitive control. Focus will be on the specificity of positive affect effects depending on, for example, different arousal levels or induction procedures. Furthermore, suggestions for future research are given, which might help in further clarifying the relationship between positive affect and cognitive control and in dissolving mixed results in the existing literature.

CHAPTER 2

Part I: How positive affect modulates cognitive control: The role of arousal

2.1. Introduction

Several empirical studies showed a valence specific effect – probably mediated via DA activity (Ashby et al., 1999; Ashby et al., 2002) – of increased flexibility under positive affect (see Chapter 1.3.1.). So far, however, little is known about possible additional influences of arousal. Arousal is also an inherent component of affect (Russell, 1980; Russell, 2003) and is, furthermore, supposed to modulate cognitive control processes via NE activity (Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b; Cohen et al., 2004). Therefore, the main aim of the first experiment of the present thesis is to investigate, whether affective modulation of cognitive control differs for positive affect with low or high arousal.

Conflict tasks are a common method for examining enhanced flexibility of cognitive control. Conflict can, for example, be manipulated within a given target stimulus as is the case in the Stroop task: Incongruent Stroop trials, like the color word BLUE written in red ink, cause a response conflict between the pre-dominant response tendency of reading and the relevant color naming task. Cognitive control is needed to resolve this conflict, which slows down RTs as compared to congruent Stroop trials (e.g., BLUE written in blue ink). An increase in cognitive flexibility should reduce this interference effect, because switching to the non-dominant, but correct response should be facilitated. Conflict can also be manipulated between a cue and a subsequent target as is the case in the AX-CPT: Therein a response conflict results when expectations are violated. The presentation of the cue A, for example, automatically activates the corresponding response for an AX trial due to the high frequency of AX trials. If A, however, is followed by another letter than X, a different response would be correct. This unexpected change of task demands induces a response conflict that needs to be overcome. Conflict resolution should again be facilitated with increased cognitive flexibility.

Experiment 1 of the present thesis also uses a conflict task, namely a spatial response cueing task with informative cues. In this paradigm, a peripheral target has to be responded with a spatially corresponding response key. The target is preceded by an also peripheral, informative cue. That is, the cue correctly indicates the possible target location with a probability of more than 50 % but less than 100 %. Responses in validly cued trials are facilitated because the spatial orientation of the cue automatically biases response selection towards the spatially corresponding response (Adam & Pratt, 2008; Wilson & Pratt, 2007). This automatic response tendency is furthermore sustained due to the informational value of the cue – and the associated expectations (Eimer, 1995; Eimer, Hommel, & Prinz, 1995). Invalid cues, on the other hand, cause task interference, because there is a response conflict between the pre-dominant, cue-congruent response and the correct response. This typical response pattern – response benefits following valid cues and costs following invalid cues – is called cue validity effect (CVE). An increase in cognitive flexibility is expected to reduce the CVE, because conflict resolution in invalid trials should be facilitated.

Two studies that controlled for arousal (Dreisbach, 2006; Dreisbach & Goschke, 2004) found converging evidence that specifically positive affect – manipulated via IAPS pictures preceding every trial – increases cognitive flexibility. Both studies found no difference between a negative affect group and a neutral affect control group, while using an IAPS picture selection of positive and negative pictures with rather low (matched) arousal levels. Demanet et al. (2011) used IAPS pictures with higher arousal levels and found also a specific positive affect effect, but furthermore increased switch costs following highly arousing affective pictures – positive and negative – as compared to neutral pictures. Taken together, these studies indicate – in line with Russell’s circumplex model of affect ((Russell, 1980; Russell, 2003) – that valence *and* arousal should both be considered when investigating affective modulations of cognitive control. However, the differences in paradigms used in these studies (see Chapter 1.3.2.) prevent strong conclusions about specific influences of valence or arousal at this point. Therefore, Experiment 1 was aimed to directly investigate how positive affect with low or high arousal influences cognitive control. To be able to manipulate valence and arousal independently, affect in the present study was also manipulated via IAPS pictures preceding every trial (see Chapter 1.4.2. for further advantages of this method). Four affective picture sets were chosen: (1) Neutral pictures with medium valence and low arousal levels for a control group. (2) Highly positive pictures with rather low arousal levels (positive$_{\text{low}}$ hereafter) comparable to those used in previous studies (Dreisbach, 2006; Dreisbach & Goschke, 2004) to replicate the influence of positive affect on cognitive flexibility. (3) Another positive picture set with high arousal levels (positive$_{\text{high}}$ hereafter). (4) Highly negative pictures with high arousal levels (negative$_{\text{high}}$ hereafter), which were matched to the positive$_{high}$ picture set, to control for negative affect effects. Negative pictures with low arousal were not included in the experiment, because this category did not differ from a neutral affect control condition in previous studies (cf., Dreisbach, 2006; Dreisbach & Goschke, 2004).

2.2. Experiment 1: Spatial response cueing with informative cues

In line with the neuropsychological theory of positive affect (Ashby et al., 1999; Ashby et al., 2002) and previous empirical studies (e.g., Baumann & Kuhl, 2005; Dreisbach, 2006; Dreisbach & Goschke, 2004; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999), positive affect with low arousal was expected to increase cognitive flexibility in form of a reduced CVE. According to Ashby and colleagues this effect is mediated by DA activity and therefore specific for positive affect and not attributable to arousal influences, which are assumed to be primarily mediated by NE activity (e.g., Grant et al., 1988). Based on the existing literature, different predictions are feasible for the positive$_{high}$ group: Positive affect could increase cognitive flexibility – mediated via DA – irrespective of different arousal levels. This would mean that the CVE should also be reduced in the positive$_{high}$ group. However, not only DA but also NE activity is supposed to modulate cognitive control (Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b; Cohen et al., 2004). Therefore, the modulatory effect of NE might influence the DA effect leading to a performance difference between positive affect with low and high arousal levels. The negative$_{high}$ group is primarily another control group besides the neutral group to see if highly arousing negative affect – in contrast to low arousing negative affect (cf., Dreisbach, 2006; Dreisbach & Goschke, 2004) – influences cognitive control performance. Furthermore, a previous study also using positive and negative highly arousing pictures (Demanet et al., 2011) found a valence effect with generally faster RTs under positive affect using a within-participants affect manipulation. Therefore, the comparison between the positive$_{high}$ and negative$_{high}$ group of the present study will show, whether this holds true in a between-groups design.

2.2.1. Method

2.2.1.1. *Participants*

Eighty-seven undergraduate students of Regensburg University participated in the experiment for course credit or 5 Euro. Eighty-three subjects (see Results for exclusion criteria) were included into the final data analysis (Mean age = 23.96 years, *SD* = 3.89, range = 19-38, 71 female). Participants were assigned randomly to the four affect groups (19 neutral, 21 $\text{positive}_{\text{low}}$, 22 $\text{positive}_{\text{high}}$, 21 $\text{negative}_{\text{high}}$). All participants signed informed consent and were debriefed after the session.

2.2.1.2. *Apparatus and stimuli*

A computer with a 17-inch-monitor (display resolution at 1024 x 768 pixel), running E-Prime 2.0 (Psychology Software Tools, Sharpsburg, USA) was used for experiment presentation and data acquisition. Viewing distance was held constant at 50 cm by using a chin rest. Responses were collected via a QWERTZ-keyboard, with the y- and m-key serving as left and right response keys.

For all four affect conditions, 10 IAPS pictures were selected for affect induction. Those pictures were all presented in landscape format and color, adjusted to a size of 800 x 600 pixels, and positioned centered on a grey background. Mean valence and arousal levels of the four picture sets can be seen in Table 2.1 (see Apendix A for IAPS picture numbers). Neutral pictures included household objects like plates or cups, $\text{positive}_{\text{low}}$ pictures showed babies and families, in the $\text{positive}_{\text{high}}$ group sport and adventure pictures were displayed, and $\text{negative}_{\text{high}}$ pictures showed mutilated bodies and accident scenes. No erotica were used in the $\text{positive}_{\text{high}}$ group to prevent different gender influences (see also Most et al., 2007).

Table 2.1. Mean valence and arousal levels (SD in parentheses) for the four IAPS picture sets

Picture set	**neutral**	**$\text{positive}_{\text{low}}$**	**$\text{positive}_{\text{high}}$**	**$\text{negative}_{\text{high}}$**
Valence *M* (*SD*)	4.99 (0.17)	7.99 (0.24)	7.25 (0.42)	1.75 (0.17)
Arousal *M* (*SD*)	2.45 (0.38)	4.55 (0.44)	6.3 (0.42)	6.32 (0.51)

The fixation cross, cue and target were all displayed in black ink and bold on grey background. The fixation cross was presented at the center of the screen in font size 32 pt. The target (a single dot) and the cue (the “§”-symbol) appeared 8.64 cm to the left or right of the fixation cross in font size 55 pt.

2.2.1.3. Procedure

Each trial started with the presentation of the fixation cross for 500 ms, followed by an IAPS picture for 350 ms. After another short fixation period (200 ms) the cue was presented left or right of the fixation cross for 200 ms. The target appeared after a variable inter stimulus interval of 50 or 150 ms, which was included to reduce premature responses to the cue, and remained on the screen until the participant pressed the spatially congruent response key. Participants were instructed to react as fast as possible while avoiding errors. In case of an error, the German word for error (“Fehler”) was presented for 1000 ms as feedback. An example trial is depicted in Figure 2.1.

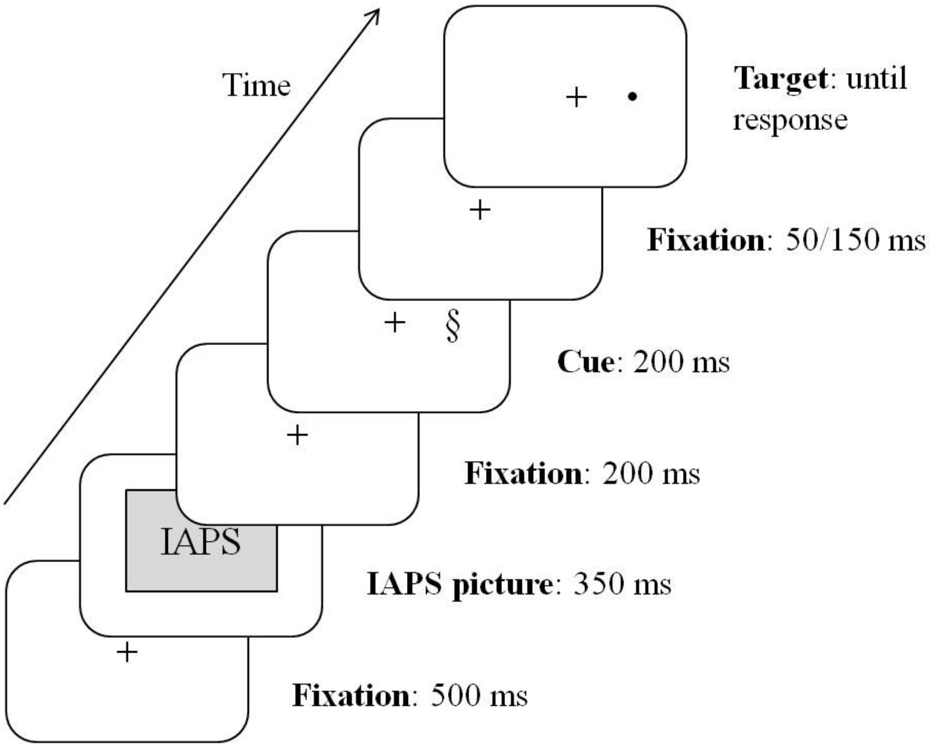

Figure 2.1. Design and procedure of a validly cued trial of the spatial response cueing task in Experiment 1.

To assure that all participants started with a similar mood, all participants passed a five minute relaxation exercise – comprised of relaxing music and spoken instructions for muscle relaxation – prior to the actual experiment. These instructions were standardized mp3-files presented via stereo headphones. Subsequently, 12 practice trials without IAPS pictures enabled the participants to get used to the cueing task. These practice trials were followed by two experimental blocks, in which an IAPS picture preceded every trial. Both blocks consisted of 120 trials (80 valid and 40 invalid), separated by a short break. The trial procedure within each block was pseudo-random: Each block consisted of 10 sequences of 12 trials and within these 12 trials the only constraint was that cues and targets appeared equally often on the left and the right side. Affective pictures were drawn from the set of the picture pool at random without replacement until all pictures had been presented once and then the procedure started all over again.

2.2.1.4. Design

A 4 (Affect: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$ vs. $\text{negative}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors design was used. Affect was manipulated between, and Cue validity varied within participants. Mean RTs (in ms) and error rates (in %) served as dependent measures.

2.2.2. Results

2.2.2.1. Data analysis

The practice trials as well as the first trial of each experimental block were excluded from analyses. In addition, error trials, trials following an error, and trials with RTs below 150 ms or above 1500 ms were excluded (4.18 % of the data). Furthermore, RTs differing more than three standard deviations from individual means were considered as outliers and also removed prior analysis (1.15 % of the trials). The data of two participants were excluded from further analyses, because of too many errors (individual mean error rates 11 % and 14 % while overall error rate was 2.37 %). Another two subjects had to be excluded due to untypical RTs throughout the experiment. One was exceptionally slow ($M = 492$ ms) in comparison to mean RTs of his affect group ($M\ positive_{low} = 344$ ms), and the other participant got continuously slower throughout the experiment and also had high mean RTs ($M = 411$ ms, while $M\ neutral = 349$ ms). Of the remaining data, mean RTs and error rates of each design cell (see Table 2.2) were entered into a 4 (Affect: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$ vs. $\text{negative}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors analysis of variance (ANOVA). Afterwards, separate analyses were conducted to isolate valence and arousal effects, respectively.

2.2.2.1.Error data, overall analysis

The overall ANOVA for the error data brought up a main effect of Cue validity, $F(1, 79) = 102.01, p < .001, \eta_p^2 = .564$. Fewer errors were made in valid than invalid trials (0.17 % vs. 4.08 %). The main effect of Affect ($F = 1.98, p = .123$) as well as the interaction of Affect x Cue ($F = 2.35, p = .079$) did not prove reliable. The overall error rate was 2.37 % ($SD = 2.36$).

Table 2.2. Mean RTs (in ms) and error rates (in %) in the spatial response cueing task of Experiment 1 (SD in parentheses) as a function of Affect group and Cue validity.

	Affect group							
	neutral		**positive$_{low}$**		**positive$_{high}$**		**negative$_{high}$**	
	valid	**invalid**	**valid**	**invalid**	**valid**	**invalid**	**valid**	**invalid**
RT	332	367	332	357	320	363	349	394
(*SD*)	(21.4)	(35.5)	(33.3)	(40.69)	(26.0)	(43.9)	(40.7)	(49.66)
Errors	0.24	4.11	0.19	3.05	0.09	5.64	0.15	3.54
(*SD*)	(0.38)	(3.1)	(0.3)	(3.16)	(0.23)	(3.95)	(0.28)	(3.8)

2.2.2.2. RT data, overall analysis

Significant main effects of Affect, $F(3, 79) = 3.33, p < .05, \eta_p^2 = .112$, and Cue validity, $F(1, 79) = 123.75, p < .001, \eta_p^2 = .61$, were found. Planned comparisons showed that the negative$_{high}$ group (372 ms) responded slower than the neutral (349 ms, $F(1, 79) = 4.1$, $p < .05$) as well as the positive$_{low}$ (342 ms, $F(1, 79) = 6.62, p < .05$) and the positive$_{high}$ group (344 ms, $F(1, 79) = 8.21, p < .01$). No significant differences were found between neutral and both positive groups as well as between the two positive groups (all $F < 0.55$, all $p > .459$). Participants responded significantly faster after valid than after invalid trials (333 ms vs. 370 ms), resulting in an overall CVE of 37 ms. The interaction of Affect x Cue validity did not prove reliable ($F = 1.88, p = .139$).

The overall analysis of mean RTs and error rates did not reveal a significant interaction of Affect x Cue validity. However, descriptively the positive$_{low}$ group, as expected, showed the smallest CVE in both RTs and error rates (see Figure 2.2). Because the neutral group was more of a descriptive baseline – it differed on both valence and arousal levels from all other affect groups – additional analyses without the neutral group were conducted to search more directly for valence and arousal effects on cognitive control.

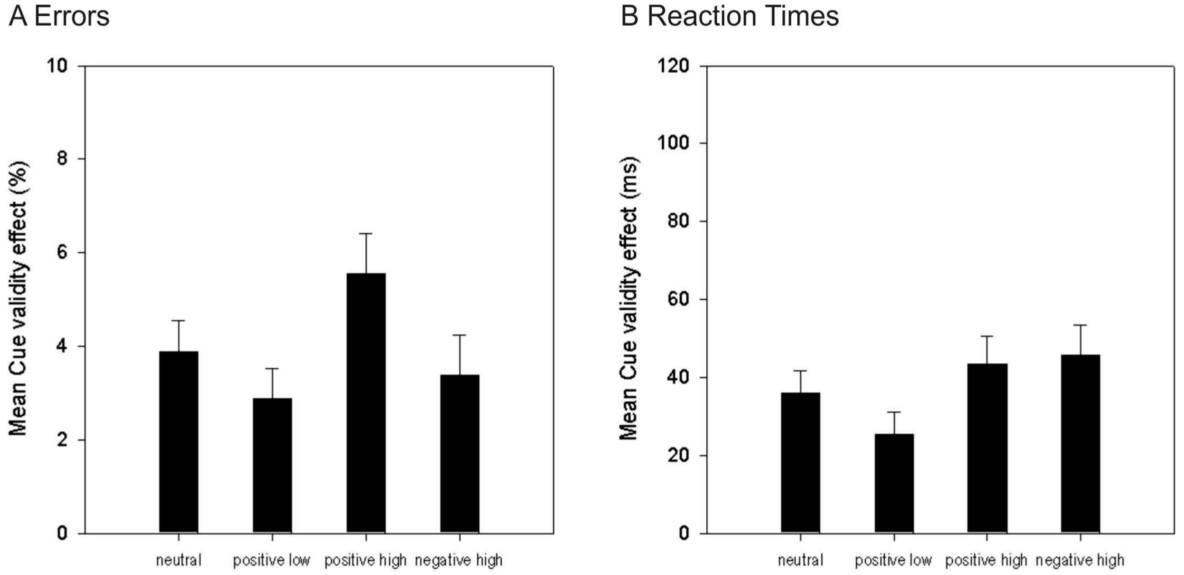

Figure 2.2. Mean cue validity effects (CVE) in the spatial response cueing task of Experiment 1 as a function of Affect group. The left panel (A) represents CVE differences in error rates (in %), the right panel (B) represents CVE differences in RTs (in ms). Error bars represent 1 standard error of the mean.

2.2.2.3. *Arousal effect, $positive_{low}$ vs. $positive_{high}$*

Mean error rates were entered into a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA. Significant main effects of Arousal, $F(1, 41) = 5.01$, $p < .05$, $\eta_p^2 = 109$, and Cue validity, $F(1, 41) = 60.34$, $\eta_p^2 = .595$, were found, which were further qualified by a significant interaction of Arousal and Cue validity, $F(1, 41) = 6.12$, $p < .05$, $\eta_p^2 = .13$. CVE was smaller in the $\text{positive}_{\text{low}}$ group, while especially less errors were made in invalid trials (3.05 % vs. 5.64 %). The same analysis for mean RTs revealed a significant main effect of Cue validity, $F(1, 41) = 54.19$, $p < .001$, $\eta_p^2 = .569$. Participants responded faster after valid trials (326 ms vs. 360 ms), resulting in a CVE of 34 ms. The interaction of Arousal x Cue validity, $F(1, 41) = 3.74$, $p = .059$, $\eta_p^2 = .084$, was on the threshold of significance. Therefore, the JZS-Bayes factor (Rouder, Speckman, Sun, Morey, & Iverson, 2009) was additionally calculated, which gives information about the probability of a hypothesis conditionally on observed data. JZS-Bayes factor was 0.895, which means that there is indeed some evidence in favor of a difference in CVEs between $\text{positive}_{\text{low}}$ and $\text{positive}_{\text{high}}$ group. The main effect of Arousal did not prove reliable ($F < 1$, $p = .787$).

2.2.2.4. *Valence effect, positive$_{high}$ vs. negative$_{high}$*

Another 2 (Valence: positive$_{high}$ vs. negative$_{high}$) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA for mean error rates revealed a significant main effect of Cue validity, $F(1, 41) = 54.96$, $p < .001$, $\eta_p^2 = .573$, with less errors in validly cued trials (0.12 % vs. 4.59 %). The main effect of Valence ($F = 3.04$, $p = .089$) and the interaction of Valence x Cue validity ($F = 3.23$, $p = .08$) did not prove reliable. The same analysis for mean RTs revealed significant main effects of Valence, $F(1, 41) = 7.02$, $p < .05$, $\eta_p^2 = .146$, and Cue validity, $F(1, 41) = 71.95$, $p < .001$, $\eta_p^2 = .637$, with slower RTs in the negative group (372 ms vs. 342 ms) and faster RTs following valid trials (334 ms vs. 379 ms). The interaction of Valence and Cue validity did not prove reliable ($F < 1$, $p = .822$).

2.2.3. Discussion

As expected, the results of Experiment 1 showed a reliable CVE with faster RTs and fewer errors on valid trials in all affect groups. More importantly, with respect to the topic of the present thesis, Experiment 1 resulted in preliminary evidence for enhanced cognitive flexibility specifically under positive affect with low arousal. The positive$_{low}$ group descriptively had the smallest CVE, both in error rates and RTs. When directly comparing positive affect with low and high arousal, this effect was significant in the error data and just at the threshold of significance in the RT data. Furthermore, Experiment 1 revealed a general slowdown of RTs in the negative$_{high}$ group. A direct comparison between negative$_{high}$ and positive$_{high}$ group showed that this effect is not attributable to high arousal, because participants under highly arousing positive affect were significantly faster as was also the case in the study by Demanet et al. (2011). Comparable to previous studies including a low arousal negative control group (Dreisbach, 2006; Dreisbach & Goschke, 2004), negative affect with high arousal, however, did not influence cognitive flexibility. This suggests that only positive affect modulates cognitive control processes, while highly arousing negative stimuli cause a valence specific general interference effect.

In sum, Experiment 1 already indicates that arousal influences should not be neglected when investigating positive affect effects, and that only positive affect in combination with low arousal increases cognitive flexibility. However, the statistical effects in this first experiment were rather subtle. Therefore, Experiment 2 was run to collect more empirical support for the modulation of the CVE by positive affect with differing arousal levels.

2.3. Experiment 2: Spatial response cueing under increased working memory load

A very simple response cueing task was used in Experiment 1, which resulted in very fast overall RTs (*M* = 333 ms) and a low overall error rate (2.37 %). Therefore, marginally significant differences between groups might be due to a floor effect. To increase variance and thereby provide room for affective modulations, task difficulty was increased in Experiment 2. To assure that both experiments were still comparable the same cueing task with informative cues (66 % cue validity) was used, but this time in combination with a concurrent math task.

Experiment 1 showed general task interference in the negative$_{\text{high}}$ group, but no additional influence on cognitive flexibility. Based on this result and due to the focus on positive affect in the present thesis the negative control group was dropped for Experiment 2. Following the results of Experiment 1 the CVE was assumed to be reduced in the positive$_{\text{low}}$ group, but increased in the positive$_{\text{high}}$ group, compared to the neutral group.

2.3.1. Method

2.3.1.1. Participants

Another 60 students of Regensburg University participated in the experiment for course credit or 5 Euro. Fifty-five subjects (see Results for exclusion criteria) were included into the final data analysis (Mean age = 22.86 years, *SD* = 3.79, range = 19-45, 40 female). Participants were assigned randomly to the three affect groups (18 neutral, 19 positive$_{\text{low}}$, 18 positive$_{\text{high}}$). All participants signed informed consent and were debriefed after the session.

2.3.1.2. Apparatus and stimuli

Apparatus and stimuli were the same as in Experiment 1 except for the numbers presented in the math task. The numbers 1 to 5 were presented centrally, in black ink and in size 32 pt. Responses in the math task had to be typed in with the number keys of the first row of the keyboard.

2.3.1.3. Procedure

Procedure in Experiment 2 was the same as in Experiment 1 with the following exceptions: First, in each trial of the cueing task the first fixation was replaced by a random number from 1 to 5 for 800 ms. These numbers were part of the additional math task.

Participants performed the cueing task, and at the same time had to add up the random numbers. Every 12 trials subjects were asked to type in the result of the summation task, which was followed by an informative feedback (3500 ms). Second, the actual experiment was preceded by a math test to assure that the affect groups did not differ according to their calculating skills. To this end, a subtest of the Leistungsprüfsystem (L-P-S, Horn 1983) was used, which requires adding up lines of 10 random numbers from 2 to 9 under speeded conditions and is therefore similar to the actual experimental situation. And third, because of the increased task difficulty additional practice blocks were added. The first block comprised 12 trials of the spatial response cueing task. The next practice block (24 trials) introduced the math task in addition to the response cueing task. It included two complete math task cycles of 12 trials with feedback. In a final practice block (12 trials) an IAPS picture preceded every cueing trial. Data acquisition took part in the following 3 experimental blocks with 120 trials each (80 valid and 40 invalid trials, 10 math task cycles per block).

2.3.1.4. Design

A 3 (Affect: neutral vs. positive$_{\text{low}}$ vs. positive$_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors design was used. Affect was manipulated between, whereas Cue validity varied within participants. Mean RTs (in ms) and error rates (in %) served as dependent measures.

2.3.2. Results

2.3.2.1. Data analysis

Possible group differences in calculating skills were checked before the experiment and during the experiment with an ANOVA on performance in the L-P-S subtest as well as in the additional math task. For analysis of error rates and RTs in the cueing task, trials with math task responses differing more than 2 from the correct result were excluded from analysis (6.31 % of the data)[1]. Further preprocessing was the same as in Experiment 1, which resulted in the exclusion of another 6.83 % of the trials. Furthermore one participant of the neutral group was excluded because he did not follow the instructions. Also two subjects of the positive$_{\text{low}}$ group had to be excluded. The first made too many errors in the math task (76.7 %,

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[1] To assure that participants were truly engaged with both the response cueing task and the additional math task, cueing task performance was controlled for performance in the math task. A rather moderate criterion (correct response +/- 2) was chosen to minimize data loss, because exclusion due to math task performance meant to exclude a complete cycle of 12 cueing trials. With an absolute criterion (only correct responses included) 17.7 % of all trials would have been excluded. The moderate criterion aimed to include all trials where participants genuinely tried to follow instructions.

while mean error rate was 14.7 %), and the second made too many errors in the cueing task (14.8 %, while mean error rate was 1.3 %). Finally, two participants of the positive$_{\text{high}}$ group were excluded from further analysis, because they were exceptionally slow (715 ms and 894 ms, while mean RTs were 448 ms). Of the remaining data, mean RTs and error rates of each design cell (see Table 2.3) were entered into a 3 (Affect: neutral vs. positive$_{\text{low}}$ vs. positive$_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA.

Table 2.3. Mean RTs (in ms) and error rates (in %) in the spatial response cueing task of Experiment 2 (SD in parenthesis) as a function of Affect group and Cue validity.

	Affect group					
	neutral		**positive$_{\text{low}}$**		**positive$_{\text{high}}$**	
	valid	**invalid**	**valid**	**invalid**	**valid**	**invalid**
RT (*SD*)	405 (77.6)	477 (105.8)	445 (111.9)	487 (111.2)	401 (60.3)	471 (90.7)
Errors (*SD*)	0.21 (0.33)	3.32 (3.61)	0.09 (0.18)	1.86 (2.38)	0.0 (0.0)	2.35 (2.84)

2.3.2.2. *Math performance*

There were no performance differences in the L-P-S subtest between affect groups before the experiment, $F(2, 52) = 2.62, p = .082, \eta_p^2 = .092$. Also, no significant differences between the three affect groups were found in the additional math task during the experiment ($F < 1, p = .395$).

2.3.2.3. *Error data, overall analysis*

The overall error rate was 1.3 % ($SD = 1.5$), and individual mean error rates were below 7.5 % for all subjects. The overall ANOVA for the error data brought up a main effect of Cue validity, $F(1, 52) = 36.63, p < .001, \eta_p^2 = .413$, with fewer errors in valid than in invalid trials (0.10 % vs. 2.51 %). The main effect Affect as well as the interaction of Affect x Cue validity did not prove reliable (Fs < 1.37, ps $> .263$).

2.3.2.4. *RT data, overall analysis*

The ANOVA yielded a significant main effect of Cue validity, $F(1, 52) = 142.39$, $p < .001, \eta_p^2 = .732$. Participants responded significantly faster after valid than after invalid trials (418 ms vs. 478 ms), resulting in an overall CVE of 60 ms. More importantly, a significant interaction of Affect x Cue validity was found, $F(2, 52) = 3.51, p < .05, \eta_p^2 = .119$, which is depicted in Figure 2.3. Planned comparisons showed a reduced CVE in the positive$_{\text{low}}$ group (41 ms) as compared to the neutral group (72 ms; $F = 5.49, p < .05$) and the positive$_{high}$ group (70 ms; $F = 4.94, p < .05$). There was no significant difference between neutral and positive$_{high}$ group ($F < 1, p = .904$). Also, the main effect of Affect was not significant ($F < 1, p = .578$).

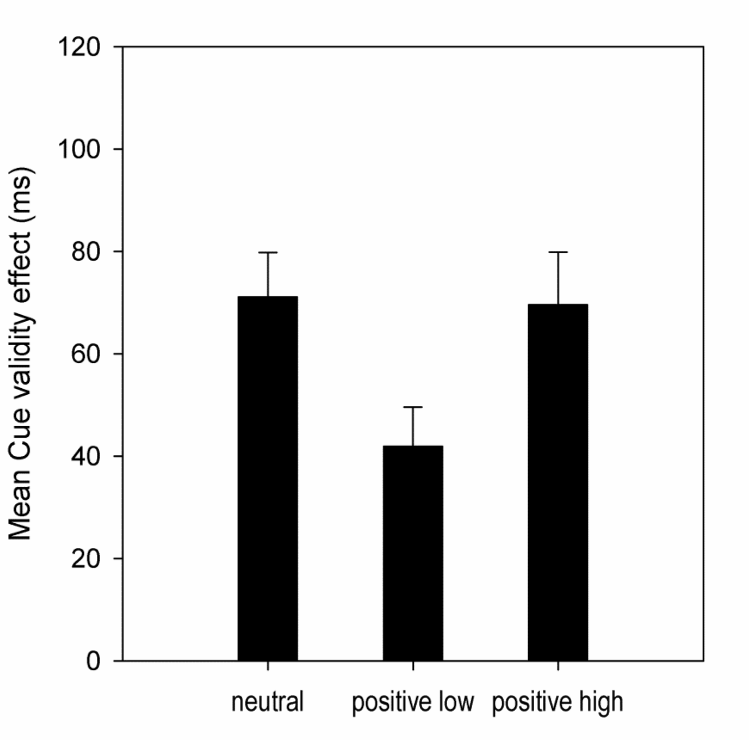

Figure 2.3. Mean Cue validity effects (in ms) in the spatial response cueing task of Experiment 2 as a function of Affect group. Error bars represent 1 standard error of the mean.

2.3.3. Discussion

The slowdown of mean RTs from Experiment 1 to 2 (333 ms vs. 437 ms) indicates that the intended increase in task difficulty was successful. The paradigm adaptations resulted in clear-cut evidence of a reduced CVE in the positive$_{low}$ group compared to the neutral and the positive$_{high}$ group. This suggests that only positive affect in combination with low arousal, but not positive affect in combination with high arousal, increases cognitive flexibility.

2.4. Discussion of Experiments 1 and 2

Taken together, Experiment 1 and 2 confirm previous results of increased cognitive flexibility under positive affect (e.g., Baumann & Kuhl, 2005; Dreisbach, 2006; Dreisbach & Goschke, 2004;Kazen & Kuhl, 2005; Kuhl & Kazen, 1999; van Wouwe et al., 2011), and, furthermore, add a new finding: Positive affect effects on cognitive control are not independent from arousal. Only positive affect in combination with low arousal reduced the CVE. This strengthens the assumptions that both valence *and* arousal are important components of affect (Russell, 1980; Russell, 2003), and that arousal – mediated via NE activity – has an additional modulatory influence on cognitive control (cf., Aston-Jones & Cohen, 2005a; Aston-Jones & Cohen, 2005b). Furthermore, Experiment 1 revealed a valence specific general task interference effect for negative, highly arousing pictures.

The reduced CVE in the positive$_{\text{low}}$ group indicates that participants under low arousing positive affect were better able to adapt to a violation of expectations. According to the neuropsychological theory of positive affect (Ashby et al., 1999; Ashby et al., 2002) this enhancement in flexibility is assumed to be mediated by DA activity. Interestingly, no reduction in CVE was found for positive affect with high arousal. It might be that NE activity, which is associated with arousal (cf., Grant et al., 1988), counteracts this DA mediated positive affect effect. Part II of the present thesis will gather more evidence for this arousal dependent positive affect effect. Therefore, a more detailed discussion will be given later on in the General Discussion section (see Chapter 5).

The valence effect between the negative$_{\text{high}}$ and positive$_{\text{high}}$ group of Experiment 1 replicates previous results by Demanet et al. (2011), who also found a slowdown of RTs after negative highly arousing pictures as compared to positive highly arousing pictures in a within-participants design. Also Pereira and colleagues (Pereira et al., 2010; Pereira et al., 2006) found a valence specific task interference effect by negative pictures in a simple target detection task. In one study (2006) they directly investigated differences between a blocked (Experiments 1, 2, and 4) or a random (Experiment 3) – mixed with positive and neutral pictures – presentation of negative pictures, and found evidence for both a sustained (blocked presentation) and a transient (random presentation) interference effect. Moreover, Kleinsorge (2007; 2009) showed that this negative affect effect is modulated by anticipation: Paradoxically, interference by negative pictures in an arithmetic verification task increased, when a cue indicated the valence of the upcoming picture in advance. There are several concurring theories for explaining this robust interference effect: For example, Pessoa (2009) assumes that negative stimuli are prioritized in perception as well as processing due to their high threat level. Because of the overlap between affective and cognitive control systems (cf., Chapter 1.3.) he suggests, furthermore, that threatening stimuli lead to task interference by diverting limited processing resources. Pereira et al. (2006; 2010) agree with the assumption that negative stimuli are a special category. They suggest, however, that the high threat level influences behavior through motivational systems: Negative stimuli are assumed to activate the defense system. More precisely, highly arousing negative pictures have been shown to elicit a freezing-like state (Azevedo et al., 2005), which is supposed to underlie the slowdown of RTs. The present results might also fit with the attentional control theory (Derakshan & Eysenck, 2009; Eysenck & Derakshan, 2011; Eysenck, Derakshan, Santos, & Calvo, 2007), which makes predictions about the cognitive effects of anxiety. Worrisome thoughts, which are associated with anxiety, are supposed to interfere with cognitive control by using up task-relevant resources. The attentional control theory, furthermore, assumes that this resource competition particularly worsens processing efficiency: By increasing effort, compensatory mechanisms are able to maintain performance effectiveness, which results in a constant accuracy performance but accompanied by a slowdown in RTs. That is exactly the response pattern found in the negative$_{\text{high}}$ group of Experiment 1. Anxiety is associated with threatening situations, and threat is characteristic for highly arousing negative stimuli. Furthermore, repeated presentation of negative affective pictures has been shown to induce a sustained negative mood state (Bradley et al., 1996). Thus, it might be that the affect induction procedure of Experiment 1 resulted in an anxiety-like mood state with the associated cognitive consequences. For completion, it should also be noted that some researchers (e.g., De Houwer & Tibboel, 2010; Schimmack, 2005) suggest an arousal based interference effect of task-irrelevant affective stimuli: In accordance with Scherer’s sequential evaluation check model (2001) an affective stimulus is assumed to be first of all appraised according to its arousal level, which then determines its relevance and the amount of processing the stimulus gets. Following again a resource competition framework, this appraisal is supposed to consume processing capacity, which is then missing for the primary cognitive task and thus impairs performance. This theory would, therefore, predict that both positive and negative highly arousing stimuli cause general task interference, which is at odds with the present results and several findings of other empirical studies (e.g., Demanet et al., 2011; Kleinsorge, 2007; Kleinsorge, 2009; Pereira et al., 2010; Pereira et al., 2006). Concerning the remaining alternative explanations, results of Experiment 1 allow no decision on the true mechanism behind this valence specific interference effect. However, with respect to the scope of the present thesis, it is more important that negative affect in combination with high arousal only impaired performance in general, and had no specific modulatory effect on cognitive control.

2.5. Interim Summary

Part I of the present thesis succeeded in gathering further insight into the affective modulation of cognitive control. Considering both valence and arousal influences revealed specific positive affect effects: As indicated by a reduced CVE, specifically positive affect with low arousal seems to increase cognitive flexibility, while high arousal appears to counteract this positive affect effect. Negative affect with high arousal caused a valence specific general task interference effect with slower RTs than all other affect groups, while no further modulation of the CVE by negative affect was found.

CHAPTER 3

Part II: How positive affect modulates cognitive control: proactive vs. reactive control

3.1. Introduction

Part I of the present thesis showed that positive affect in combination with low or high arousal differentially influences the CVE. Only low arousing positive affect reduced the CVE, which was interpreted as a sign of increased cognitive flexibility in form of an enhanced ability to overcome pre-dominant response tendencies. A problem for this interpretation is, however, that two different mechanisms are feasible for explaining a reduced CVE in the simple response cueing paradigm of Experiments 1 and 2: On the one hand, participants in the $\text{positive}_{\text{low}}$ group might have indeed been better able to overcome the pre-activated, but incorrect response tendency in an invalid trial. That is, there might have been a performance benefit specifically in unexpected, invalid trials as compared to the other affect groups. On the other hand, a reduced CVE could have been a consequence of a reduced reliance on the informative cues. Normally informative cues are used to optimize performance, which results in benefits in the more frequent valid trials and costs in the less frequent invalid trials (= CVE). A correct response in the cueing task of Experiments 1 and 2 is, however, also possible without using the cue for response preparation, because the target alone has sufficient information for a correct response. Thus, performance of participants in the $\text{positive}_{\text{low}}$ group as compared to the other affect groups might have been less dependent on the cues resulting in costs in valid trials and benefits in invalid trials (= reduced CVE). So far, however, based on the cueing paradigm used in Experiments 1 and 2 only, it cannot be decided, which mechanism drove the reduced CVE, because no neutral cue condition was included.

Interestingly, the oppositional explanations described above correspond to the differential control modes of the DMC framework (Braver, 2012; Braver et al., 2007): An enhanced ability to overcome pre-dominant response tendencies would mean *increased reactive control* (i.e., control processes *after* target onset). Less reliance on informative cues, however, would mean *reduced proactive control* (i.e., preparatory control processes *before* target onset). Moreover, affect is one of the factors that are assumed to moderate, which control strategy is favored in a given situation. Therefore, it would be interesting to know not only, whether positive affect influences cognitive control in general, but more precisely, whether positive affect modulates proactive or reactive control.

In contrast to the response cueing paradigm used in Experiments 1 and 2, the AX-CPT paradigm theoretically allows a differentiation between both control strategies: Increased reactive control should specifically improve AY performance, where a cue-induced response bias has to be overcome. Reduced proactive control should cause a benefit in AY trials, too, but additionally costs in BX and BY trials, because performance is in general less dependent on the cue information. Two studies (Dreisbach, 2006; van Wouwe et al., 2011) already investigated how positive affect influences performance in the AX-CPT: The Dreisbach study – manipulating affect via IAPS pictures preceding every trial – found evidence for less cue usage (benefit in AY trials, costs in BX and BY trials) under positive affect, which indicates a reduction of proactive control. Van Wouwe et al. – manipulating affect via emotional film clips before the actual experiment – found, in line with the Dreisbach study, improved performance in AY trials, but no impairment in BX and BY trials, which indicates an increase in reactive control. Thus, it still remains an open question, whether positive affect modulates proactive or reactive control. Therefore, the main aim of Part II of the present thesis is to further investigate this interesting research question. Additionally, further evidence will be gathered on the differential influences on cognitive control of positive affect in combination with low or high arousal levels.

3.2. Experiment 3: Spatial response cueing with non-informative cues

Based on Experiments 1 and 2, it cannot be decided, whether positive affect with low arousal modulated proactive or reactive control, because the reduced CVE found in the $\text{positive}_{\text{low}}$ group can be explained by either increased reactive control or reduced proactive control. To investigate, which kind of control was influenced by positive affect, Experiment 3 was conducted with a modified cueing paradigm: Uninformative cues were used, so that participants could not optimize their performance with a proactive control strategy (cf., Braver et al., 2007). Further modifications (see Methods section below) were taken to strengthen bottom-up, automatic cueing effects. In this way, there should again be a strong response bias toward cue-congruent reactions, which has to be overcome by reactive control in invalidly cued trials.

If the specific reduction in CVE under positive affect with low arousal can be replicated in the following experiment with a paradigm that amplifies automatic response activation, this would speak in favor of a modulation of reactive control. Conversely, any difference in results between the Experiments of Part I and Experiment 3 can be interpreted in favor of a modulation of proactive control in Experiments 1 and 2.

3.2.1. Method

3.2.1.1. Participants

Another 59 students of Regensburg University participated in Experiment 3 (Mean age = 22.02 years, *SD* = 3.55, range = 19-35, 55 female) were again assigned randomly to the same three affect groups as in Experiment 2 (20 neutral, 20 positive$_{\text{low}}$, 19 positive$_{\text{high}}$). All participants signed informed consent and were debriefed after the session.

3.2.1.2. Apparatus and stimuli

The apparatus and stimuli equaled those of Experiment 1 except for the following changes: The fixation cross as well as the two possible target locations were always enclosed by black bordered boxes (size 100 x 100 pixels). As a cue the border of one peripheral box changed border width from 1 to 5 pt. Figure 3.1 illustrates the design and procedure of an example trial of Experiment 3.

3.2.1.3. Procedure

The procedure was the same as in Experiment 1 with the following three changes: First, the stimulus onset asynchrony (SOA) between cue and target was changed to 50 or 150 ms. So, the SOA was shorter than in Experiment 1 but equaled the inter stimulus interval of Experiment 1. Second, the cue remained on screen with the target until the participant pressed a response key. And third, the cue validity percentage was reduced to 50 %, which resulted in 60 valid and 60 invalid trials per block. All these variations should boost bottom-up cueing effects and reduce top-down involvement, which was made to induce a bias in favor of a reactive control strategy. Note that both SOAs lie within the range where CVEs due to early facilitation can usually be found (e.g., Maruff, Yucel, Danckert, Stuart, & Currie, 1999[2]).

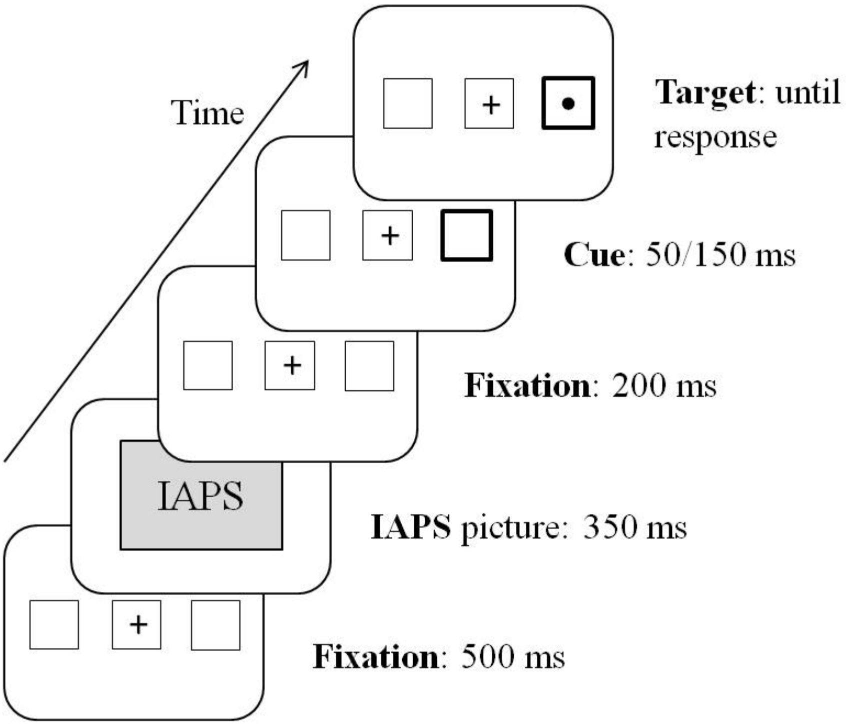

Figure 3.1. Design and procedure of a validly cued trial of the spatial response cueing task in Experiment 3.

3.2.1.4. Design

Again a 3 (Affect: negative vs. neutral vs. positive$_{low}$ vs. positive$_{high}$) x 2 (Cue validity: valid vs. invalid) mixed factor design was used. Affect was manipulated between, and Cue validity varied within participants. Mean RTs (in ms) and error rates (in %) served as dependent measures.

3.2.2. Results

3.2.2.1. Data analysis

Data preprocessing was the same as in Experiment 1 and resulted in exclusion of 2.73 % of the data. Additional 1.24 % of the trials were excluded by trimming individual RTs with a cutoff at three standard deviations. Of the remaining data, mean RTs and error rates of

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[2] This reference investigated effects of different SOAs in an attentional cueing paradigm. Wilson & Pratt (2007) could, however, show that attentional cueing also induces a bias in response selection. Therefore, the same SOA thresholds were used in the present response cueing paradigm.

each design cell (see Table 3.1) were entered into a 3 (Affect: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA.

Table 3.1. Mean RTs (in ms) and error rates (in %) in the spatial response cueing task of Experiment 3 (SD in parenthesis) as a function of Affect group and Cue validity.

	Affect group					
	neutral		**$\text{positive}_{\text{low}}$**		**$\text{positive}_{\text{high}}$**	
	valid	**invalid**	**valid**	**invalid**	**valid**	**invalid**
RT (*SD*)	326 (30.3)	366 (39.2)	312 (36.8)	355 (36.1)	320 (33.0)	355 (35.5)
Errors (*SD*)	0.17 (0.35)	1.72 (1.81)	0.13 (.31)	2.65 (2.55)	0.22 (0.47)	2.26 (2.38)

3.2.2.2. Error data

As expected, the ANOVA for the error data revealed a main effect of Cue validity, $F(1, 65) = 49.79, p < .001, \eta_p^2 = .471$. Participants made fewer errors in valid than invalid trials (0.17 % vs. 2.21 %). No further significant effects were found (all $F < 1$, all $p > .39$). The overall error rate was 1.11 % ($SD = 1.17$), while individual mean error rates were below 7 % for all subjects.

3.2.2.3. RT data

The overall ANOVA for the RT data also revealed a significant main effect of Cue validity, $F(1, 56) = 474.0, p < .001, \eta_p^2 = .894$. Participant responded faster in validly cued trials (319 ms vs. 359 ms), resulting in an overall CVE of 40 ms. The main effect of Affect and the interaction of Affect x Cue validity did not prove reliable (all $F < 1.13$, all $p > .33$).

There were no significant differences in CVE between the three affect groups (neutral = 40 ms, $\text{positive}_{\text{low}}$ = 43 ms, and $\text{positive}_{\text{high}}$ = 35 ms; see Figure 3.2). However, a non significant result in conventional significance testing does not allow a confirmation of invariances (cf., Rouder et al., 2009). Therefore, JZS-Bayes factors for CVE comparisons between the affect groups were additionally calculated to be able to state evidence for the null hypothesis. JZS-Bayes factors in Experiment 3 ranged from 1.66 to 3.75, that is, the null hypothesis – no affective difference in CVE – was indeed more likely.

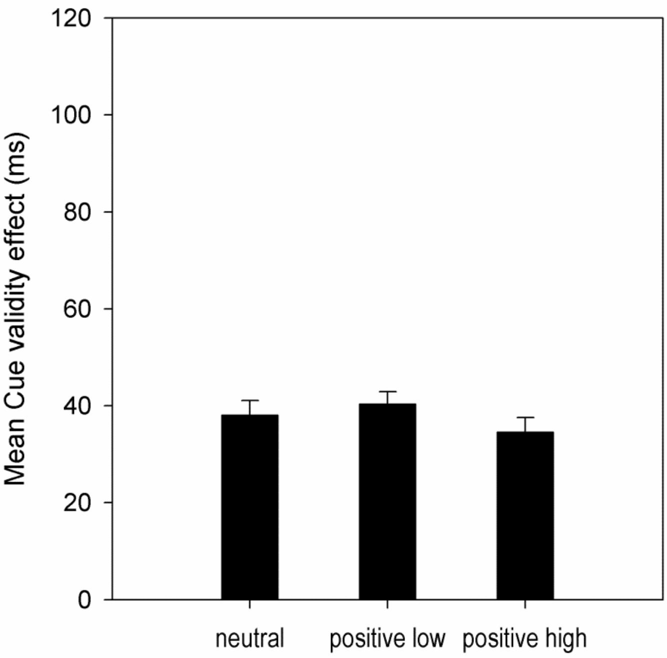

Figure 3.2. Mean Cue validity effects (in ms) in the spatial response cueing task of Experiment 3 as a function of Affect group. Error bars represent 1 standard error of the mean.

3.2.3. Discussion

Results of Experiment 3 are clear-cut. Positive affect – irrespective of valence level – had no influence on task performance. Since the CVE was again highly significant and present in all affect conditions, reactive control was still involved in order to overcome the wrongly activated response tendency. However, because of the more bottom-up cueing paradigm with non-informative cues, the involvement of proactive control, if at all, should have been minimized in Experiment 3 (cf., Braver et al., 2007). It can thus be concluded that the reduced CVE in the positive$_{\text{low}}$ group found in Experiments 1 and 2 was caused by a reduced reliance on informative cues.

So, in sum the results of the response cueing experiments (Experiments 1 to 3) speak in favor of an affective modulation of proactive control only, which was reduced specifically under positive affect with low arousal. However, it would be even better proof, if this specific affect effect – modulation of proactive and not reactive control – could be shown in a unique experiment. Therefore, Experiment 4 was conducted.

3.3. Experiment 4: Task switching with informative task cues

The main aim of Experiment 4 was to gather more direct evidence that specifically proactive control and not reactive control is influenced by positive affect. Furthermore, it was aimed to test, whether the affective modulation of proactive control can also be found for *task* cues instead of *response* cues (as was the case with the response cueing paradigm used here and the AX-CPT in previous studies). A task switching paradigm was employed to address these issues. Task switching (for recent reviews, see e.g. Kiesel et al., 2010; Vandierendonck, Liefooghe, & Verbruggen, 2010) with univalent stimuli (e.g., digits and letters) is well suited to investigate reactive control in form of differences in switch costs. Using univalent stimuli (i.e., a given stimulus is only associated with one of the two possible tasks) and no pre-cues, variations in switch costs can be taken as a direct indicator for reactive control processes. Furthermore, it has been shown that participants are generally very sensitive to probability cues (i.e., informative, but not 100 % valid) in task switching (Dreisbach & Haider, 2006; Dreisbach, Haider, & Kluwe, 2002; Hübner, Kluwe, Luna-Rodriguez, & Peters, 2004; Miniussi, Marzi, & Nobre, 2005; Wendt, Luna-Rodriguez, Reisenauer, Jacobsen, & Dreisbach, 2012). Therefore, a cued task switching paradigm with valid and invalid cues does not only allow the investigation of reactive control (in form of differences in switch costs) but also proactive control (in form of differences in the CVE like in Experiments 1 and 2).

Thus, in Experiment 4 a task switching paradigm with a digit and a letter task was used that started without task cues. After the first experimental block without cues, informative task cues with a cue validity of 75 % preceded each trial. If positive affect with low arousal reduces proactive control – as Experiments 1 to 3 suggest – the CVE should again be reduced in the positive$_{\text{low}}$ group. If positive affect, however, increases reactive control, there should be a reduction of switch costs in the positive$_{\text{low}}$ group – especially so in the block without pre-cues.

3.3.1. Method

3.3.1.1. Participants

Sixty undergraduate students from the Regensburg University (age M = 22.53 years, SD = 4.02, range = 18 – 36, 53 female) participated in the experiment for course credit or 5 Euro. Participants were assigned randomly to the three affect groups (20 positive$_{\text{low}}$, 20 positive$_{\text{high}}$, 20 neutral). All participants signed informed consent and were debriefed after the session. Because a possible modulation of switch costs was of special theoretical interest, participants with negative switch costs were excluded and replaced (2 in the neutral, 3 in the positive$_{low}$, and 2 in the positive$_{high}$ group).

3.3.1.2. Apparatus and stimuli

Apparatus and IAPS picture sets (neutral, positive$_{low}$, and positive$_{high}$) were the same as in Experiments 1 to 3.

Eight digits (1, 2, 3, 4, 6, 7, 8, and 9) written in green and eight letters (A, E, O, U, C, K, G, and T) written in purple served as target stimuli and were presented at the center of the screen in font size 52. The color coding of the digit and letter task was counterbalanced across participants. Odd numbers and vowels were always assigned to one response key, even numbers and consonants to the other, while response mapping to the left and right response key (y- and m-key on a QWERTZ keyboard) was also counterbalanced between participants. In experimental blocks 2 to 4, a color coded fixation cross (purple or green) served as informative task cue.

3.3.1.3. Procedure

The experiment comprised one task switching block without task cues followed by three blocks including informative task cues. In the first block each trial started with an IAPS picture (350 ms) followed by a blank screen (150 ms) and a black fixation cross (1000 ms). Then the target stimulus appeared and remained on screen until the participant responded. Subjects had to decide whether a number was odd or even (digit task) or whether a letter was a vowel or consonant (letter task). Participants were instructed to react as fast as possible while avoiding errors. Feedback was given for errors only (2000 ms), each trial ended with an intertrial interval of 500 ms. Procedure in the following blocks with informative task cues was the same as in the first block except that the fixation cross was now color coded and served as a task cue for the following task. In valid trials (75 % of all trials) the colored fixation cross was followed by a target stimulus in the same color, thereby enabling the preparation of the upcoming task in a proactive manner. In contrast, in invalid trials (25 % of all trials) the fixation color incorrectly predicted the upcoming target color, and can therefore mislead to prepare the wrong task. An example trial is visualized in Figure 3.3.

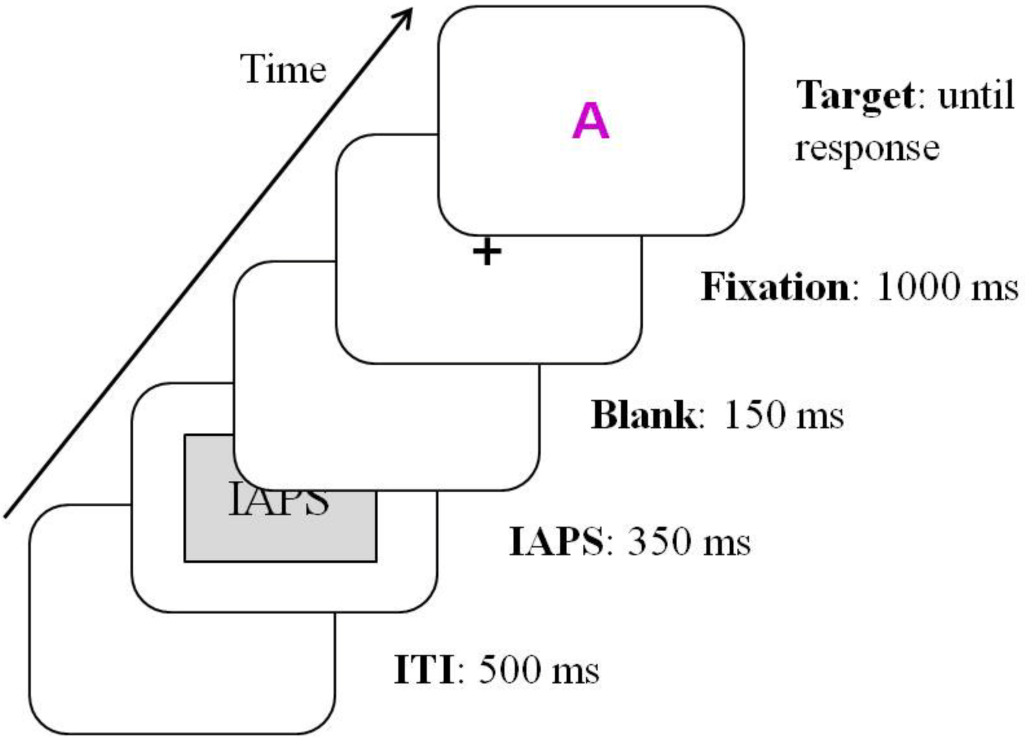

Figure 3.3. Design and procedure of a letter task trial in experimental block 1 (= task switching without informative precues) of Experiment 4.

The experiment started with the same relaxation exercise that was also used in the previous experiments. Subsequently, 16 practice trials (random presentation of all target stimuli) without IAPS pictures enabled the participants to get used to the task switching procedure. This practice block was followed by 64 trials with an IAPS picture preceding every trial. Data acquisition took place in the following four experimental blocks – the first without informative task cues – with 128 trials each. Each block contained 64 digit tasks (4 x 8 numbers) and 64 letter tasks (4 x 8 letters). Stimulus presentation was pseudo-randomized with the following constraints: Repeat and switch trials were evenly distributed. Immediate repetitions of target stimuli or IAPS pictures were not allowed. Task cues (96 valid, 32 invalid) were counterbalanced across all trial types.

3.3.1.4. Design

A 3 (Affect: neutral vs. positive$_{low}$ vs. positive$_{high}$) x 2 (Trial type: repeat vs. switch) design with Affect as between and Trial type as within factor was used in the first block without task cues. The experimental blocks including informative task cues had a 3 (Affect) x 3 (Block: 2 vs. 3 vs. 4) x 2 (Trial type) x 2 (Cue validity: valid vs. invalid) repeated measures design. Mean RTs (in ms) and error rates (in %) served as dependent measures.

3.3.2. Results

3.3.2.1. *Data analysis*

Practice trials as well as the first trial of each experimental block were excluded from analyses. In addition, error trials, trials following an error, and trials with RTs differing more than three standard deviations from individual means were also removed prior analysis (9.34 % of all trials). Separate analyses were conducted for task switching performance (mean error rates and RTs) in the first experimental block without task cues, and for performance in experimental blocks 2 to 4 with informative task cues.

3.3.2.2. *Task switching performance, Block 1 without task cues*

Mean RTs (see Table 3.2) were entered into a 3 (Affect: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Trial type: repeat vs. switch) mixed factors ANOVA. A significant main effect of Trial type, $F(1, 57) = 106.45$, $p < .001$, $\eta_p^2 = .651$, with faster responses in repeat trials (655 ms vs. 733 ms) was found. The main effect of Affect as well as the interaction of Affect x Trial type did not prove reliable (all $F < 1.97$, all $p > .150$). The same analysis for mean error rates (see Table 3.2) also resulted in a significant main effect of Trial type, $F(1, 57) = 26.82$, $p < .001$, $\eta_p^2 = .319$, with less errors in repeat trials (2.28 % vs. 5.97 %). Again, no significant affect effects were found (all $F < 1.19$, all $p > .31$). JZS-Bayes factors for differences in switch costs between the affect groups ranged from 2.95 to 4.04, which means that it is more likely that there are indeed equal switch costs in all three groups (see Figure 3.3).

Table 3.2. Mean RTs (in ms) and error rates (in %) in the in the first experimental block of Experiment 4 (task switching without task cues) as a function of Affect group and Trial type.

	Affect group					
	neutral		**$\text{positive}_{\text{low}}$**		**$\text{positive}_{\text{high}}$**	
	repeat	**switch**	**repeat**	**switch**	**repeat**	**switch**
RT (*SD*)	646 (76.9)	731 (116.7)	705 (170.5)	774 (202.0)	615 (96.9)	693 (133.5)
Errors (*SD*)	2.7 (2.89)	5.89 (4.68)	1.52 (2.09)	4.83 (3.72)	2.64 (2.73)	7.18 (8.19)

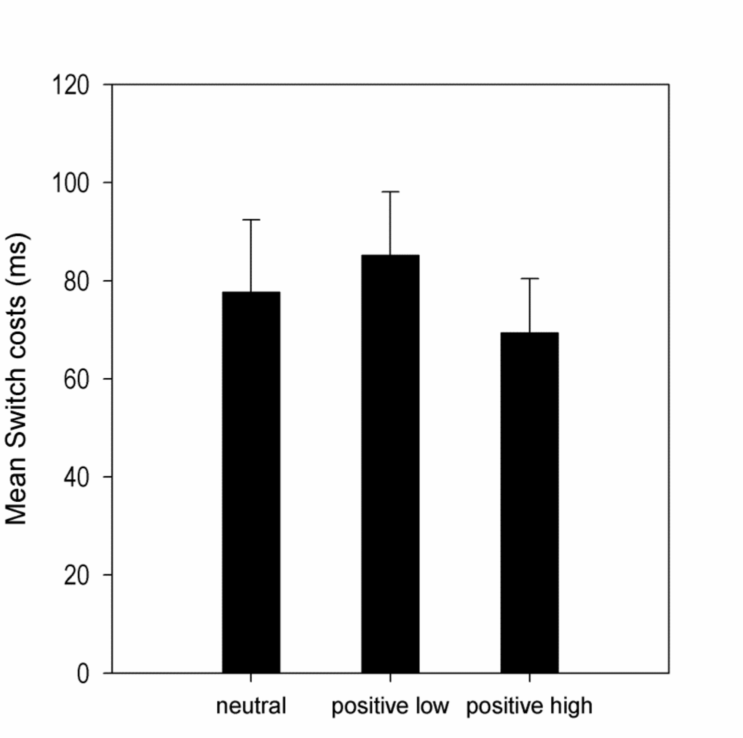

Figure 3.3. Mean switch costs (in ms) in the task switching block without pre-cues of Experiment 4 as a function of Affect group. Error bars represent 1 standard error of the mean.

3.3.2.3. *Task switching performance, Blocks 2 to 4 with informative task cues*

To check the effectiveness of the cues over time, a 3 (Affect: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 3 (Block: 2 vs. 3 vs. 4) x 2 (Trial type: repeat vs. switch) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA was conducted for the three experimental blocks with informative task cues (see Tables 3.3 and 3.4 for mean RTs and error rates). The analysis of mean error rates resulted in significant main effects of Block, $F(2, 114) = 8.65$, $p < .001$, $\eta_p^2 = .131$, Trial type, $F(1, 57) = 37.34$, $p < .001$, $\eta_p^2 = .397$, and Cue validity, $F(1, 57) = 4.40$, $p < .05$, $\eta_p^2 = .072$, as well as an interaction of Trial type x Cue validity, $F(1, 57) = 4.19$, $p < .05$, $\eta_p^2 = .069$. Planned comparisons showed significantly more errors in Block 2 (3.61 %) as compared to Block 3 (2,81 %, $F(1, 57) = 7.97$, $p < .01$) and Block 4 (2.42 %, $F(1, 57) = 14.20$, $p < .001$). Blocks 3 and 4 did not differ significantly ($F = 2.01$, $p = .162$). Cue validity had no significant influence on error rates in task repetitions (2.09 % vs. 2.12 %, $F < 1$, $p = .915$), but there was a significant negative CVE in task switches ($F(1,57) = 6.41$, $p < .05$) with more errors in valid trials (4.30 % vs. 3.27 %). The interaction of Block and Trial type did not prove reliable ($F = 2.82$, $p = .064$). There was no significant main effect of Affect or significant interactions with Affect (all $F < 1.68$, all $p > .185$).

Table 3.3. Mean error rates (in %, SD in parentheses) in experimental blocks 2 to 4 of Experiment 4 (task switching with informative task cues) as a function of Affect group, Trial type, and Cue validity.

	Affect group					
	neutral		**positive$_{\text{low}}$**		**positive$_{\text{high}}$**	
Cue	**repeat**	**switch**	**repeat**	**switch**	**repeat**	**switch**
			Block 2			
valid	2.76 (2.3)	5.55 (4.7)	2.27 (2.0)	4.89 (4.6)	1.87 (2.1)	4.88 (4.0)
invalid	2.29 (3.7)	5.67 (4.8)	2.5 (4.8)	3.17 (4.6)	2.5 (5.5)	5.01 (5.3)
			Block3			
valid	2.27 (2.8)	4.62 (5.6)	2.39 (3.4)	4.44 (4.6)	1.67 (2.8)	4.15 (3.9)
invalid	1.91 (3.2)	2.96 (4.2)	2.15 (3.3)	2.28 (4.0)	2.15 (3.9)	2.73 (5.2)
			Block 4			
valid	1.7 (2.3)	4.2 (3.8)	2.39 (2.7)	2.8 (2.5)	1.52 (2.0)	3.2 (3.3)
invalid	2.95 (3.6)	1.96 (3.2)	0.59 (2.6)	2.49 (4.2)	2.06 (4.4)	3.21 (4.9)

Table 3.4 Mean RTs (in ms, SD in parentheses) in experimental blocks 2 to 4 of Experiment 4 (task switching with informative task cues) as a function of Affect group, Trial type, and Cue validity.

	Affect group					
	neutral		**positive$_{\text{low}}$**		**positive$_{\text{high}}$**	
Cue	**repeat**	**switch**	**repeat**	**switch**	**repeat**	**switch**
			Block 2			
valid	568 (81.1)	639 (133.9)	588 (61.1)	661 (83.4)	615 (119.9)	702 (142.4)
invalid	613 (111.9)	626 (92.3)	617 (103.2)	665 (92.9)	702 (176.9)	685 (125.63)
			Block3			
valid	561 (73.4)	617 (110.2)	590 (91.9)	648 (105.5)	600 (99.8)	665 (141.0)
invalid	558 (82.7)	643 (151.9)	600 (104.3)	654 (125.5)	603 (123.3)	656 (124.0)
			Block 4			
valid	557 (86.8)	595 (108.1)	566 (71.4)	608 (140.0)	591 (102.5)	635 (133.8)
invalid	567 (109.2)	631 (151.1)	579 (81.2)	645 (140.0)	602 (115.6)	631 (126.9)

In the RT analysis significant main effects for Block, $F(2, 114) = 19.83$, $p < .001$, $\eta_p^2 = .258$, Trial type, $F(1, 57) = 98.88$, $p < .001$, $\eta_p^2 = .634$, and Cue validity, $F(1, 57) = 19.53$, $p < .001$, $\eta_p^2 = .255$, were found, which were further qualified by a significant three-way interaction of these factors, $F(2, 114) = 11.28$, $p < .001$, $\eta_p^2 = .165$. Planned comparisons showed a significant interaction of Trial type x Cue validity specifically in the first block with informative task cues, $F(1, 57) = 2.54$, $p < .001$ (Blocks 3 and 4: all $F < .07$, all $p > .41$). Further analysis of Block 2 showed a significant CVE with faster RTs after valid cues in repeat trials (590 ms vs. 644 ms, $F(1, 57) = 32.28$, $p < .001$), but not in switch trials (667 ms vs. 659 ms, $F = 1.32$, $p = .26$). So, there was a strong cueing effect only in the first block with informative task cues, and specifically in repeat trials. The main effect of Affect as well as all other interactions did not prove reliable (all $F < 3.36$, all $p > .067$). With respect to the hypotheses, also in these blocks with informative task cues the affect groups did not differ significantly in switch costs (*M neutral* = 54 ms, $M\ positive_{low}$ = 57 ms, $M\ positive_{high}$ = 44 ms). JZS- Bayes factors for single comparisons of switch costs ranged from 2.46 to 4.24, which further supports that switch costs were indeed comparable in all three groups.

Regarding the hypothesis of reduced proactive control under positive affect with low arousal, a possible affective modulation of the CVE was especially interesting. Therefore, an additional analysis was conducted, this time only including Block 2 (i.e., the first block with informative task cues), which was the only block where the CVE was significant.

3.3.2.4. Affect effects, first task switching block with informative task cues only

A 3 (Affect: neutral vs. $positive_{low}$ vs. $positive_{high}$) x 2 (Trial type: repeat vs. switch) x 2 (Cue validity: valid vs. invalid) mixed factors ANOVA revealed significant main effects for Trial type, $F(1, 57) = 39.46$, $p < .001$, $\eta_p^2 = .409$, and Cue validity, $F(1, 57) = 18.07$, $p < .001$, $\eta_p^2 = .241$. Participants responded faster in repeat trials (617 ms vs. 663 ms) as well as in valid trials (629 ms vs. 651 ms). Furthermore, a significant interaction of Trial type x Cue validity, $F(1, 57) = 22.54$, $p < .001$, $\eta_p^2 = .283$, was found. Planned comparisons showed a significant CVE in repeat trials (590 ms vs. 644 ms, $F(1, 57) = 32.28$, $p < .001$), but not in switch trials (667 ms vs. 659 ms, $F = 1.32$, $p = .26$). Most important with respect to the present hypothesis, there was a significant interaction of Affect x Trial type x Cue validity, $F(2, 57) = 3.08$, $p = .05$, $\eta_p^2 = .098$, which is depicted in Figure 3.4. CVE was significantly smaller in the $\text{positive}_{\text{low}}$ compared to the $\text{positive}_{\text{high}}$ group (29 ms vs. 87 ms, $F(1, 57) = 6.32$, $p < .05$). The CVE in the neutral group (45ms) was descriptively between both positive groups but did not differ significantly from either group (Fs < 3.35, ps > .072). The main effect Affect and all other interactions did not prove reliable (all $F < 1.94$, all $p > .15$). The same analysis for mean error rates resulted only in a significant main effect of Trial type, $F(1, 57) = 25.06$, $p < .001$, $\eta_p^2 = .306$, with less errors in repeat trials (2.36 % vs. 4.86 %). No further significant main effects or interactions were found (all $F < 1$, all $p > .47$).

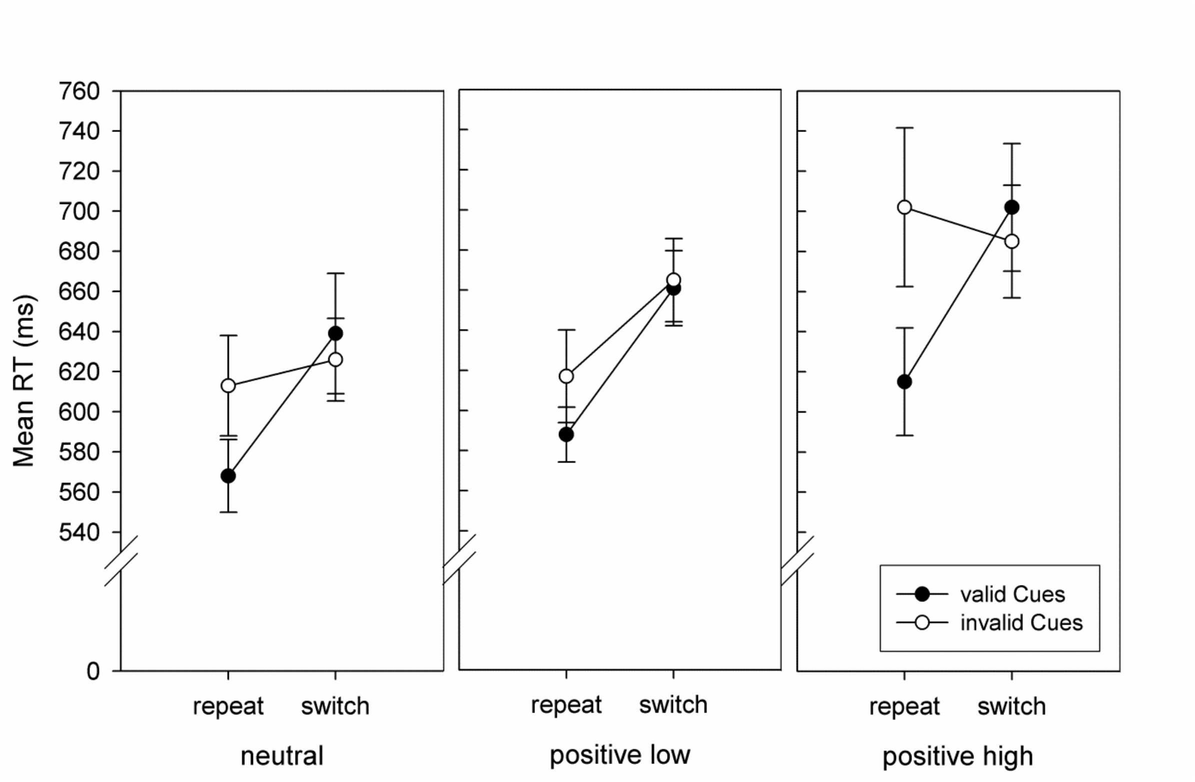

Figure 3.4. Mean RTs (in ms) in the first task switching block with informative task cues of Experiment 4 as a function of Affect group, Trial type, and Cue validity. Error bars represent 1 standard error of the mean.

3.3.3. Discussion

In Experiment 4 switch costs did not differ between affect groups, neither in the first experimental block without task cues nor in the following blocks with informative cues. Strong cueing effects were found only in the first block with informative task cues and specifically in repeat trials. In this block, also an affect effect similar to the results of Experiments 1 and 2 was found: The CVE in repeat trials was reduced in the positive$_{\text{low}}$ group as compared to the positive high group, while the CVE was descriptively in between both positive groups in the neutral group. It is not surprising that an affective modulation was only found in Block 2, because blockwise analysis of all three blocks including cues showed that the informative task cues only had an impact on performance while they were new, whereas their influence diminished with more practice in the task (RTs and error rates declined throughout the experiment, see Tables 3.2 to 3.4). The generally reduced reliance on cues over blocks might be due to the fact that the task cues were neither necessary (because univalent stimuli were used) nor entirely useful (e.g., Sudevan & Taylor, 1987). The fact that the CVE is restricted to repeat trials only was also found by Miniussi et al. (2005), and might be a consequence of anticipatory backward inhibition (Hübner, Dreisbach, Haider, & Kluwe, 2003; Li & Dupuis, 2008; Mayr & Keele, 2000): In task switching, backward inhibition refers to the phenomenon that preparation for a task switch leads to inhibition of the just executed task set, and is hence also a form of proactive control. There is plenty of evidence that the foreknowledge about an upcoming task switch suffices to trigger the inhibition of the preceding task (Mayr & Keele, 2000, Exp. 5; Hübner et al., 2003; Li & Dupuis, 2008; Wendt et al., 2012). Applied to the present data, an invalidly cued repetition may have already caused inhibition of the previous task resulting in performance costs when this very task unexpectedly repeats. In invalidly cued switches, on the other hand, the cue predicts a repetition and as such does not trigger backward inhibition resulting in typical switch costs – like in validly cued switches.

In sum, Experiment 4 succeeded in showing that specifically proactive control and not reactive control is modulated by positive affect: Switch costs – as a measure of reactive control – were comparable in all three affect groups. Positive affect along with high or low arousal did neither improve nor impair the adaption to a (unexpected) task switch. In contrast, the CVE – as a measure of proactive control – was again modulated by affect, and indicated a reduction of proactive control specifically in the $\text{positive}_{\text{low}}$ group. So, together with results from Experiments 1 to 3 there is converging evidence that performance under positive affect with low arousal is less dependent on informative cues. Positive affect with high arousal, on the other hand, may even increase the usage of informative cues.

3.4. Experiment 5: Cued global-local task with a within-participants affect manipulation

Experiments 1 to 4 used mixed factorial designs with affect always being manipulated between groups. In each group, every experimental trial was preceded by an IAPS picture from a specific affective category ($\text{negative}_{\text{high}}$, neutral, $\text{positive}_{\text{low}}$, or $\text{positive}_{\text{high}}$). Most likely this procedure resulted in both transient and sustained affective reactions: IAPS pictures can, on the one hand, elicit typical affective responses very quickly (Codispoti et al., 2001; Codispoti et al., 2009), but, on the other hand, are also suited to induce certain mood states via repetitive exposure to pictures of the same valence (Bradley et al., 1996; Smith et al., 2005). So far, it cannot be decided, whether a sustained affective influence is really necessary for the specific affect effects found in Experiments 1 to 4. The transient affective influence might be sufficient on its own. For example, van Steenbergen and colleagues found the same positive affect effects on the sequential modulation of response conflicts using either randomized affective signals – happy, sad, or neutral smilies – between trials (van Steenbergen, Band, & Hommel, 2009) or specific mood induction – inducing calmness, happiness, sadness, and anxiety – in a between groups design (van Steenbergen et al., 2010): In both studies positive affect was associated with reduced conflict adaptation.

A successful replication of the specific affect effects found in Experiments 1 to 4 in a complete within-participants design would be of both theoretical and practical interest: Theoretically, because it would show that not only sustained but also transient affective states modulate cognitive control processes. And it would be of practical interest, because future experimental designs would need considerably less participants. Thus, the main aim of Experiment 5 was to replicate the diverging influences on proactive control by positive affect with low or high arousal using a within-participants design with randomized IAPS picture presentation. Moreover, the external validity of this specific positive affect effect should be tested further. The task switching experiment with informative task cues (Experiment 4) could already demonstrate that a reduced CVE under positive affect with low arousal is not restricted to simple spatial response cueing paradigms with informative cues (see Experiments 1 and 2). Therefore, again a new kind of task will be applied in Experiment 5, namely a global-local task (cf. Navon, 1977) with informative response cues.

In this paradigm, global figures consisting of grouped local figures (e.g., several small squares forming a large triangle) were used as target stimuli. In each trial participants had to detect, whether a prespecified target shape (triangle, diamond, circle, or square) was present on the global or local level. An informative cue preceded every trial to indicate, at which level the next target would be more likely to occur. Figures with identical shapes both on the global and local level (e.g., a large triangle made up of small triangles) were also included, in which case subjects could choose freely to respond to either the global or the local level. Including these ambiguous target shapes enabled additional measures besides the CVE: In ambiguous target trials participants were free to respond to either level, so one interesting new analysis was to what extent responses would be in correspondence with the preceding cue (frequency analysis). Another new analysis concerned the impact of the two kinds of cues – global vs. local – on RTs in a situation, where invalid trials and wrong responses are impossible (RT analysis). Furthermore, a final experimental block without cues was added to investigate performance differences between positive affect with high or low arousal, when proactive control is not involved. In this block, the analysis of trials with ambiguous targets will be of special interest: In general, global processing is preferred over local processing (e.g., Navon, 1977), a bias which has been shown to be even more pronounced under positive affect (Gasper & Clore, 2002). So far, however, it is unknown whether this increased global processing preference is further modulated by different arousal levels.

Naturally, a within-participant affect manipulation results in an increased number of trials per participant, because an adequate number of measurements for each factor combination is needed to justify the subsequent statistical analyses. To ensure a reasonable length of the entire experiment, affective manipulation was restricted to the two positive affect conditions with different arousal levels only. Based on the previous results diverging influences on proactive control by positive affect with low or high arousal were assumed: The CVE in experimental blocks with informative response cues was expected to be reduced in the $\text{positive}_{\text{low}}$ condition as compared to the $\text{positive}_{\text{high}}$ condition. If positive affect with low arousal reduces the usage of informative cues, differences in the additional analyses for trials with ambiguous targets are also feasible: There might be less cue-congruent responses in the $\text{positive}_{\text{low}}$ as compared to the $\text{positive}_{\text{high}}$ condition (frequency analysis), and also less RT differences between global or local cues in the $\text{positive}_{\text{low}}$ condition. In contrast, no affect related performance differences in RTs or error rates were expected in the additional block without informative response cues, where a proactive control strategy is not possible. A separate exploratory analysis for trials with ambiguous targets only will show whether the usually found global processing preference differs between arousal conditions.

3.4.1. Method

3.4.1.1. Participants

Thirty-three undergraduate students from the Regensburg University participated in the experiment for course credit or 5 Euro. Thirty subjects (see Results for exclusion criteria) were included into the final data analysis (age *M* = 22.87 years, *SD* = 4.18, range = 18 – 35, 26 female). All participants signed informed consent and were debriefed after the session.

3.4.1.2. Apparatus and stimuli

Apparatus and the IAPS picture sets for the $\text{positive}_{\text{low}}$ and $\text{positive}_{\text{high}}$ condition were the same as in the previous experiments. Again, the y- and m-key were used as left and right response buttons.

All stimuli in the global-local task were presented centrally in black on a white background. Line drawings of the four shapes triangle, diamond, circle, and square in size 69 x 69 pixels were used to create global figures of the same four kinds of local shapes. This resulted in 16 different target stimuli (see Figure 3.5) of the following sizes: 2.7 x 2.3 cm for global triangles, 3.2 x 3.2 cm for global diamonds, 2.6 x 2.6 cm for global circles, and 2.6 x 2.6 cm for global squares. The uppercase letters G and K – presented in font Arial, size 48 – were used as response cues for the global or local level: G stood for the German “große Form” (meaning big shape), and K for “kleine Form” (meaning small shape).

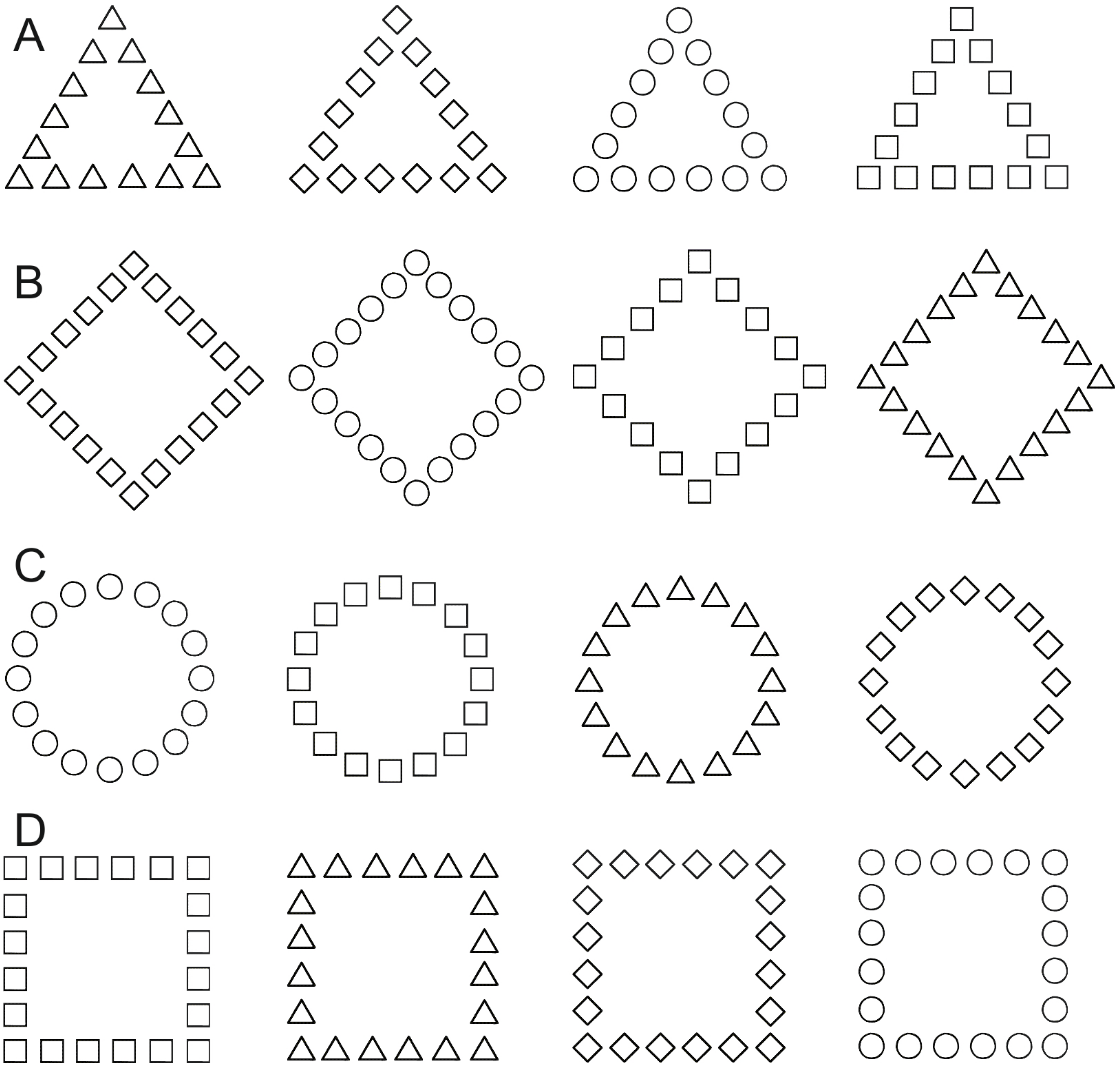

Figure 3.5. The 16 different target stimuli used in the global-local task of Experiment 5. The left column shows the ambiguous target stimuli, in which the same shape is present on both the local and the global level (e.g., big triangle made of small triangles).

3.4.1.3. *Procedure*

The experiment comprised four experimental blocks with informative response cues followed by an additional block without cues. In the cued blocks, each trial of the global-local task started with an IAPS picture (400 ms) followed by a blank screen (200 ms) and the informative response cue (500 ms). After another blank screen (500 ms) the target stimulus appeared and remained on screen until the participant responded. Subjects had to detect whether a prespecified target shape was present on the global or the local level. In case of an ambiguous target (same shape on both levels) participants could choose freely to which level they responded. Feedback (1500 ms) was given for errors only, and each trial ended with an intertrial interval of 500 ms. An example trial is visualized in Figure 3.6. Single trial procedure in the additional block without cues was the same, except that the response cue was replaced by an uninformative fixation cross.

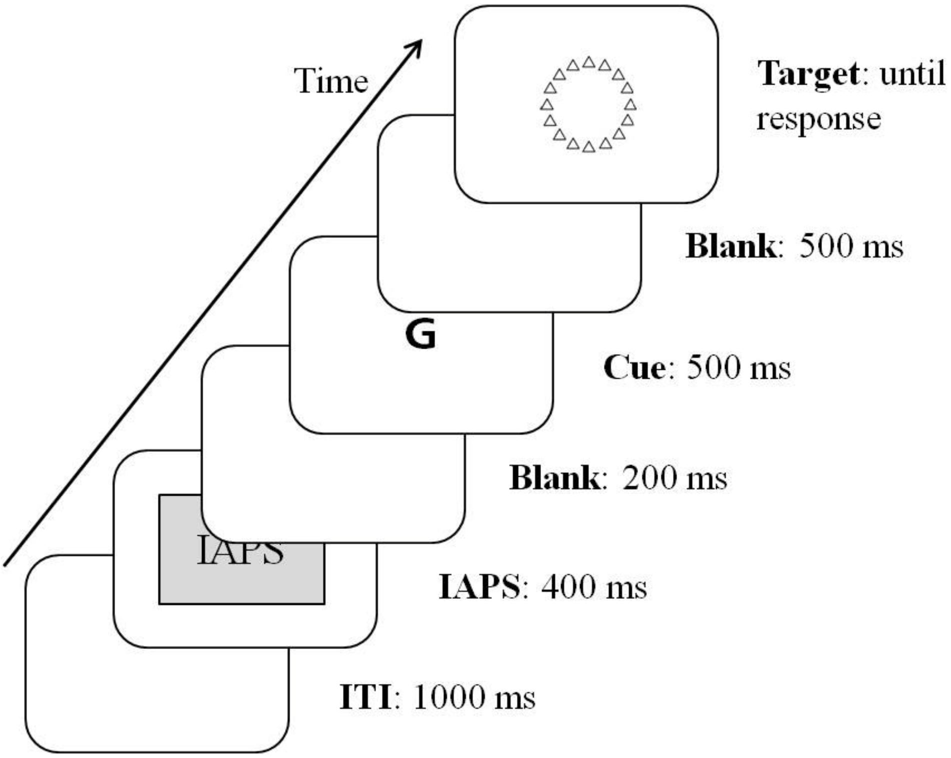

Figure 3.6. Design and procedure of the global-local task used in Experiment 5.

The experiment started with the same relaxation exercise that was also used in the previous experiments. Subsequently, a short practice block without IAPS pictures, in which participants had to search for a diamond shape, enabled the participants to get used to the global-local task. The practice block included all possible combinations for figures including a diamond shape (3 global diamond figures, 3 figures made up from local diamonds, and one ambiguous target stimulus with the diamond present on both levels), which were presented twice – once preceded by a local cue, and once preceded by a global cue – and in randomized order. Data acquisition took place in the following five experimental blocks – the last without informative response cues – with 84 trials each. Each block was preceded by a specific instruction that informed about the relevant target shape for the upcoming block. In each block a different target shape was used with the order of the relevant shape being counterbalanced across participants. Target shape of the no-cue block was selected randomly between participants. Each block consisted of 36 global targets (3 possible combinations x 12), 36 local targets (3 possible combination x 12), and 12 ambiguous target stimuli. Half of the trials of a given block were cued by a local or a global cue, respectively. In each block, 60 trials were validly cued (48 correctly predicted global or local targets + 12 cued ambiguous targets) and 24 trials invalidly cued. Global and local cues were counterbalanced across all stimulus types. Moreover, the 42 $\text{positive}_{\text{low}}$ and 42 $\text{positive}_{\text{high}}$ IAPS pictures were evenly distributed on the different trial types. Trial order was randomized with the exception that immediate repetitions of target stimuli or IAPS pictures were not allowed. The response mapping of target level (global or local) to response key (left or right) was counterbalanced across participants.

3.4.1.4. Design

In the first four experimental blocks with informative response cues, a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) x 2 (Target type: global vs. local) design was applied for trials with global or local targets, and a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue type: global vs. local) design for trials with ambiguous targets. The additional experimental block without cues had a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 3 (Target type: global vs. local vs. ambiguous) design. All variables were repeated measures within participants. Mean RTs (in ms) and error rates (in %) served as dependent measures.

3.4.2. Results

3.4.2.1. *Data analysis*

The first experimental block of the cued global-local task was declared an additional practice block ex post, because RTs were significantly slower than in the following blocks ($M_{\text{Block 1}}$ = 612 ms, $M_{\text{Block 2}}$ = 537 ms, $M_{\text{Block 3}}$ = 490 ms, $M_{\text{Block 4}}$ = 514 ms, $M_{\text{Block 5}}$ = 482). Data preprocessing for the remaining blocks including informative response cues (2-4) and the no-cue block was the same as in Experiment 4: Practice trials as well as the first trial of each experimental block were excluded from analyses. In addition, error trials, trials following an error, and trials with RTs differing more than three standard deviations from individual means were also removed prior analysis, which resulted in an exclusion of 10.37 % of all trials. Furthermore, data from three subjects were excluded from statistical analyses: One participant was exceptionally slow in the experimental blocks including informative response cues (835 ms, while mean RTs were 499 ms), one made too many errors in the experimental blocks including informative response cues (19.31 %, while mean error rate was 4.42 %), and one responded extremely slow in the no-cue block (739 ms, while mean RTs were 471 ms). The remaining data will be analyzed separately for blocks including informative cues, for ambiguous and non-ambiguous trials, and for the no-cue block.

3.4.2.2. *Blocks 2 to 4 with informative response cues: global and local targets, ambiguous targets*

Global and local targets. Mean RTs (see Table 3.5) were entered into A 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue validity: valid vs. invalid) x 2 (Target type: global vs. local) repeated measures ANOVA. Significant main effects of Cue validity, $F(1, 29) = 6.55$, $p < .05$, $\eta_p^2 = .184$, and Target type, $F(1, 29) = 24.8$, $p < .001$, $\eta_p^2 = .461$, were found. Participants responded faster in validly cued trials (499 ms vs. 533 ms), resulting in an overall CVE of 35 ms, and faster in trials with global targets (492 ms vs. 539 ms). Furthermore, Cue validity significantly interacted with Target type, $F(1, 29) = 5.2$, $p < .05$, $\eta_p^2 = .152$, and – more importantly with respect to the hypotheses – also with Arousal, $F(1, 29) = 5.0$, $p < .05$, $\eta_p^2 = .147$. Contrast analyses showed a significant CVE in trials with global targets (462 ms vs. 522 ms; $F = 7.09$, $p < .05$), but no significant difference in trials with local targets (534 ms vs. 544 ms; $F < 1$, $p = .336$). Like in the previous experiments (cf., chapters 2.2., 2.3., 3.3.), the CVE was significantly smaller in the $\text{positive}_{\text{low}}$ condition as compared to the $\text{positive}_{\text{high}}$ condition (26 ms vs. 44 ms, see Figure 3.7). The main effect Arousal and all other interactions did not prove reliable (all $F < 1.91$, all $p > .18$).

The same analysis for mean error rates (see Table 3.6) revealed marginal significant main effects of Arousal ($F = 3.11$, $p = .088$) and Cue validity ($F = 4.06$, $p = .05$), which were further qualified by a significant interaction of Arousal x Cue validity, $F(1, 29) = 6.99$, $p < .05$, $\eta_p^2 = .194$. Contrary to the RT data, single comparisons showed a larger CVE in the positive$_{low}$ condition (3.47 % vs. 6.39 %) as compared to the positive$_{high}$ condition (3.68 % vs. 4.15 %, see Figure 3.7). All other main effects or interactions did not prove reliable (all $F < 2.04$, all $p > .16$). Mean overall error rate was 4.42 % ($SD = 2.88$).

Table 3.5. Mean RTs (in ms; SD in parentheses) from trials with global or local targets in the cued global-local task of Experiment 5 (experimental blocks 2-4) as a function of Arousal, Cue validity, and Target type.

	Arousal condition			
	positive$_{low}$		**positive$_{high}$**	
Target Cue	**valid**	**invalid**	**valid**	**invalid**
global	466 (80.1)	519 (132.7)	459 (73.9)	525 (146.9)
local	533 (76.9)	531 (84.4)	535 (85.9)	557 (110.1)

Table 3.6. Mean error rates (in %; SD in parentheses) from trials with global or local targets in the cued global-local task of Experiment 5 (experimental blocks 2-4) as a function of Arousal, Cue validity, and Target type.

	Arousal condition			
	positive$_{low}$		**positive$_{high}$**	
Target Cue	**valid**	**invalid**	**valid**	**invalid**
global	3.24 (3.5)	7.22 (6.71)	3.61 (5.27)	4.7 (5.32)
local	3.7 (3.54)	5.56 (6.84)	3.76 (3.42)	3.6 (6.13)

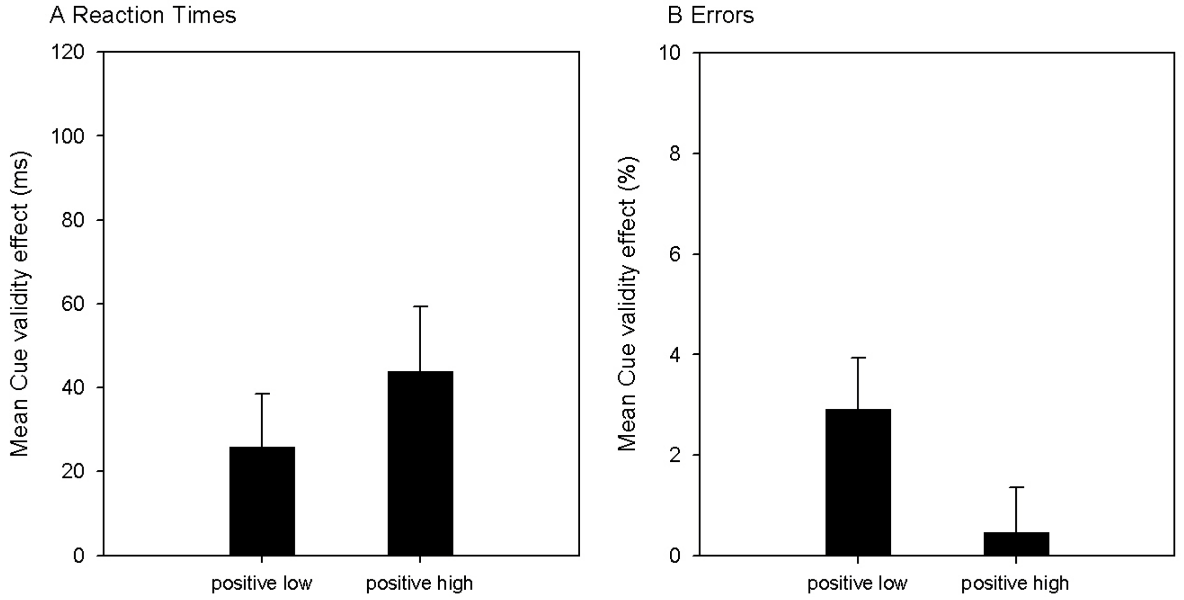

Figure 3.7. Mean cue validity effects (CVE) in the cued global-local task of Experiment 5 as a function of Arousal. The left panel (A) represents CVE differences in RTs (in ms), the right panel (B) represents CVE differences in error rates (in %). Error bars represent 1 standard error of the mean.

Due to the oppositional response patterns between positive affect with low or high arousal in RTs and error rates, additional analyses on potential speed-accuracy trade-offs were conducted. Therefore, individual Pearson's product-moment correlation coefficients *r* were determined between RTs and error rates of all factor combinations, and tested for significance. Of the entire sample of 30 participants only 6 subjects showed a significant correlation between RTs and error rates ($r_{\min} = -.643$, $r_{\max} = .842$, all $p < .05$), whereof only one correlation was negative ($r = -.643$) and thus in line with a speed-accuracy trade-off. Overall, there was a marginal significant positive correlation, $t(28) = 1.83$, $p = .079$ (two-tailed), between RTs and error rates with a mean *r* of .157 ($SD = .462$) indicating that more subjects showed a response pattern with slower RTs associated with more errors and faster RTs associated with fewer errors (see Appendix B for individual *r*s from all participants of Experiment 5).

Ambiguous targets. Mean RTs (see Table 3.7) of the trials with ambiguous target stimuli were entered into a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue type: global vs. local) repeated measures ANOVA. A significant main effect of Cue type, $F(1, 29) = 9.28$, $p < .01$, $\eta_p^2 = .243$, was found. Participants responded faster after global cues (444 ms vs. 489 ms). The main effect of Affect and the interaction of Arousal x Cue type did not prove reliable (all $F < 1.2$, all $p > .28$). Descriptively, however, RTs following global cues differed less from RTs following local cues in the $\text{positive}_{\text{low}}$ condition (34 ms) as compared to the $\text{positive}_{\text{high}}$ condition (57 ms).

Table 3.7. Mean RTs (in ms; SD in parentheses) in trials with ambiguous targets in the cued global-local task of Experiment 5 (experimental blocks 2-4) as a function of Arousal and Cue type.

	Arousal condition	
Cue	**$\text{positive}_{\text{low}}$**	**$\text{positive}_{\text{high}}$**
global	452 (98.9)	436 (80.3)
local	486 (148.1)	493 (115.8)

3.4.2.3. No-cue block: RT data and error data

A 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 3 (Target type: global vs. local vs. ambiguous) repeated measures ANOVA for mean RTs (see Table 3.8) revealed a significant main effect of Target type, $F(1, 29) = 11.96$, $p < .001$, $\eta_p^2 = .292$. Contrast analyses showed that participants responded significantly slower in trials with local targets (509 ms) as compared to trials with global targets (456 ms; $F = 16.39$, $p < .001$) or ambiguous targets (449 ms; $F = 16.8$, $p < .001$). RTs in trials with global targets did not differ significantly from RTs in trials with ambiguous targets ($F < 1$, $p = .58$). The main effect of Arousal and the interaction Arousal x Target type did not prove reliable (all $F < 1$, all $p > .55$). By definition errors were not possible in trials with ambiguous targets. Therefore only error rates from trials with global or local targets (see Table 3.8) were analyzed with a 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Target type: global vs. local) repeated measures ANOVA. No significant main effects or interactions were found (all $F < 1$, all $p > .41$). Mean overall error rate was 4.0 % ($SD = 3.16$).

No significant affective modulations were found in the additional block without informative response cues, where a proactive control strategy could not have been applied. To address the problem of interpreting non-significant results, JZS-Bayes factors were again calculated for RT and error rates comparisons between the $\text{positive}_{\text{low}}$ and $\text{positive}_{\text{high}}$ condition. JZS-Bayes factors ranged from 3.1 to 7.08 meaning that the null hypotheses – no differences as a function of affect condition – were indeed more likely.

Table 3.8. Mean RTs (in ms) and error rates (in %) in the no-cue block of Experiment 5 as a function of Arousal and Target type.

	Arousal condition					
	$\text{positive}_{\text{low}}$			**$\text{positive}_{\text{high}}$**		
Target	**global**	**local**	**ambiguous**	**global**	**local**	**ambiguous**
RT (*SD*)	450 (89.2)	505 (78.9)	453 (86.8)	462 (94.3)	512 (72.7)	446 (114.6)
Errors (*SD*)	3.92 (5.86)	4.77 (5.56)		3.93 (4.91)	3.43 (3.97)	

3.4.2.4. *Frequency analyses of trials with ambiguous targets*

In trials with ambiguous targets participants could freely choose, whether to respond to the global or the local level. In this special situation of free choice it is possible to consider not only RT measures but also measures regarding response choice. This enables the following theoretically interesting additional analyses: For experimental blocks including informative response cues (blocks 2-4), it is possible to analyze to what extent responses followed the preceding cue, which is, therefore, another way of testing how arousal modulates cue usage. Furthermore, analyzing response choice in the no-cue block enables the investigation of possible differences in global processing preference under different arousal conditions. In the no-cue block, participants were not only free to choose the local or global shape but also not influenced by preceding cues. Therefore, the percentage of global responses in trials with ambiguous targets is a direct measure of global processing preferences.

Percentage of cue-congruent responses (ambiguous trials of experimental blocks 2-4). A 2 (Arousal: $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$) x 2 (Cue type: global vs. local) repeated measures ANOVA for mean percentages of cue-congruent responses revealed a significant main effect of Cue type, $F(1, 29) = 35.87, p < .001, \eta_p^2 = .553$. Ambiguous targets following global cues were responded with a global response in 85.3 % of the trials, whereas after local cues participants responded to the local level in only 21.4 % of the trials. The main effect of Arousal and the interaction of Arousal x Cue type did not prove reliable (all $F < 1.51$, all $p > .23$). So, irrespective of the kind of cue or arousal condition, participants preferentially responded to the global level, when having free choice of response.

Percentage of global responses (ambiguous trials of the no-cue block). There was a clear-cut global processing preference with an overall mean of 89.14 % global responses

(*SD* = 24.4 %) in trials with ambiguous targets. Global processing preference did not differ significantly between the positive$_{low}$ (*M* = 90 %) and the positive$_{high}$ condition (*M* = 88.3 %; $t < 1$, $p = .47$).

3.4.3. Discussion

Experiment 5 showed that positive affect with low or high arousal has diverging influences on the CVE also with a within-participants affect manipulation: Interestingly, the RT analysis replicated the results of Experiments 1, 2, and 4 with a reduced CVE under positive affect with low arousal, whereas the analysis of error rates showed an opposite response pattern with a reduced CVE in the positive$_{high}$ condition. The separate analysis of trials with ambiguous targets, at least descriptively, corresponded with the CVE results in RTs by indicating that RTs differ less between different cues – global vs. local – in the positive$_{low}$ condition as compared to the positive$_{high}$ condition. As expected, no affective modulations were found in the no-cue block, where a proactive control strategy was not possible. Moreover, in line with results from Navon (1977) and Gasper and Clore (2002) this additional block showed a typical global processing preference with slower RTs in trials with local targets as compared to trials with global or ambiguous targets. Also, the additional analyses of trials with ambiguous targets, where participants were free to respond to either level in the global-local task, suggested a general global processing preference: Under free choice, subjects predominantly responded to the global level – irrespective of affect condition and even after local cues.

In line with results from the previous experiments presented in this thesis, affective modulations in the global-local task of Experiment 5 were again only found in experimental blocks including informative cues, that is, where a proactive control strategy can be used to optimize performance (cf. Braver et al., 2007). The RT analysis of trials with global or local targets showed that with a within-participants affect manipulation positive affect with low arousal still reduced the CVE, which indicates less usage of the cues and consequently less proactive control. However, the analysis of error rates showed a reduced CVE in the positive$_{high}$ condition. At first sight, this response pattern with oppositional effects in RTs and error rates suggests a speed-accuracy trade-off with a shift in response criterion between the two arousal conditions. Subsequent analyses, however, did not support this assumption. Only one subject showed a significant negative correlation between RTs and error rates, whereas five participants even showed significant positive correlations. Therefore, the question remains, why the diverging effects of positive affect with low or high arousal were of different direction in RTs and error rates. Such an oppositional response pattern was not present in any of the experiments presented in the previous chapters: Experiments 2 and 4 revealed no affective influences on error rates at all, and Experiment 1 – where the CVE difference in RTs between $\text{positive}_{\text{low}}$ and $\text{positive}_{\text{high}}$ group was on the threshold of significance – showed parallel response patterns in RTs and error rates with a significantly reduced CVE in error rates under positive affect with low arousal. Experiment 1 and the present Experiment 5 differed in terms of affect manipulation as well as task. Thus, the differences in results might be due to diverging effects of sustained versus transient affect induction, special characteristics of the spatial response cueing task as compared to the cued global-local task, or a combination of both. Since a reverse CVE pattern in error rates was also not present in Experiments 2 and 4, which also used a between groups affect manipulation but differed in task, diverging effects of sustained versus transient affect induction seem to be the most likely explanation.

For example, Kazen and Kuhl (1999) also used a within-participants affect manipulation – thereby most likely inducing transient affective reactions – and found, somewhat similar to the present Experiment 5, oppositional effects in RTs and error rates (also not explainable with a speed-accuracy trade-off) in their Experiment 1 about influences of positive affect on the Stroop effect: Positive affective prime words as compared to neutral and negative words significantly reduced Stroop interference in the first of two consecutive Stroop tasks in RTs, but significantly increased error rates in the longest SOA condition (2250 ms). Because of the fact that this oppositional response pattern was restricted to the longest SOA only, the authors suggested that positive affect might increase impulsive tendencies over time. This hypothesis was, however, not discussed in more detail, because this effect was no longer present in the following experiments of this study. The present cued global-local experiment and Kazen and Kuhl's Experiment 1 are aside from the within-participants affect manipulation procedure hardly comparable. Kuhl and Kazen varied different valence conditions only and not different arousal conditions, they used affective words and not pictures, and participants had to respond to two consecutive Stroop tasks per trial, what most likely requires reactive control, and not a cued global-local task, where most likely proactive control is involved. Nonetheless, the idea of increased error rates as an indicator of increased impulsivity is interesting, because it seems to fit with current theories on cognitive control: The DMC framework (Braver, 2012; Braver et al., 2007) as well as the stability-flexibility framework (Goschke, 2003) assume that each cognitive control strategy is associated with specific behavioral costs: For example, less proactive control or less stability is associated with increased flexibility but also more impulsivity and distractibility (e.g., Dreisbach & Goschke, 2004). Therefore, a reduced dependence on informative cues accompanied by more impulsivity indicated by oppositional response pattern in RTs and error rates under positive affect with low arousal – and the reverse response pattern under positive affect with high arousal – might just be a natural consequence of the diverging influences of positive affect with different arousal levels on proactive control[3]. However, this speculation cannot explain, why this response pattern was only found in Experiment 5. Maybe the additional sustained affective influence in Experiments 1, 2, and 4 due to the between-groups affect manipulation had some kind of compensatory effect that was not possible with a randomized within-participants affect manipulation. But of course, based on the results from a single experiment alone, each explanation remains only speculative in nature. Further experiments using within-participants affect manipulations will have to show whether this specific response pattern can be replicated, before any final conclusions are possible.

More clear-cut are the results of Experiment 5 regarding the main question of Part II of this thesis, namely whether positive affect with different arousal levels modulates proactive or reactive control. Even though a new task and a within-participant affect manipulation was used, significant affective modulations were once again – in line with the experiments reported above – only found in experimental blocks including informative response cues, that is, where a proactive control strategy could be used to optimize performance. The inclusion of trials with ambiguous targets, where participants were free to choose the local or global response allowed new analyses concerning the usage of informative cues besides the CVE. However, for ambiguous trials, no significant differences between positive affect with low or high arousal were found neither in RTs nor in percentage of cue-congruent responses. The latter analysis only confirmed a general global processing preference even after local cues, but no affective modulation thereof. However, at least descriptively, the RT difference between local and global cues preceding ambiguous targets was less pronounced in the $\text{positive}_{\text{low}}$ condition, which might be another sign of less cue usage under positive affect with low arousal as it parallels the affective differences in CVE performance found in RT analyses before (namely, in trials with global or local targets of the present experiment as well as in RT analyses of Experiments 1, 2, and 4 of the present thesis). The mere descriptive affective

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[3] For this speculation to be valid, RTs and error rates have to be assumed to be influenced – at least partially – by different cognitive processes. A recent study (van Ede, de Lange, & Maris, 2012) showed that in paradigms using informative cues this might indeed be the case.

modulation in trials with ambiguous targets might be a consequence of insufficient statistical power: In the cued global-local task used here, trials with ambiguous targets were presented rarely (12 per experimental block), and even less trials remain when regarding trials with global or local cues separately (3 trials per factor combination in each experimental block, i.e., 9 trials over the whole experiment).

Taken together, results from the experimental blocks including informative response cues strengthened the assumption of diverging influences of positive affect with low or high arousal specifically on proactive control. However, the inverse response pattern – as compared to previous experiments reported in this thesis – in error rates analysis of CVEs as well as the mere descriptive affective differences of cue effects in trials with ambiguous targets strongly recommend a replication study.

Global processing is generally preferred to local processing (cf., Navon, 1977). Moreover, this preference has been shown to be increased under positive affect (Gasper & Clore, 2002). Therefore, a secondary question of the present experiment was, whether positive affect with low or high arousal further modulates this global processing preference. The above discussed results from experimental blocks including informative cues already indicated that both positive affect conditions are associated with a strong, comparable preference for global processing. Analysis of free choices on ambiguous targets in the no-cue block further confirmed this null-effect. Without pre-cues, participants showed an unequivocal preference for the global level, which did not differ between both arousal conditions. Taken together, these results suggest that differences in arousal have no major influence on the increased global processing preference under positive affect.

3.5. Discussion of Experiments 3 to 5

Part II of the present thesis gathered converging evidence over three different experiments in favor of the assumption that positive affect modulates proactive and not reactive control: (1) In the spatial response cueing paradigm of Experiment 3 uninformative cues (50 % cue validity) were presented, so that performance could no longer be optimized by a proactive control strategy like in Experiments 1 and 2. Therefore, the CVE in Experiment 3 could be interpreted as a measure of reactive control. No affective modulation of the CVE and as such, no modulation of reactive control was found. (2) Experiment 4 considered both reactive (in terms of switch costs) and proactive control (in terms of the CVE) in a single experiment using the task switching paradigm, first without task cues and afterwards with informative task cues included. No affective modulation was found in mere task switching performance, that is, participants of all affect groups showed comparable switch costs when no cues were presented, which indicates no differences in reactive control. But, like in Experiments 1 and 2, affect modulated the CVE, indicating less usage of informative cues and thereby reduced proactive control under positive affect with low arousal as compared to positive affect with high arousal. (3) Last but not least, Experiment 5 – the first experiment presented here using a within-participants affect manipulation – provided further evidence for the affective modulation of proactive control. Performance in a global-local task was only modulated by affect, when proactive control was involved (in experimental blocks including informative response cues), but no affective modulation was found, when a proactive control strategy was not possible (in the no-cue block). Interestingly, results from Experiment 5 showed a reduced CVE under positive affect with low arousal as compared to positive affect with high arousal in RTs, but a reversed response pattern in error rates. The RT data replicated results from Experiments 1, 2, and 4, which all used a between groups affect manipulation. Thus, this specific positive affect effect seems to be quite robust, as it has been found with different kinds of tasks (a spatial response cueing, a task switching, and a global-local task), different kinds of informative cues (response cues or task cues), and different kinds of affect manipulation (sustained or transient). The fact that besides Experiment 5 no other experiment found a reverse affective influence on the CVE in error rates suggests that this difference might be due to different affect induction procedures, because only Experiment 5 manipulated affect within participants.

Results from Part I were interpreted as a sign of increased flexibility under positive affect with low arousal in form of an increased ability to overcome predominant response tendencies. Based on the results of Part II this interpretation is no longer tenable. Instead of an increase of reactive control – which would have corresponded to an increased ability to overcome predominant response tendencies –, evidence for a reduction of proactive control under positive affect with low arousal was found. However, depending on the specific definition of cognitive flexibility, this positive affect effect can still be interpreted as increased flexibility: For example, Compton, Wirtz, Pajoumand, Claus and Heller (2004) argued that a reduced CVE – in a paradigm with informative cues – is also a kind of flexibility, because the behavior is less dependent on the cue information. Comparable to the experiments presented here, the authors found (using an attentional orienting paradigm) slower responses after validly cued targets and faster responses following invalidly cued targets under positive affect. Mood was measured via the Profile of Mood states (Mc Nair, Lorr, & Droppleman, 1971) –, and they found no influence of negative affect on attentional orienting but a reduced CVE under positive affect. Taken together, results from the present thesis fit with the existing literature on increased flexibility under positive affect, but it seems to be flexibility in terms of an enhanced independence from context information (i.e., reduced proactive control), specifically under positive affect in combination with low arousal.

3.6. Interim Summary

Results from Experiments 4 and 5 replicated diverging effects of positive affect in combination with low or high arousal. Furthermore, Part II of the present thesis showed that positive affect specifically modulates proactive and not reactive control: Low arousing positive affect reduces proactive control, while high arousing positive affect seems to increase proactive control.

CHAPTER 4

Part III: How positive affect modulates cognitive control: novelty bias and distractibility

4.1. Introduction

Positive affect is assumed to increase cognitive flexibility (cf., Ashby et al., 1999; Ashby et al., 2002). The experiments presented so far showed a reduction of proactive control under positive affect with low arousal. This result is in line with the assumption of increased flexibility under positive affect, because reduced proactive control means that the behavior is less dependent on context information (see also Dreisbach, 2006). According to current theories on cognitive control (Braver, 2012; Braver et al., 2007; Goschke, 2003) each control strategy – proactive versus reactive control or stability versus flexibility – is associated with a behavioral trade-off: For example, less proactive control or flexibility is associated with benefits in form of less perseveration but also with costs in form of increased impulsivity and distractibility, resulting in a higher vulnerability to interference by task-irrelevant information. Therefore, positive affect with low arousal should not only increase flexibility or reduce proactive control, but also increase distractibility at the same time. The oppositional results in RT and error rates found in Experiment 5 might be explained within this framework. But, of course, it is problematic to draw such conclusions based on a single experiment alone – especially as such a response pattern was not present in all other experiments presented here.

But two previous studies by Dreisbach (2006) and Dreisbach and Goschke (2004) showed converging evidence on behavioral trade-offs under positive affect with a comparable low arousal level as in the present studies: In a cognitive set-switching task (Dreisbach & Goschke, 2004), participants under positive affect showed increased flexibility and less perseveration in one switching condition, but also more distractibility in another switching condition, where new information had to be ignored. And in an AX-CPT paradigm (Dreisbach, 2006), positive affect resulted in costs, when a to be maintained goal had to be executed (BX and BY trials; less stability) and benefits when a to be maintained goal unexpectedly changed (AY trials; more flexibility). This short review (see Chapter 1.3. for a more detailed review) demonstrates that it is not sufficient to consider only increased flexibility under positive affect without regarding the corresponding behavioral costs, when investigating how positive affect modulates cognitive control. Therefore, Part III of the present thesis will focus on the costs of positive affect with low arousal, namely increased distractibility in particular.

4.2. Experiment 6: Stroop-like word-picture interference task with familiar and new distractors

Goal of Experiment 6 was to investigate a specific hypothesis concerning the increased distractibility under positive affect, which originated from a study by Dreisbach and Goschke (2004): Therein the authors used a paradigm including two switching conditions with different color changes of targets and task-irrelevant distractors: After the switch, either the targets appeared in a new color, while the former target color became the distractor color (perseveration condition), or the distractors appeared in a new color, while the former distractor color became the target color (learned irrelevance condition). Positive affect was found to reduce or virtually eliminate switch costs in the perseveration condition, where subjects had to switch to a new task dimension. On the other hand, positive affect increased switch cost – especially in incompatible trials – in the learned irrelevance condition, where subjects had to ignore a new task dimension. Based on these results the authors speculated an enhanced vulnerability for the processing of novel stimuli, that is, an increased novelty bias, under positive affect. So far, however, this specific hypothesis has never been tested empirically.

To directly address this question of an increased novelty bias under positive affect, Experiment 6 compared performance under positive affect with low arousal with a neutral affect group – with matched arousal levels – in a Stroop-like word-picture interference task with familiar and new distractors. In this paradigm, compound word-picture stimuli were used with the words always serving as targets and the pictures always being the distractors. Subjects had to respond to the target words with a left or right button press according to single stimulus-response (S-R) assignments. Specific arbitrary S-R assignments were chosen, so that participants would not be able to respond by using a simpler, binary categorization rule (task set), which has repeatedly been shown to prevent response interference by irrelevant distractors (see Dreisbach, 2012, for a review). Familiar distractors in the present experiment were pictorial representations of the target words – presented very frequently throughout the experiment –, while spatially left or right oriented animal pictures – unrelated to the target words and presented rarely and irregularly – were used as new distractors. Both distractor types could be compatible or incompatible with respect to the required response, that is, the depicted object (familiar distractors) or the spatial orientation of the animal (new distractors) could match or mismatch with the response mapping of a given target word. Following the hypothesis of an increased novelty bias under positive affect, it was assumed that participants in the positive affect group should be more distractible than participants in the neutral affect group, particularly by new distractors.

4.2.1. Method

4.2.1.1. Participants

51 subjects participated in the experiment for course credit or 5 Euro. Thereof 41 participants (see Results for exclusion criteria) were included into the final data analysis (Mean age = 24.61 years, *SD* = 6.21, range = 17-47, 27 female). All participants were German native speakers. Subjects were assigned randomly to the positive (n = 19) or neutral affect group (n = 22). All participants signed informed consent and were debriefed after the session.

4.2.1.2. Apparatus and stimuli

Apparatus was the same as in the previous experiments. The y- and m-key were again used as left and right response buttons.

Four German words served as target stimuli – “Trommel” (drum), “Bluse” (blouse), “Waage” (scales), and “Schemel” (stool) – and were presented in front of standardized black-and-white line drawings (Snodgrass & Vanderwart, 1980). To assure that both the words and the picture stimuli were recognizable in the compound word-picture stimuli, words were presented in purple, font size 32 pt, and the picture stimuli were all adjusted to a size of 240 x 240 pixel. The picture stimuli were always distractors and never served as targets. The words drum and blouse were mapped to the left (right) response key, and scale and stool were mapped to the right (left) key. Response mapping of the S-R assignments to the left and right key was counterbalanced across subjects.

Four distractors depicted the same objects that were also used as target words (familiar distractors, see Figure 4.2 A). Another 24 distractors showed spatially oriented – 12 to the left side, 12 to the right side – animals (new distractors, see Figure 4.2 B). All possible combinations of target words and familiar distractors (4 x 4) were used in the experiment. The 24 new distractors were evenly distributed amongst the four target words. As a consequence, in the entire experiment half of the target words had compatible distractors (i.e., the depicted familiar object or the spatial orientation of the animal matched the response mapping of the target word), whereas the other half had incompatible distractors. Examples of compound stimuli with compatible and incompatible distractors are given in Figure 4.1.

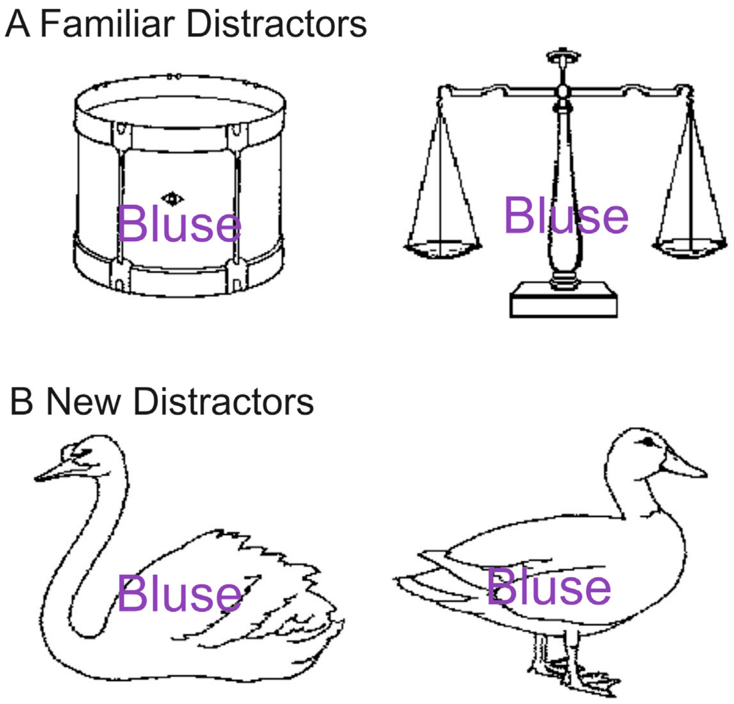

Figure 4.1. Examples of word-picture stimuli. The left column shows response compatible compound stimuli, the right column response incompatible compound stimuli.

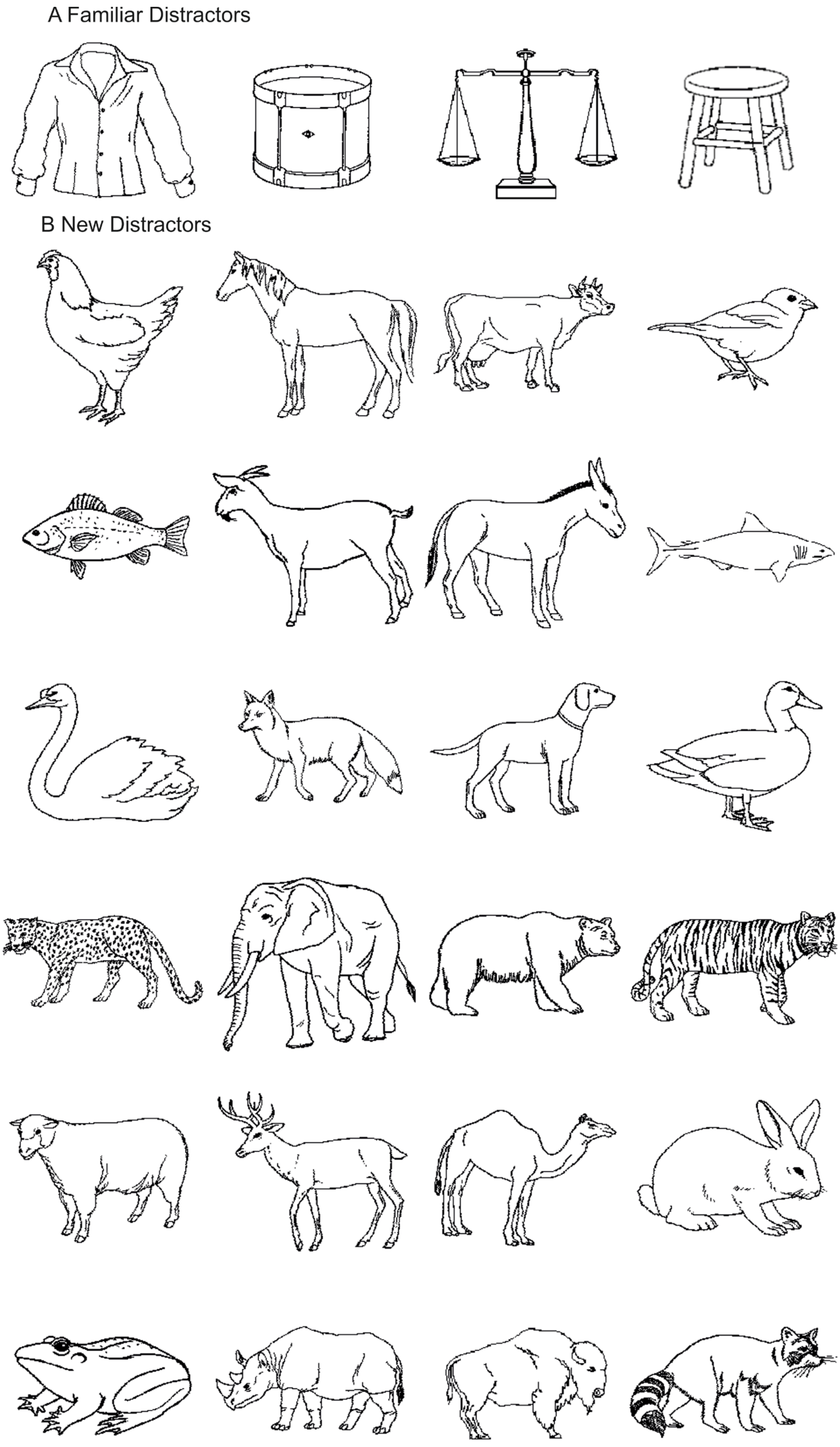

Figure 4.2. Line drawings (Snodgrass & Vanderwart, 1980) used as distractors: The upper panel (A) shows all four familiar distractors. The lower panel (B) shows all 24 left- or right-oriented animals used as new distractors.

Ten new IAPS pictures (see Table A1, Appendix A) were selected for the neutral affect group in Experiment 6: Like the previous neutral set, the new selection also had neutral valence levels ($M = 5.1$, $SD = 0.48$) but in combination with a higher arousal level ($M = 4.48$, $SD = 0.56$), which matched the arousal level of the positive$_{\text{low}}$ picture set (see Table 2.1, Chapter 2.2.). Furthermore, both the neutral and the positive picture set were matched for the number of pictures depicting animals to prevent a possible confound due to the line drawings of animals serving as new distractors.

4.2.1.3. Procedure

Each trial of the word-picture interference task started with the presentation of an IAPS picture for 350 ms. After a short blank screen (150 ms) the compound stimulus appeared and remained visible until the participant pressed the corresponding response key. Feedback (1500 ms) was given for errors only. Each trial ended with an intertrial interval of 1000 ms. Participants were instructed to react as fast as possible while avoiding errors. An example trial is visualized in Figure 4.3.

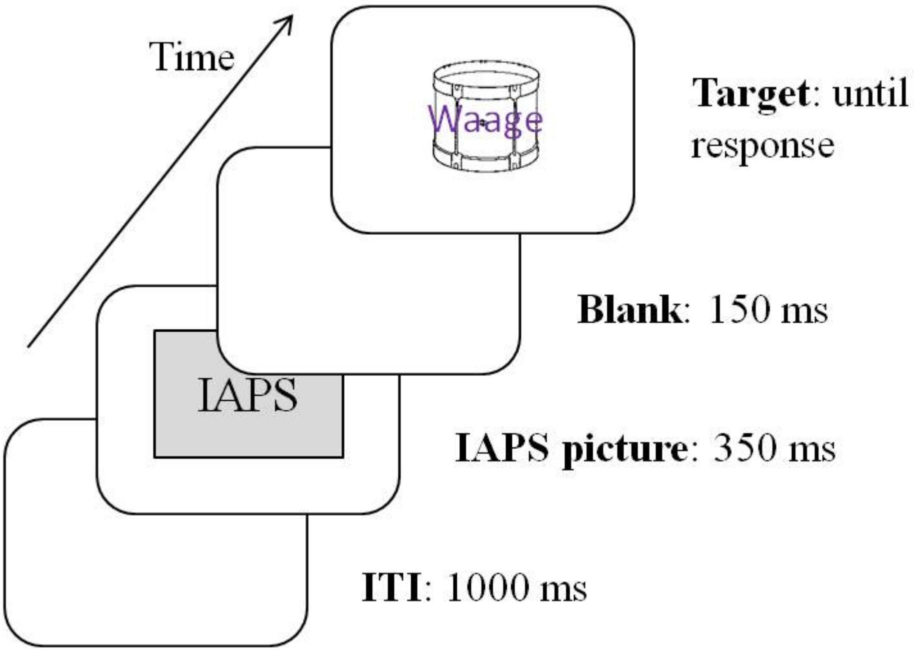

Figure 4.3. Design and procedure of a single trial of the word-picture interference task in Experiment 6.

The experiment was divided into two blocks, each consisting of 252 trials (15 x all 16 combinations of target words and familiar distractors + 12 trials with new distractors). Trial order was random with the following restrictions: To ensure the novelty effect of the new distractors, each new distractor was shown only once throughout the experiment and there was a mean distance of 20 trials (minimum 10, maximum 30 trials) between two trials with new distractors. The 12 new distractors per block included six left oriented and six right oriented animals, thereof three with a response compatible target word and three with an incompatible word. Consecutive repetitions of target words, distractor pictures, or IAPS pictures were not allowed.

Experiment 6 started with the same relaxation exercise that was also used in the previous experiments. In the following instructions participants were told to learn all four S-R assignments by heart and were instructed to respond to the words only. Subsequently, eight practice trials without IAPS pictures enabled the participants to get used to the Stroop-like word-picture interference task. In this first practice block, each target word was shown twice, once with a familiar, compatible distractor and once with a familiar, incompatible distractor. This was followed by another 16, now randomized practice trials (4 target words x 4 familiar distractors) with IAPS pictures included. Data acquisition took place in the subsequent two experimental blocks, which additionally included the 24 trials with new distractors. After the experiment a short interview followed to identify participants with self-generated task sets. Therein all subjects were asked whether they used a certain rule or strategy for memorizing the assignments of target words and corresponding responses.

4.2.1.4. Design

A 2 (Affect: neutral vs. positive) x 2 (Distractor type: familiar vs. new) x 2 (Distractor compatibility: compatible vs. incompatible) mixed factors design was used. Affect was manipulated between participants. Distractor type and compatibility were repeated measures within participants. RTs (in ms) and error rates (in %) served as dependent measures.

4.2.2. Results

4.2.2.1. Data analysis

Like in the previous experiments, practice trials, the first trial of each experimental block, error trials, trials following an error, and trials with RTs differing more than three standard deviations from individual means were excluded from analyses, which resulted in exclusion of 11.33 % of all trials. Furthermore, the data of one participant were excluded, because of too many errors (> 50 % error rate). Another two subjects had to be excluded due to slow performance far below the group mean (M = 947 ms vs. M_{positive} = 622 ms; M = 1135 ms vs. $M_{\text{neutral}} = 596$ ms). Furthermore, in spite of the single S-R instructions seven participants (two in the neutral group, and five in the positive group) were able to generate a task set on their own (e.g., “Drücke links, wenn man sich draufstellen kann [d.h. Schemel, Waage]” [“press left, if one can step on it {i.e., stool, scales}”]). These participants were also excluded because the application of self-generated task rules – like instructed task rules – has repeatedly been shown to eliminate interference by irrelevant distractors like spatially oriented animals (Dreisbach & Haider, 2009, Experiments 1 and 2; Dreisbach, 2012). For the remaining 41 participants mean RTs and error rates of each design cell (see Table 4.1) were entered into separate mixed factors ANOVAs.

Table 4.1. Mean RTs (in ms) and error rates (in %) in the word-picture interference task of Experiment 6 (SD in parentheses) as a factor of Affect group, Distractor type, and Distractor compatibility.

	Affect group			
	neutral		**positive**	
Distractor	**familiar**	**new**	**familiar**	**new**
		RT (SD)		
compatible	560 (63.2)	616 (90.1)	566 (71.0)	666 (141.3)
incompatible	578 (69.0)	630 (87.9)	592 (90.8)	668 (115.1)
		Errors (SD)		
compatible	3.08 (3.04)	4.54 (5.59)	3.26 (2.28)	4.39 (8.04)
incompatible	4.91 (3.54)	2.65 (4.73)	5.1 (2.71)	3.94 (5.81)

4.2.2.2. RT data

A 2 (Affect: neutral vs. positive) x 2 (Distractor type: familiar vs. new) x 2 (Distractor compatibility: compatible vs. incompatible) mixed factors ANOVA revealed significant main effects of Distractor type, $F(1, 39) = 81.49, p < .001, \eta_p^2 = .676$, and Distractor compatibility, $F(1, 39) = 4.65, p < .05, \eta_p^2 = .107$. Participants responded slower in trials with new distractors (645 ms vs. 574 ms) and also with incompatible distractors (617 vs. 602 ms). More importantly with respect to the hypotheses, there was a significant interaction of Affect x Distractor type, $F(1, 39) = 4.64, p < .05, \eta_p^2 = .106$. Both affect groups showed increased RTs with new distracters, but more so in the positive group (mean slowdown = 88 ms) than in the neutral group (mean slowdown = 54 ms; see Figure 4.4). No further significant effects were found (all $F < 1.03$, all $p > .32$).

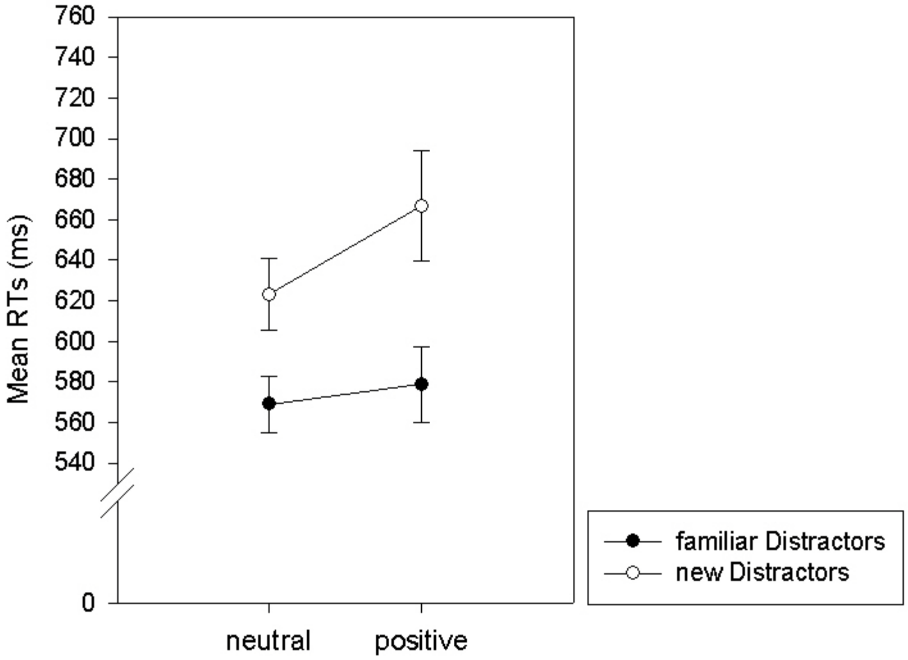

Figure 4.4. Mean RTs (in ms) in the word-picture interference task of Experiment 6 as a function of Affect group and Distractor type. Error bars represent 1 standard error of the mean.

4.2.2.3. Error data

In the same analyses for mean error rates only a significant interaction of Distractor type x Distractor compatibility, $F(1, 39) = 7.27$, $p < .05$, $\eta_p^2 = .156$, was found. Planned comparisons showed that a typical compatibility effect was present for familiar distractors (3.17 % vs. 5.01 %, $F(1, 39) = 33.42$, $p < .001$) but not for new distractors (4.46 % vs. 3.29 %, $F = 1.5$, $p = .23$). All main effects as well as all other interactions did not prove reliable (all $F < 0.68$, all $p > .42$). Mean overall error rate was 3.97 % (*SD* = 3.57).

For the sake of completeness: The same analyses for RTs and error rates without exclusion of participants with a self-generated task set showed basically the same results with one exception: The theoretically very important interaction of Affect x Distrator type in RTs was less pronounced and no longer significant ($F = 2.52$, $p = .119$). Mean slowdown by new distractors as compared to familiar distractors in the positive group was reduced to 77 ms. Complete descriptive and inferential statistics are included in Appendix C (Tables C1 to C3).

4.2.3. Discussion

Experiment 6 showed a general interference effect in form of slower RTs in trials with new distractors as compared to trials with familiar distractors. As expected, this interruptive effect of novel stimuli was more pronounced under positive affect. Furthermore, Experiment 6 found a descriptively small but significant main effect of Distractor compatibility on RTs, whereas in the error data, the typical compatibility effect – benefits in compatible trials and costs in incompatible trials – was only present in trials with familiar distractors, but absent in trials with new distractors.

Experiment 6 was run to test the hypothesis of an increased novelty bias under positive affect which originated from a study by Dreisbach and Goschke (2004). To assure that any differences between the two affect groups would be interpretable as a true valence effect a new neutral affect control group was used, in which affect was manipulated with neutral IAPS pictures that were matched to the arousal levels of the positive$_{\text{low}}$ picture set. Furthermore, picture sets for both affect groups were matched for the number of pictures depicting animals, because line drawings of spatially oriented animals served as new distractors. This procedure should prevent that an effect of Distractor type would be explainable as an induced animal bias. Therefore, the interaction of Affect x Distractor type can indeed be taken as evidence for an increased novelty bias under positive affect with low arousal as compared to neutral affect: While both affect groups showed slower responses in trials with new distractors as compared to trials with familiar distractors, this slowdown was more pronounced in the positive affect group indicating an increased sensitivity for novel stimuli. Interestingly, this valence based difference in the novelty bias was reduced and no longer significant, when participants with a self-generated task set were included into the statistical analysis. Task sets are simple, binary categorization rules, in which relevant stimulus and response features are specified (e.g., if stimulus is a consonant, press left, and if stimulus is a vowel, press right). Furthermore, several studies showed a shielding function of task sets (Dreisbach & Haider, 2008; Dreisbach & Haider, 2009; Dreisbach & Wenke, 2011; Reisenauer & Dreisbach, 2012; see also Dreisbach, 2012 for a review): In contrast to single S-R assignments (e.g., if "A" appears, press right, if "B" appears, press left, if "C" appears, press left…), task sets prevent response interference by irrelevant distractors, that is, stimuli that are not part of the present task representation. Regarding the paradigm of Experiment 6, this means that a task rule enables shielding of new distractors, which were not semantically related to the target words and consequently did not share relevant stimulus features. That is, in this paradigm the shielding function of a task rule should counteract the novelty bias, which perfectly explains why an increased novelty bias under positive affect could no longer be detected, when participants with a self-generated task set were included. It is, however, theoretically interesting and noteworthy, that the shielding function of task sets seems to outweigh the distractibility incurred by positive affect.

Another interesting result in this context is the fact that five participants from the positive group but only two from the neutral group were able to generate a task set on their own. This fits with results from previous studies showing enhanced performance in creative problem solving tasks in association with positive affect (e.g., Estrada, Isen, & Young, 1994; Isen, Daubman, & Nowicki, 1987; Isen, Johnson, Mertz, & Robinson, 1985). For example, participants under positive affect generated more correct solutions in the Remote Associates Test, which bears some resemblance to finding a task rule in the present experiment. Thus, although Experiment 6 was specifically aimed at finding an increased novelty bias under positive affect, it nonetheless gathered further evidence for an increase in cognitive flexibility under positive affect – at least descriptively. So, like results from Dreisbach and Goschke (2004) and Dreisbach (2006), Experiment 6 fits with and endorses the assumption that favoring a specific cognitive control strategy is accompanied with corresponding behavioral costs (cf., Braver, 2012; Braver et al., 2007; Goschke, 2003): That is, if positive affect increases flexibility, it should consequently also increase distractibility, and vice versa.

The distractor compatibility effect in Experiment 6 was descriptively rather small and statistically non significant for error rates in trials with new distractors. Also in RTs the compatibility effect was more pronounced in trials with familiar distractors (23 ms vs. 8 ms in trials with new distractors). This might be a consequence of the procedural precautions taken to assure the novelty effect of new distractors. Practice blocks did not include trials with new distractors, and their appearance in experimental blocks was rare and irregular. Experiment 3 from a study by Dreisbach and Haider (2009), which used a similar paradigm to the one used here, found that stable, well-practiced S-R assignments are able to prevent interference from irrelevant information comparable to the shielding function of task sets. So, maybe the special procedure used here resulted in establishing such stable S-R assignments that diminished the vulnerability to compatibility effects in trials with new distractors. However, in the Dreisbach and Haider study, those stable S-R assignments were established in an experimental practice block with 128 trials, where no distractors – neither semantically related nor unrelated – were presented, which was not the case in the present experiment. Therefore, it is arguable, whether the results from Dreisbach and Haider are really applicable to the present results. An alternative explanation might be that this small compatibility effect especially in trials with new distractors is simply a consequence of the successfully induced novelty effect: Task-irrelevant spatial information – like the orientation of the animals in trials with new distractors – automatically induces a spatially congruent response tendency (cf., Eimer, 1995; see also Rueda et al., 2004; Tucker & Ellis, 1998), which decays over time. The presentation of new distractors had a disruptive effect on performance with a significant slowdown in RTs in both affect groups. Therefore, only a diminished spatial compatibility effect might have been left with such delayed responses.

4.3. Interim Summary

Part III of the present thesis focused on the costs of positive affect in form of increased distractibility. More precisely, Experiment 6 tested the hypothesis that positive affect specifically increases the vulnerability to interference by novel information. Results revealed indeed an increased novelty bias under positive affect with low arousal as compared to a (arousal matched) neutral affect group. Furthermore, results of Experiment 6 indicated that increased distractibility and increased flexibility are two sides of the same coin, which endorses current theories on cognitive control (cf., Braver, 2012; Braver et al., 2007; Goschke, 2003).

CHAPTER 5 General Discussion

The main aim of the present thesis was to gather further insight into the affective modulation of cognitive control. Results from the studies presented here replicate and exceed the existing literature on increased cognitive flexibility under positive affect (cf., Ashby et al., 1999; Baumann & Kuhl, 2005; Compton et al., 2004; Dreisbach, 2006; Dreisbach & Goschke, 2004; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999;van Wouwe et al., 2011) by showing very specific affective influences: (1) Converging evidence was found for dissociating effects of positive affect in combination with low or high arousal indicating not only valence specific but also arousal specific positive affect effects. Therefore, and in line with Russell’s circumplex model of affect (e.g., Posner et al., 2005; Russell, 1980), any investigation of positive affect effects should consider both dimensions of affect, namely, valence *and* arousal. (2) According to the DMC framework (Braver, 2012; Braver et al., 2007) cognitive control can be differentiated into proactive and reactive control: Proactive control means sustained preparation for an upcoming event – for example, by using informative cues to optimize performance –, while reactive control means a just-in-time activation of control as soon as a demanding event appears. A series of five Experiments (see Chapters 2.2. to 3.4.) using different paradigms and cues gathered converging evidence that positive affect specifically modulates *proactive* control and not reactive control. Positive affect with low arousal – but not positive affect with high arousal – consistently reduced proactive control as indicated by a reduced CVE. Although the “classical” interpretation of increased cognitive flexibility would have suggested an increase in reactive control, this result is still interpretable as increased flexibility. A behavior that is less reliant on informative cues is consequently also more flexible, because it is less dependent on in advance information (cf., Compton et al., 2004). (3) According to current theories on cognitive control (Braver, 2012; Braver et al., 2007; Goschke, 2003) increased flexibility or reduced proactive control is associated with corresponding behavioral costs. In line with these theories positive affect has been shown to increase distractibility and reduce maintenance capability (cf., Dreisbach, 2006; Dreisbach & Goschke, 2004). More specifically, Part III of the present thesis could show an increased novelty bias – that is, an enhanced distractibility especially towards new events – under positive affect with low arousal, thereby presenting first empirical evidence for a hypothesis suggested by Dreisbach and Goschke (2004). For an overview of all experiments presented here (including paradigm, cueing procedure, affect manipulation method, and most important results) see Table 5.1.

Table 5.1. Overview of all experiments from the present thesis.

	Paradigm	**Cueing Procedure**	**Affect Manipulation**	**Results**
Part I				
Experiment 1	Spatial response cueing task	Informative response cues (66 % cue validity)	IAPS pictures preceding every trial 4 between-subjects affect groups: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$ vs. $\text{negative}_{\text{high}}$	Reduced CVE under positive affect with low arousal as compared to positive affect with high arousal in error rates ($p < .05$) as well as RTs ($p = .059$) General slowdown of RTs in the $\text{negative}_{\text{high}}$ as compared to the $\text{positive}_{\text{high}}$ affect group ($p < .05$)
Experiment 2	Spatial response cueing task + increased working memory load	Informative response cues (66 % cue validity)	IAPS pictures preceding every trial 3 between-subjects affect groups: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$	Reduced CVE in RTs in the $\text{positive}_{\text{low}}$ as compared to the $\text{positive}_{\text{high}}$ ($p < .05$) and neutral affect group ($p < .05$)
Part II				
Experiment 3	Spatial response cueing task	Non-informative response cues (50 % cue validity)	IAPS pictures preceding every trial 3 between-subjects affect groups: neutral vs. $\text{positive}_{\text{low}}$ vs. $\text{positive}_{\text{high}}$	No affective modulation of the CVE

Table 5.1. (continued) Overview of all experiments from the present thesis.

	Paradigm	**Cueing Procedure**	**Affect Manipulation**	**Results**
Experiment 4	Task Switching	No-cue (1 block) vs. informative task cues (75 % cue validity, 3 blocks)	IAPS pictures preceding every trial 3 between-subjects affect groups: neutral vs. positive$_{low}$ vs. positive$_{high}$	No cue: No affective modulation of switch costs Informative cues: Reduced CVE in RTs in the positive$_{low}$ as compared to the positive$_{high}$ affect group (*p* = .05)
Experiment 5	Global-local task with global, local, and ambivalent targets	Informative response cues (71.4 % cue validity, 3 blocks) vs. no-cue (1 block)	IAPS pictures preceding every trial 2 within-participants affect conditions: positive$_{low}$ vs. positive$_{high}$	Informative cues: Reduced CVE in RTs under positive affect with low arousal as compared to positive affect with high arousal ($p < .05$), reverse response pattern in error rates No cues: No affective modulation
Part III				
Experiment 6	Stroop-like word-picture interference task with familiar vs. new distractors	No cues	IAPS pictures preceding every trial 2 between-subjects affect groups: neutral vs. positive$_{low}$	Increased novelty bias under positive affect: stronger interference by new distractors in the positive$_{low}$ as compared to the neutral affect group ($p < .05$)

Taken together, results of the present thesis strongly recommend that future research on the modulation of cognitive control by positive affect should consider valence as well as arousal, differentiate between proactive and reactive control, and be aware of benefits as well as costs associated with different cognitive control strategies. Exceeding the previous discussions included in Parts I to III, some general topics – with respect to the original research presented here – concerning the influence of positive affect on cognitive control will be addressed in the following.

5.1. Positive affect with low arousal reduces proactive control

The experiments of the present thesis repeatedly found a reduced CVE under positive affect with low arousal, which converges with findings from previous studies by Compton et al. (2004) and Dreisbach (2006). While investigating associations between baseline mood state and performance in an attentional orienting task with informative cues, Compton et al. found no relationship between self-reported negative affect and attentional orienting performance, whereas high positive affect as compared to low positive affect was associated with a reduced CVE. Dreisbach (2006) used the AX-CPT and found enhanced performance in AY trials, that is, in invalidly cued trials, but impaired performance in BX and BY trials, that is, in validly cued trials, under positive affect (comparable to the low arousal conditions used here) as compared to neutral or negative affect. Thus in both studies, positive affect resulted in a benefit in expected events, but also in costs in unexpected events. These findings – like the present results – can be explained by a reduced usage of informative cues, which indicates a reduction in proactive control. However, a recent study by van Wouwe et al. (2011) – also using the AX-CPT – found no influence of positive affect on cue usage (no impairment in BX and BY trials), and hence proactive control, but, instead, differences between their positive and neutral affect group in reactive control: Participants in the positive affect group showed a performance benefit and ERP differences in AY trials only, where a pre-dominant response tendency had to be overcome. In line with these results are also several studies by Kuhl and colleagues (Baumann & Kuhl, 2005; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999) that used paradigms without informative cues or predictable task orders, thus leaving no room for proactive control strategies. They used the Stroop task and a version of the global-local task (different to the one used here in Experiment 5) and found a reduction in Stroop interference and a reduced global precedence under positive affect indicating also an enhanced ability to overcome predominant response tendencies. So overall, there is evidence for increased flexibility in form of a reduction in *proactive* control (this thesis; Compton et al., 2004; Dreisbach, 2006), but also evidence for increased flexibility in form of a modulation of *reactive* control (Baumann & Kuhl, 2005; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999; van Wouwe et al., 2011).

One reason for these mixed results might be differential affect induction procedures: The current studies (except for Experiment 5) manipulated affect in a between groups design with affective pictures preceding every trial – as was done also in the AX-CPT study by Dreisbach (2006) –, Compton et al. (2004) investigated differences in baseline mood state, van Wouwe et al. (2011) used emotional film clips prior to the actual experiment (for a more detailed discussion on differences between the two AX-CPT studies see van Wouwe et al., 2011), and Kuhl and colleagues (Baumann & Kuhl, 2005; Kazen & Kuhl, 2005; Kuhl & Kazen, 1999) used a within participants design with random presentation of positive, negative or neutral prime words preceding every trial. So, Compton et al. as well as van Wouwe et al. were concerned with effects of a sustained mood state – in the former case the currently existing mood state, in the latter case an induced mood state –, whereas Kuhl and colleagues investigated influences of rather transient affective reactions. The affect induction procedure used here and elsewhere (cf., Dreisbach 2006; Dreisbach & Goschke, 2004) – affective pictures preceding every trial in a between groups design – most likely resulted in both transient *and* sustained affective reactions. IAPS pictures elicit typical emotional reactions very quickly with specific changes in cortical, autonomic, and facial activity, as well as evaluative ratings even with short presentation durations (Codispoti et al., 2001; Codispoti et al., 2009). Furthermore, repetitive exposure to pictures of the same valence leads to maintained or even sensitized affective reactions and can therefore be seen as a mood induction procedure (Bradley et al., 1996; Smith et al., 2005). Thus, it cannot be decided at this point, whether a sustained affective influence is really necessary, whether transient affective reactions alone might be sufficient, or whether it is the specific combination of both that is responsible for the specific positive affect effects found in Experiments 1 to 4. The fact, that Experiment 5 – that is, the only Experiment presented here using a within participants affect manipulation – showed an oppositional response pattern in RTs and error rates, which was not present in any of the previous experiments, suggest that differences in affect induction procedure might indeed be a relevant factor. But, of course, there are other procedural factors that might as well be crucial. For example, the reduced Stroop interference found by Kuhl and colleagues was restricted to specific conditions, namely, when intention memory is activated (i.e., in the first of two consecutive Stroop tasks in a single trial; see Kuhl & Kazen, 1999) or when using specific positive primes related to achievement (see Kazen & Kuhl, 2005). Also, none of the above-quoted studies considered differences in arousal levels[4]. In sum, the existing literature is characterized by mixed results, which might be due to different affect induction procedures – pictures vs. film clips vs. words, between vs. within, affect induction previous to vs. during the actual experiment –, differences in intention memory load, as well as different arousal levels. Therefore, future studies are clearly needed – with a systematic variation of these potential factors – to further clarify under which conditions positive affect influences proactive or reactive control.

But, irrespective of the exact underlying mechanisms, the present Experiments 1 to 5 – in line with results from some previous studies (Compton et al., 2004; Dreisbach, 2006) – showed converging evidence that positive affect specifically modulates *proactive* control: Only in situations, where performance could be optimized with a proactive control strategy – that is, when useful advance information was present (cf., Braver, 2012; Braver et al., 2007) – results revealed affective modulations, whereas reactive control was never influenced by positive affect (see Part II of the present thesis). More precisely, positive affect with low arousal repeatedly reduced the CVE when using paradigms including informative cues, thereby indicating less reliance on those cues. But, why is it that low arousing positive affect reduces proactive control? Intuitively, it seems to converge with our everyday experience: When being in a relaxed, mildly positive mood one tends to enjoy the moment without looking ahead. Moreover, this intuitive correspondence would also be in line with Carver's coasting theory (2003). This theory assumes a feedback function of affect: More precisely, positive affect presumably signals better progress than necessary, and consequently reduces the effort invested in the ongoing task (= coasting). Proactive control in this sense is associated with more effort than reactive control, because it involves sustained maintenance of informative cues or task goals for an optimized behavior (Braver, 2012; Braver, Gray, & Burgess, 2007). Applied to the present results, a reduction of proactive control could, thus, be a sign of coasting: Participants in the positive$_{\text{low}}$ condition apply less effort in sustained task preparation, and instead rely on reactive control as soon as the target appears. Similar predictions would be made by Schwarz's feelings-as-information theory (1990, 2012). Schwarz suggests that feelings are often used as a source of information with negative

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[4] But note that in the Dreisbach studies (Dreisbach & Goschke, 2004; Dreisbach, 2006) the positive IAPS pictures had low arousal levels comparable to the ones used in the present thesis.

feelings signaling threat or a lack of positive outcomes, whereas positive feelings signal a benign situation. This is assumed to result in corresponding processing strategies: Negative affect is a signal to be careful, which causes an analytic processing style. Positive affect, on the other hand, is a safety signal, thereby allowing less effortful strategies. So, following the same reasoning as before, the present results of a reduction in proactive control (i.e., the more effortful control strategy) under positive affect with low arousal would also be in line with the feelings-as-information theory. Taken together, reducing proactive control under low arousing positive affect seems to be a form of adaptive behavior, wherein positive affect might serve as feedback on goal progress (Carver, 2003) or as a safety signal (Schwarz, 1990, 2012).

5.2. Diverging effects of positive affect with low or high arousal

Experiments of Parts I and II showed clear-cut evidence for arousal differences within positive affect. Only positive affect in combination with low arousal resulted in a reduction of proactive control, whereas positive affect in combination with high arousal – if anything – seemed to even increase proactive control. First of all, these diverging results endorse the basic assumption of Russell's circumplex model of affect (Russell, 1980; Russell, 2003; Russell & Feldman-Barrett, 1999), namely, that each affective state is an inseparable combination of the two independent dimensions valence and arousal. Moreover, the results presented here emphasize that future research focusing on positive affect effects should not neglect arousal influences as was common procedure in a lot of previous studies.

As already discussed above, the reduction of proactive control under positive affect with low arousal might serve an adaptive function in line with Carver's coasting theory (2003) or Schwarz's feelings-as-information theory (1990, 2012). But, why was this effect restricted to low arousal levels? In Schwarz's theory, positive affect serves as a safety signal, which allows switching to less effortful strategies. Obviously, any high arousal signal might, however, rather serve as a warning or alertness signal. For example, Fuentes and Campoy (2008) showed in an attention network task that alerting tones increase the CVE, and inferred that alerting enhances the effect of informative cues. Furthermore, positive affect effects are assumed to be mediated by DA activity (cf., Ashby et al., 1999; Ashby et al., 2002), whereas arousal is associated primarily with NE activity (e.g., Grant, Aston-Jones, & Redmond, JR., 1988; Rasmussen, Morilak, & Jacobs, 1986). According to the integrative LC-NE theory (Aston-Jones & Cohen, 2005a, 2005b; see also Chapter 1.2.2.) phasic LC-NE activity promotes exploitative behavior, whereas tonic activity is associated with explorative behavior. Exploitative behavior helps to optimize task performance by enhancing task-related processing, while explorative behavior worsens current task performance and facilitates disengagement from a given task. In the present paradigms with informative cues, optimizing task performance means using the cues for response or task preparation, that is, using a proactive control strategy. So, applied to the present data, the short presentation of highly arousing positive pictures might have triggered phasic NE activity and thereby resulted in increased proactive control (i.e., exploitative behavior) and, as a consequence, an increased CVE. That is, arousal effects may have counteracted and outweighed the effects of positive affect in the positive$_{\text{high}}$ condition. This argumentation, of course, is mere speculation at this point, because the present thesis considered behavioral results only. Furthermore, Aston-Jones and Cohen's LC-NE theory is based on animal studies (monkeys) and correlational in nature. First studies testing human subjects showed mixed results so far: A psychopharmacological study (Jepma, te Beek, Wagenmakers, van Gerven, & Nieuwenhuis, 2010) manipulated the LC-NE system via a selective NE reuptake inhibitors, which was, however, not followed by a predicted influence on explorative behavior. In contrast, two other studies (Gilzenrat, Nieuwenhuis, Jepma, & Cohen, 2010; Jepma & Nieuwenhuis, 2011) – measuring differences in baseline pupil diameter as an indicator of LC-NE activity (cf., Phillips, Szabadi, & Bradshaw, 2000; Rajkowski, Kubiak, & Aston-Jones, 1993) – could show indirect evidence for an association between exploitative or explorative behavior and LC-NE activity in humans as predicted by Aston-Jones and Cohen's theory. Thus, to shed further light on the diverging effects of positive affect with low or high arousal future studies including functional markers – baseline pupil diameter for NE activity and for DA activity spontaneous EBR (cf., Elsworth et al., 1991; Dreisbach et al., 2005) or DA related gene polymorphisms (cf., Oak et al., 2000) (cf., Chapter 1.3.1.) – would be especially useful.

Irrespective of the underlying mechanisms, one might in general criticize the conclusion of diverging effects of positive affect with low or high arousal due to the lack of significant differences compared to the (baseline) neutral affect group: In Experiments 1 and 4, the CVE in the neutral group was descriptively between both positive groups, but there were no significant differences. Only Experiment 2 showed a significant reduction of the CVE in the positive$_{\text{low}}$ group compared to the neutral group, but therein the magnitude of the CVE was equally high in the neutral and the positive$_{\text{high}}$ group. These rather subtle differences between neutral affect and the positive affect groups might be a byproduct of the special procedure used in the present experiments: Each experiment started with a short relaxation exercise to create a similar baseline mood in all participants. This procedure, however, might already have resulted in a mild positive affect induction, thereby possibly reducing the differences between the neutral group and the positive group especially with low arousal. Admittedly, what speaks against this assumption is that in Experiment 2, the CVE of the neutral group actually resembled the positive$_{high}$ group. It is, however, conceivable that the higher task demands due to the additional math task have counteracted the relaxed mood in the neutral group. Thus, the significant difference found in Experiment 2 might in fact be closer to the actual difference between neutral affect and positive affect with low arousal. Also, it can be assumed that everyday mood is generally rather mildly positive than truly neutral. Therefore, it might not be too surprising that differences between mild positive affect and neutral affect are not easily detected (see also Posner et al., 2005, for a more general discussion concerning neutral affect control conditions). Having said that, the observed differences in the CVE between positive affect with low arousal and neutral affect and positive affect with high arousal provide sufficient evidence for the conclusion that positive affect with low arousal decreases proactive control, while positive affect with high arousal increases proactive control compared to neutral affect.

5.3. Novelty bias and positive affect

Experiment 6 of the present thesis succeeded in gathering empirical evidence for an increased novelty bias under positive affect with low arousal. That is, it was the first study directly addressing a specific hypothesis suggested by Dreisbach and Goschke (2004) in their study on the modulatory influence of positive affect on cognitive control. In line with Goschke's stability-flexibility framework of cognitive control (2003) they found evidence for reduced perseveration (= increased flexibility) as well as increased distractibility under positive affect in a cognitive set-switching task. This was interpreted as indication of an increased novelty bias under positive affect, because performance benefits were found, when participants had to switch to a new task dimension (perseveration condition), and performance costs, when novel distractors had to be ignored (learned irrelevance condition). Taken together, the results from present Experiment 6 and from Dreisbach and Goschke (2004) might help explaining some mixed results in the existing literature on positive affect effects (cf., review by Mitchell & Phillips, 2007), because such an increased novelty bias results in costs or benefits depending on whether new events are task-irrelevant or task-relevant in a given situation.

Furthermore, these findings seem to fit with neuropsychological theories of positive affect, cognitive control processes and PFC functions (Ashby et al., 1999, 2002; Cohen et al., 2004; Miller & Cohen, 2001). An adaptive dopaminergic gating mechanism is assumed to regulate updating of representations in PFC (Cohen et al., 2004; Miller & Cohen, 2001; see also Chapter 1.2.2.), and the modulation of cognitive control by positive affect is also supposed to be mediated via DA activity in prefrontal cortical areas (Ashby et al., 1999, 2002). Thus, applied to the present results, positive IAPS pictures might have caused a mild increase in phasic DA activity, which promoted updating in PFC, thereby resulting in an increased novelty bias. Again, this argumentation is limited by the fact that Experiment 6 considered behavioral data only, but there are other studies (Dreisbach et al., 2005; Müller et al., 2007; Tharp & Pickering, 2011) showing more direct evidence for the modulatory influence of DA in this respect: Using the same paradigm as Dreisbach & Goschke (2004) these studies found the same response pattern for participants with higher central DA activity – indicated by functional markers of DA activity (e.g., spontaneous EBR) – as in the positive affect group of the original study.

On a more general level, results of Experiment 6 are in line with theories that stress the functional value of positive affect (Carver, 2003; Fredrickson, 1998). As already described above, in Carver's coasting theory positive affect is assumed to serve as feedback, signaling better than expected progress in the current task. As a consequence, effort in this task will be reduced, which is called coasting. Carver, furthermore, suggests that coasting promotes exploration ("Pleasure as a sign you can attend to something else", p. 241), which has the adaptive value of facilitating the detection of unexpected opportunities. Obviously, increased exploratory behavior should be accompanied by an increased susceptibility to novel stimuli. Thus, the increased novelty bias under positive affect with low arousal might be a sign of coasting – like the reduction of proactive control (see discussion above) –, which is especially advantageous, whenever novel events are associated with benefits. The increased novelty bias under positive affect with low arousal also seems to fit with Fredrickson's broaden-and-build model of positive emotions (Fredrickson, 1998). The basic assumption in this model is that positive emotions arise in situations perceived as safe or saturated, that is, free from threat or acute needs. Therefore, positive affective states – in contrast to negative affective states – permit a broadening of the individual's thought-action repertoire, which results, for example, in increased exploratory behavior. So, following the same reasoning as before, the increased novelty bias found under positive affect with low arousal (see Experiment 6) also fits with Fredrickson's theory. Whereas Carver's coasting theory only considers short-term effects of positive affect, Fredrickson's broaden-and-build model, furthermore, includes assumptions about long-term effects. An increase of exploratory behavior can result in learning new skills or behaviors. That is, positive emotions are assumed to be evolutionary adaptive in the long run by building new resources, which outlive the transient affective states. Obviously, such an increase in personal resources (behavioral as well as cognitive) facilitates adaptive behavior in a complex, dynamically changing environment.

The original focus of Part III of the present thesis was on the behavioral costs of positive affect. Following the flexibility-stability framework of cognitive control (Goschke, 2003) as well as the DMC framework (Braver, 2012; Braver et al., 2007), an increase in flexibility under positive affect – repeatedly shown in the literature and in the present experiments – was assumed to be accompanied by costs in form of increased distractibility, especially to novel stimuli. So far, however, the discussion of this increased novelty bias under positive affect illustrates that such a black-and-white account – with flexibility as beneficial and distractibility as detrimental – is an inadequate simplification. Both flexibility and distractibility seem to be two sides of the same coin, which depending on the given situation might result in costs or benefits (cf., Dreisbach & Goschke, 2004), and might even be altogether beneficial from a long-term perspective (cf. Fredrickson, 1998).

5.4. Positive affect versus reward: Differentiating emotion and motivation

Exceeding the discussion above on the importance of further research on diverging effects of different affect induction procedures (see Chapter 5.1.), one related caveat shall be addressed in the following. The existing literature so far often made no differentiation between reward and positive affect based on the fact that reward typically is accompanied by positive affective reactions. For example, Ashby and colleagues' (1999) hypothesis on DA mediating the cognitive effects of positive affect is derived from research showing that reward is associated with DA activity. However, some recent studies (Braem, Verguts, Roggeman, Notebaert, & Roggeman, 2012; Dreisbach, 2006; Locke & Braver, 2008; van Steenbergen et al., 2009; van Steenbergen et al., 2010) have illustrated diverging effects of positive affect and reward on cognitive control: Dreisbach (2006) as well as Locke and Braver (2008) used an AX-CPT paradigm, but Dreisbach manipulated affect via IAPS pictures preceding every trial, whereas Locke and Braver manipulated reward by giving monetary incentives, when participants RTs were faster than their median RT in a baseline condition. In the Dreisbach study, positive affect resulted in benefits in unexpected events (i.e., AY trials) and costs in expected events (i.e., BX and BY trials), which can be interpreted as a reduction in maintenance capability and proactive control. In contrast, Locke and Braver observed a reversed response pattern indicating increased maintenance capability and proactive control following reward. Likewise, Braem and colleagues (2012) as well as van Steenbergen and colleagues (2009, 2010) observed oppositional effects of reward and positive affect on conflict adaptation effects using both an Erikson flanker paradigm. Van Steenbergen et al. manipulated positive affect – once with performance non-contingent smilies during the experiment indicating a monetary gain (2009), and once with a mood induction procedure combining imagination and music (2010) –, and found both times reduced conflict adaptation under positive affect. In contrast, Braem et al. manipulated reward – by including 25 % trials with performance-related reward cues, where participants could win a monetary gain, if they responded correct and faster than 1000 ms – and found increased conflict adaptation in reward trials. Taken together, these studies demonstrate that positive affect and reward appear to be accompanied by exactly opposite modulations of cognitive control.

As such, two recent reviews on this topic (Chiew & Braver, 2011; Dreisbach & Fischer, 2012b) emphasize the importance of differentiating between emotional (i.e., affective) and motivational influences (i.e., reward) on cognitive control. Experimental procedures that manipulate subjective affective experience only (e.g., via exposure to affective stimuli) have to be distinguished from procedures that use motivational manipulations (e.g., via performance-contingent incentives). Chiew and Braver speculate that positive affect and reward might indeed both be associated with DA activity, while their diverging influences may be due to dissociable modes of DA activity: Tonic versus phasic DA activation and/or D1 versus D2 receptor dominated states may be the underlying mechanisms (cf., Cohen, Braver, & Brown, 2002; Durstewitz & Seamans, 2008). Moreover, Dreisbach and Fischer theorize that positive affect and reward might have diverging effects on intrinsic reinforcement signals: Especially in cognitively demanding tasks correct responses are associated with activation in the ventral striatum, which is assumed to act as an intrinsic motivational signal (cf., Satterthwaite et al., 2012). Performance contingent reward might enhance this intrinsic reinforcement signal thereby increasing proactive control and conflict adaptation (cf., Braem et al., 2012; Locke & Braver, 2008), while positive affect, in contrast, might counteract and outweigh this signal thereby reducing proactive control and conflict adaptation (cf., Dreisbach, 2006; van Steenbergen et al., 2009; van Steenbergen et al., 2010). Therefore, current researchers on positive affect effects should be most careful in planning their affect inductions procedures, because any confound with a reward manipulation will make it extremely difficult to interpret the results.

Interestingly, the diverging effects of positive affect with low or high arousal found in the present thesis seem to parallel the diverging effects of positive affect and reward reported in the literature: Positive affect in combination with high arousal like performance-contingent reward has been shown to increase proactive control (cf., present Experiments 1-5; Locke & Braver, 2008), whereas positive affect with low arousal reduced proactive control (cf., present Experiments 1-5; Dreisbach, 2006). Moreover, it was discussed above that highly arousing positive affect effects might be mediated via NE activity (see Chapter 5.2.), which perfectly fits with the idea that an NE modulated learning signal might account for the reward effects (Braem et al., 2012). Thus, positive affect in combination with high arousal might possibly have an additional motivational effect that is not present under positive affect with low arousal. Again, future research would be most interesting and important to clarify, whether indeed similar underlying mechanisms could be responsible for the influences of reward and positive affect with high arousal on cognitive control.

In sum, the existing literature together with the present results illustrate that even though there is considerable progress in understanding how positive affect modulates cognitive control, there is still a long way to go: (1) Effects of positive affect have proven to be much more specific than classic theories suggested. For example, Part I of the present thesis showed diverging effects of positive affect with low or high arousal, and Part II revealed that positive affect specifically modulates proactive control, whereas no impact on reactive control was found. Further investigations regarding the specificity of positive affect effects would be helpful for clarifying underlying mechanisms and updating of existing theories. (2) Furthermore, positive affect per se seems to be much more specific than previously thought as can be seen in the oppositional effects of positive affect and reward (see short review above), or in mixed results associated with different affect induction procedures (cf., chapter 5.1.). Therefore, it would be another interesting and important prospective line of research to further specify and clarify the concept of positive affect. (3) And, last but not least, it would be most interesting as well as highly desirable to gain further insight into the functionality of positive affect, since even ostensible behavioral costs – like the increased novelty bias found in Part III – can turn out to be of adaptive value on closer inspection (see chapter 5.3.).

CHAPTER 6 Conclusion

Results from the present thesis revealed that the hypothesis of increased cognitive flexibility under positive affect (cf., Ashby et al., 1999; Ashby et al., 2002) oversimplifies the modulatory influence of positive affect on cognitive control: First of all, in line with Russell's circumplex model of affect (1980), research on positive affect should always consider both dimensions of affect – namely, valence *and* arousal – as the present studies repeatedly showed diverging effects of positive affect with low or high arousal levels. Second, differentiating between proactive and reactive control (Braver, 2012; Braver, Gray, & Burgess, 2007) resulted in the new finding that positive affect specifically modulates *proactive* control. More precisely, positive affect with low arousal reduced proactive control, while positive affect with high arousal seems to increase proactive control. That is, specifically low arousing positive affect increases flexibility in form of an enhanced independence from context information. Finally, fitting with current theories on cognitive control (cf., Braver, 2012; Braver, Gray, & Burgess, 2007; Goschke, 2003), the present thesis showed that this increased flexibility under low arousing positive affect is associated with behavioral costs in form of increased distractibility, especially towards new events. In sum, these specific modulations of cognitive control endorse existing theories on the functionality of positive affect (cf., Carver, 2003; Fredrickson, 1998; Schwarz, 1990, 2012): Therein, positive affect is assumed to support adaptive behavior in a constantly changing environment by increasing flexibility and susceptibility towards new events, which facilitates the utilization of unforeseen opportunities.

CHAPTER 7 References

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CHAPTER 8 Appendix

8.1. Appendix A

Overview of the selection of IAPS pictures used for affect manipulation in the present studies.

Table A1. Numbers of selected IAPS pictures used in Experiments 1 to 6.

	Affect group				
	neutral	**positive$_{low}$**	**positive$_{high}$**	**negative$_{high}$**	**neutral$_2$**
IAPS-No.	7000	1440	5260	2800	1390
	7004	1710	5621	3030	1560
	7006	1750	5623	3064	1616
	7009	1920	5626	3071	1945
	7035	2057	5629	3100	2200
	7040	2150	8161	3110	2372
	7080	2260	8180	3120	2410
	7090	2311	8190	9433	2575
	7175	2340	8200	9570	5395
	7233	2530	8490	9571	5535

Note. neutral$_2$ = alternative neutral affect picture set used in Experiment 6, which was matched to the positive$_{low}$ set in arousal levels as well as in number of pictures depicting animals

8.2. Appendix B

Results of the speed-accuracy analysis for RTs and error rates of Experiment 5.

Table B1. Individual correlations between RTs and error rates for trials with global or local targets in the cued global-local task of Experiment 5.

Subject	***r***
1	.346
2	.192
3	.716*
4	.058
5	.820**
6	.072
7	.582
8	-.550
9	.320
10	.494
11	.442
12	-.344
13	-.511
14	-.643*
15	.161
16	.558
17	-.302
18	.842**
19	-.595
20	.535
21	.110
22	.718*
23	.287
24	-.357
25	.371
26	–[a]
27	.667*
28	-.303
29	-.358
30	.215

Note. *r* = Pearson product-moment correlation coefficient for corresponding pairs of mean RTs and error rates (as a factor of Affect, Cue validity, and Target type)

[a] No correlation coefficient could be calculated for Subject 26, because this participant did not commit errors in any factor combination.

* $p < .05$, one-tailed. ** $p < .01$, one-tailed.

8.3. Appendix C

Descriptive and inferential statistics for RT and error rates analyses of Experiment 6 including the entire sample of 48 participants (24 in neutral, 24 in positive affect group).

Table C1. Mean RTs (in ms) and error rates (in %) in the word-picture interference task of Experiment 6 (SD in parentheses) as a factor of Affect group, Distractor type, and Distractor compatibility.

	Affect group			
	neutral		**positive**	
Distractor	**familiar**	**new**	**familiar**	**new**
		RT (SD)		
compatible	561 (60.6)	619 (88.3)	561 (73.0)	650 (134.5)
incompatible	579 (66.8)	629 (87.2)	588 (96.7)	654 (110.4)
		Errors (SD)		
compatible	2.95 (2.94)	4.16 (5.49)	3.2 (2.17)	3.82 (7.37)
incompatible	4.63 (3.52)	2.77 (4.7)	5.14 (2.47)	4.16 (5.49)

Table C2. ANOVA results for RT data as a factor of Affect group, Distractor type, and Distractor compatibility.

Source	***dfs***	***F***	***p***	η_p^2
		Main effects		
		between		
Affect (A)	1, 46	0.47	.498	.01
		within		
Distractor type (T)	1, 46	78.22	< .001	.63
Distractor compatibility (C)	1, 46	5.49	< .05	.107
		Interactions		
A x T	1, 46	2.52	.119	.052
A x C	1, 46	0.01	.924	< .001
T x C	1, 46	1.31	.258	.028
A x T x C	1, 46	0.37	.546	.008

Table C2. ANOVA results for error rates data as a factor of Affect group, Distractor type, and Distractor compatibility.

Source	***dfs***	***F***	***p***	η_p^2
		Main effects		
		between		
Affect (A)	1, 46	0.22	.647	.005
		within		
Distractor type (T)	1, 46	0.18	.675	.004
Distractor compatibility (C)	1, 46	2.22	.143	.046
		Interactions		
A x T	1, 46	0.02	.903	< .001
A x C	1, 46	1.32	.257	.028
T x C	1, 46	5.08	< .05	.099
A x T x C	1, 46	0.5	.483	.011