The Influence of Emotions on Cognitive Flexibility

by

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Note

Chapter 3 was co-authored with Professor Richard Gonzalez.

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Chapter I

Introduction

Cognitive flexibility is important for creativity, for learning when reward contingencies change, and for redirecting our attention. Previous research has shown that creative behavior improves with positive mood, but researchers disagree about whether other behaviors under the umbrella term "cognitive flexibility" are similarly facilitated. Also, the outcomes of positive mood might depend on the particular positive emotion. In my dissertation research, I contribute to the current debate on this issue by assessing which emotional states influence which types of cognitive flexibility, and why.

I focus on the distinction between associative, regulative, and attentional flexibility. Breaking the set of typical associations and creating new associations is called associative flexibility. Associative flexibility underlies creative performance in idea generation and enhances inclusiveness in categorization tasks. Regulative flexibility is an executive function, and is important when people need to deal with changing rules and reward contingencies. It refers to the ability to identify and adjust to different contingencies. Attentional flexibility is the ability to switch attention between different types of tasks, or between different stimulus features. Other types of cognitive flexibility are not the topic of the dissertation; for example, flexibility can refer to evaluative flexibility (the ease of re-evaluating something), spatial flexibility (the ease of re-constructing a spatial configuration), or temporal flexibility (e.g., variability in rhythm).

Studies in social psychology have typically used associative flexibility tasks to measure cognitive flexibility. For example, ”[f]lexibility as a measure of creativity manifests itself in the use of different cognitive categories and perspectives and of broad and inclusive cognitive categories” (De Dreu, Baas, & Nijstad, 2008, p. 740). Similarly, “creativity, remote associations, perceptions of relatedness among cognitions . . . [are seen as] indications of integration and cognitive flexibility (Isen, 1990, p. 80). A typical finding is that positive emotions improve performance (e.g., Isen and colleagues). For example, positive affect increases fluency in idea generation (e.g., Isen, Labroo, & Durlach, 2004; Murray, Sujan, Hirt, & Sujan, 1990). Also, positive affect increases the number of items included in a category and the variety of elements chosen as acceptable category members (e.g., Isen & Daubman, 1984).

However, in other areas of psychology, such as cognitive psychology, cognitive neuroscience, and psychiatry, ‘flexibility’ more often refers to attentional and regulative flexibility. For example, a study title reads “Shifting set about task switching: Behavioral and neural evidence for distinct forms of cognitive flexibility” (Ravizza & Carter, 2008). Also, flexibility impairments in schizophrenia are assessed as attentional flexibility (e.g., Morice, 1990). Similarly, in “a developmental study of cognitive flexibility,” flexibility is assessed in set shifting (Crone, Ridderinkhof, Worm, Somsen, & Molen, 2004). Others assess regulative flexibility with a reversal learning paradigm (Fellows & Farah, 2003).

Mixed effects for the influence of emotions on attentional flexibility have been found. For example, positive affect facilitates switching attention to novel stimuli, but impairs switching attention to stimuli that were previously ignored (e.g., Dreisbach & Goschke, 2004). Also, happiness impairs performance in a switching Stroop task (Phillips, Bull, Adams, & Fraser, 2002). The discrepancy in the application of the term 'flexibility,' and the discrepancy in the findings regarding the influence of emotions on flexibility need to be resolved with a theory that can integrate the research findings from the different literatures.

The goals of this research are to (a) review the influence of positive and negative emotions on associative flexibility, (b) examine how different positive emotions influence regulative and attentional flexibility, and (c) identify mediator variables. The dissertation will contribute to the literature by integrating methods from social and cognitive psychology, by examining the influence of different positive and negative emotions on different types of cognitive flexibility, and by investigating underlying mechanisms for this influence.

The influence of emotions on associative, regulative, and attentional flexibility is examined in three papers. In chapter 2, the influence of emotions on associative flexibility is reviewed meta-analytically (goal a). In chapter 3, the influence of different positive and negative emotions on regulative flexibility is assessed with an experiment (goal b). The effect of different positive emotions on associative, regulative, and attentional flexibility are assessed simultaneously in study 1 of chapter 4 (goals a and b). Study 2 of chapter 4 examines the underlying mechanisms for the findings of chapter 3 (goal c).

More specifically, in chapter 2 the influence of emotions on associative flexibility is reviewed meta-analytically. A relatively large body of experimental studies indicates that, overall, positive affect increases associative flexibility (Baas, De Dreu, & Nijstad, 2008; Davis, 2009). For example, positive compared to neutral affect increases breadth of categorization (e.g., Isen & Daubman, 1984). The effects of negative affect on associative flexibility are varied and sometimes do not differ from control conditions (Baas et al., 2008; Davis, 2009). Given the large body of research, a meta-analysis is used to review the behavioral effects of positive and negative emotions on idea generation and categorization, and to identify moderator variables.

In chapter 3, the influence of different positive and negative emotions on regulative flexibility is assessed. Research on the influence of emotions on regulative flexibility is less developed than research on associative flexibility. To our knowledge, no study has examined the importance of affective states for learning changes in reward contingencies. Therefore, the influence of different positive and negative emotions on reversal learning is assessed with a Reversal Learning task.

While the review of previous research in chapter 2 and the results from chapter 3, jointly suggest that happiness overall improves associative flexibility and reduces regulative flexibility, the simultaneous assessment of both types of flexibility is necessary to rule out confounding factors. A within-subjects design with associative and regulative flexibility has the additional benefit that it can provide specific insights. For example, does happiness improve associative flexibility and reduce regulative flexibility merely on a group level, or do individuals show negative correlations between those types of flexibility? Also, are the effects of emotions stronger for one type of flexibility than for the other? These questions are answered in study 1 of chapter 4, in which the effects of different positive emotions on associative and regulative flexibility are assessed simultaneously.

Study 1 of chapter 4 also assesses the influence of emotions on attentional flexibility. Several studies have compared the influence of positive and negative emotions on tasks that require the switching of attention and found mixed results that depend on the specific design of the task. For example, positive affect impairs performance in switching to inhibited stimuli, but switching to novel stimuli is improved under positive affect (Dreisbach & Goschke, 2004). Chapter 4 adds to this literature by examining the influence of emotions on attentional flexibility in a California Card Sorting Test (Delis, Squire, Bihrle, & Massman, 1992).

A valid concern is that the complexity of findings reported in chapters 2 and 3 cannot be encompassed by a simple a priori explanation. In an attempt to increase parsimony and directly test explanations, study 2 of chapter 4 examines underlying mechanisms for the findings of chapter 3. Previous research suggests that associative flexibility is improved due to increases in global processing (e.g., Isen, 1999). In study 2 of chapter 4, I examine whether global processing matters for regulative flexibility. Also, given that reduced goal maintenance has been associated with positive affect (Dreisbach, 2006), I examine the importance of goal maintenance for performance in regulative flexibility.

In the experimental research reviewed and conducted in this dissertation, the effect of emotions on performance in a subsequent situation is assessed. Because the emotions are aroused prior to the performance situation and are not an integral part of it, they are called incidental emotions (as opposed to integral emotions; Bodenhausen, 1993). Emotions can be defined as a syndrome of a subjective feeling (e.g., pleasant, aroused), a judgment about the situation (e.g., you are responsible), behavioral tendencies that encompass cognition (e.g., global versus local; flexible versus inflexible) and action (e.g., approaching versus avoiding), physiological changes (e.g., heart rate), and sometimes an emotion label (e.g., happy). Compared to moods, emotions typically are elicited by a specific event and are short-lived. This poses a problem in experimental designs where multiple tasks are used to measure cognitive flexibility, because emotions might vanish before the task is administered. In chapters 3 and 4, emotions are therefore aroused twice within the experimental session.

With its goals and findings, the dissertation can be perceived as a critical analysis of the statement that it "is now well recognized that positive affect leads to greater cognitive flexibility and facilitates creative problem solving across a broad range of settings" (Ashby, Isen, Turken, 1999, p. 530) with regard to four aspects: First, the validity of the statement in its explicit sense is examined by reviewing existing research on the influence of positive emotions on flexibility in the creativity domain. Second, the implied consequence that negative emotions reduce flexibility is assessed. Third, the generalizability of the statement to all positive emotions is called into question. Finally, the generalizability of the statement to different types of flexibility is examined. However, I want to emphasize that the criticism generated in this dissertation only refers to the specific claim. The findings are not a critique of the scholarship of researchers working in this domain (e.g., Ashby et al., 1999), who carefully acknowledge the limitations of our current knowledge and suggest testing the validity and limitations of their theories, thereby inspiring others like me.

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Chapter 2

A Meta-Analysis of Positive and Negative Emotions' Impact on Cognitive Breadth

Past research shows that positive emotions often increase the number and the unusualness of ideas, and the elements included in a category. The underlying cognitive tendency has been called 'flexibility' or 'cognitive breadth' (Ashby, Isen, & Turken, 1999; Fredrickson, 1998). If happiness leads to thriving in various domains, such as idea generation, social relationships, and health (e.g., Lyubomirsky, King, & Diener, 2005), it is tempting to conclude that *the more* positive affect is experienced, *the more* inventiveness, friends, and vitality will be gained. Likewise, although few positive psychologists explicitly discuss the outcomes of negative emotions, it is implied that negative emotions will narrow the chances for success. However, the outcomes of positive and negative emotions do not necessarily lie on a single continuum. Positive psychologists are often unclear about these issues, despite empirical evidence that requires clarification, and despite grounding positive psychology on the premise that the outcomes of positive and negative emotions are not mere opposites of each other (Seligman, 2003).

To investigate whether negative emotions have the opposite effect of positive emotions, the current study explicitly compares the effects of positive, neutral, and negative emotions on categorization and idea generation. Given the large body of research, a meta-analysis will be used to review the behavioral effects of positive and negative emotions on flexibility in idea generation and categorization. A second goal of the study is to identify moderators in the relationship between emotion and associative flexibility.

In the experimental research reviewed in this paper, the effect of emotions on performance in a subsequent situation is assessed. Because the emotions are aroused prior to the performance situation and are not an integral part of it, they are called incidental emotions (as opposed to integral emotions; Bodenhausen, 1993). Emotions can be defined as a syndrome of a subjective feeling (e.g., pleasant, aroused), a judgment about the situation (e.g., you are responsible), behavioral tendencies that encompass cognition (e.g., global versus local; flexible versus inflexible) and action (e.g., approaching versus avoiding), physiological changes (e.g., heart rate), and sometimes an emotion label (e.g., happy). Compared to moods, emotions typically are elicited by a specific event and are short-lived. Although in experimental research, emotions are aroused by a specific event (the experimental manipulation), the affective state is often not well differentiated in studies comparing general positive to negative affect. Therefore, the boundary of emotion and mood is somewhat blurry, and some researchers refer to the manipulated state as a mood state (e.g., Bohner & Schwarz, 1993).

The findings of a meta-analysis always depend on the aggregation of dependent variables. In previous meta-analysis on the effect of emotions on creativity, categorization tasks have been clustered in different ways; either together with idea generation and remote associate tasks in a cluster of ideation tasks (Davis, 2009), or with the flexibility component of idea generation tasks and with switch tasks as a cluster of flexibility tasks (Baas, De Dreu, & Nijstad, 2008). For the contrast of positive with negative emotions, these two types of study have found different overall effects; more specifically, for the first cluster, positive emotions increased performance compared to negative emotions, but for the second cluster, positive and negative emotions did not differ. The current meta-analysis investigates the influence of emotions across categorization and idea generation tasks, and distinguishes between the quantity and quality of ideas and category members. Also, the current meta-analysis investigates task difficulty as a moderator variable that has not been examined in previous quantitative literature reviews.

The Positivity Bias

In the current literature, the effects of positive emotions are often cited without discussing the influence of negative emotions, resulting in a biased perception of the influence of negative emotions. An example is the discussion of the findings by Isen and Daubman (1984) with 240 citations (ISI Web of Science, Sep. 15 2007). The paper presents three studies in which positive emotions lead to broader categories. In studies 1 and 2, category breadth is assessed qualitatively by asking participants to rate the extent to which unusual elements are category members. The results show that happy participants are more likely to include unusual elements in a category. In study 3, quantitative category breadth is assessed by counting the number of categories built from a fixed number of elements. Again, positive emotions result in broader categories. However, in all three studies, negative emotions also show a non-significant tendency to increase category breadth. Although Isen and Daubman (1984) thoroughly discuss the findings for negative emotions, later citations often fail to mention negative affect and focus exclusively on the broadening effect of positive emotions on categorization (e.g., Fredrickson, 1998; Friedman & Förster, 2005; Isen & Baron, 1991). The reader is left with the idea that the happier one is, the more creative one will be, and the sadder one is, the less creative.

A meta-analysis by Lyubomirsky and colleagues (2005) promotes a similar message. Analyzing cross-sectional, longitudinal, and experimental studies, the authors conclude that positive affect increases sociability and activity, altruism, liking of self and others, strong bodies and immune systems, and effective conflict resolution skills. Of particular relevance for this paper is the impact of emotions on original thinking, which includes idea generation, categorization, and creative insight tasks. The report only provides a qualitative assessment of the homogeneity of the effect sizes for originality. Although the authors state that "occasionally, people in a sad mood are also more original than those in a neutral mood" (p. 838), they later conclude that the "evidence is weaker [than for sociability and activity, altruism, liking of self and others, immune system, and effective conflict resolution], but still consistent, that pleasant moods promote original thinking" (p. 840).

The implication is that the happier one is, the more cognitive flexibility will result, and the more unhappy one is, the less flexibility occurs. However, this conclusion is not justified for several reasons. Theoretically, the outcomes of positive and negative emotions do not necessarily lie on the ends of one continuum. In fact, many positive psychologists claim that the study of positive aspects of life is different from the mere absence of negative outcomes, and requires unique theoretical and empirical work (Gable & Haidt, 2005; Seligman, 2003). Thus, from a claim that positive emotions increase cognitive breadth, it does not necessarily follow that negative emotions decrease cognitive breadth. Indeed, some studies find that negative emotions are associated with creativity (e.g., Adaman & Blaney, 1995; Goerge & Zhou, 2002). The current study examines whether negative emotions have a narrowing effect by comparing the effects of positive, neutral, as well as negative emotions.

Theoretical Predictions

Theoretical explanations for the effects of moods on cognition differ in the degree to which they distinguish between effects of positive and negative emotions. I will review the Affect as Information Model, the Mood as Input Model, the Mood Behavior Model, the Broaden and Build Theory, and the Dopaminergic Model.

According to the Affect as Information Model (Schwarz & Clore, 1983; 2007) feelings can have informational value. They signal whether a situation is benign or problematic. The organism has developed processing patterns that match the requirements of the situation. Problematic situations require a careful analysis of the situation resulting in analytic, detailed, and local processing. For benign situations, individuals can use the dominant strategy that has served them well in the past. As a result, people apply heuristics and top-down processing, and process information globally and broadly, thereby increasing creativity. The prediction is that overall, positive affect increases idea generation and categorization.

The Mood as Input Model (Martin, Ward, Achee, & Wyer, 1993) incorporates an affect as information approach (Schwarz & Clore, 1983; 2007) by predicting that affect can be used as information about a situation. Furthermore, the type of judgment influenced depends on the context. For example, mood can be used to evaluate task performance or task enjoyment. More specifically, when using mood as information about task performance, positive mood can signal success, which will result in spending less effort than when positive mood is used as information about enjoyment. These judgments affect perseverance on tasks such as idea generation (Martin et al., 1993). It is not clear whether the effect for task perseverance can be generalized to other kinds of performance. However, a larger number of ideas and more time spent on the task may increase the likelihood of creative ideas (De Dreu, Baas, & Nijstad, 2008). The model suggests that performance goals moderate the influence of positive and negative emotions on idea generation and categorization.

Another model that integrates the affect as information logic is the Mood Behavior Model (Gendolla, 2000). The model examines the motivating aspects of mood. Mood can lead to mood-repair when individuals feel the need to change their mood and when instrumental behavior is available and appropriate. Independent of this directive influence of mood, mood can be used as information that influences associations and cognitive processing. With no performance standard, previous research suggests that individuals use their mood to infer how pleasant rather than how successful task performance is, and positive mood increases performance (Gendolla & Brinkman, 2005). The model emphasizes that mood is but one piece of information about a situation. Information given by the task itself, for example, about how difficult it is or via direct performance feedback, can reduce the effect of mood as information. Thus, the difficulty of a task should moderate the informational value of mood. High task difficulty reduces the informational value of mood and thus its effect, and low task difficulty leaves room for emotional influences on thinking. In the following discussion, the prediction is that task difficulty moderates the effects of emotions on performance, resulting in no difference between positive and negative emotions with difficult tasks, and better performance with positive affect and easy tasks.

An alternative explanation for the moderating role of task difficulty exists. Difficult tasks might reduce positive mood. This may reduce the difference between positive and negative emotion groups. As a result, the influence of positive emotions may differ little from other emotions. However, with easy tasks, no prediction concerning the direction of mood effects can be derived from this perspective, whereas the Mood Behavior Model suggests that in this case, positive mood increases performance (Gendolla & Brinkman, 2005).

Although the predictions derived from the affect as information logic are often similar to the predictions based on the following two models, the underlying explanations are quite different. The starting point for the Broaden and Build Theory (Fredrickson, 1998) is that due to evolutionary pressures, negative emotions are associated with specific and narrow thought-action repertoires (Frijda, 1986). However, positive emotions cannot as easily be matched with specific behaviors (Frijda, 1986). Whereas the actions associated with negative emotions seem to have immediate evolutionary benefits (e.g., spitting something out in disgust), the evolutionary advantages of positive emotions are less proximal. Positive emotions are good, according to the theory, because they broaden thought-action repertoires leading to exploration, openness to novel things, and play. As a result of exploration, individuals acquire physical, social, and other resources. The experience of positive emotions, as well as the resources acquired through the associated broad thought-action repertoires, makes individuals happier, healthier, more creative, and better at recuperating. Creativity is seen as a result of broad thought repertoires, a tendency to explore, and general openness to the unusual. In contrast to positive emotions, negative emotions are expected to narrow cognitive breadth (Fredrickson & Branigan, 2005). Thus, the predictions are similar to the ones from the Affect as Information Model: Positive affect increases cognitive breadth, and negative affect decreases breadth.

Ashby, Isen, and Turken (1999) suggest that mediated by increased levels of dopamine in the frontal cortex and the anterior cingulate cortex, positive affect increases flexibility and creativity. The Dopaminergic Model thus makes a similar prediction like the previously reviewed models that positive affect increases idea generation and categorization. However, no predictions are made for negative affect.

The goal of this meta-analysis is to determine whether negative emotions narrow cognitive breadth. Alternatively, negative emotions might broaden idea generation and category breadth, or have no impact on cognitive breadth. To summarize, according to the Affect as Information model, the Mood as Input Model, the Mood Behavior Model, the Broaden and Build Theory, and the Dopaminergic Model, positive affect increases idea generation and categorization. Apart from the latter model, the models also predict that negative emotions will decrease idea generation and categorization. According to the Mood as Input Model and the Mood Behavior Model, the effects of positive and negative emotions may depend on salient goals and task difficulty: Performance goals will increase performance under negative mood, and pleasure goals increase performance under positive mood. Furthermore, with easy tasks, the outcomes of positive and negative emotions may differ more than with difficult tasks.

Method

Isen and Daubman's 1984 article "The influence of affect on categorization" is a key paper in the area of emotional impacts on cognitive breadth. I searched the ISI Web of Science's data base for papers that cited this key article between 1984 and Sept. 15, 2007 to gather research reports for this meta-analysis. I read the titles, abstracts, and – if necessary – the method section of the resulting 240 papers to identify relevant articles. Using the Thesaurus option with 'Emotional States' and 'Classification, Cognitive Process' as search terms, I searched for additional relevant reports in the database of PsycInfo (1900 – Sept. 15, 2007). Finally, I followed references in articles to find still more papers on the topic.

Un-published studies were not considered, and thus the estimated average effect size might over-estimate the effect of emotions on cognition. Thus, conclusions about the magnitude of the estimated effects should be drawn with caution. However, the bias should not interfere with findings about the direction of the effects of positive and negative emotion on cognitive breadth.

Experimental studies in which at least two out of three affective states (positive, neutral, negative) were aroused in healthy, human adults in a between subjects design were considered. In the majority of reports, positive and negative emotions were not further specified, but some studies aroused particular emotions (e.g., sadness and happiness; Bohner & Schwarz, 1993). Positive and negative emotions have been aroused in multiple ways, for example by watching movie clips (e.g., Fredrickson & Branigan, 2005; Isen, Daubman, & Nowicki, 1987), reading statements (Hirt et al., 1996), receiving small gifts (Isen & Daubman, 1984), or hearing positive feedback (Isen & Baron, 1991).

Westermann, Spies, Stahl, and Hesse (1995) describe the occurrence and success of various emotion induction procedures meta-analytically. Table 2.1 provides on overview of the type of emotion and the emotion inductions in the studies analyzed in this paper. In the majority of comparisons, the neutral control group also received a treatment.

Studies only needed to have one of the outcome variables of interest. Some of the studies (categorization studies) required participants to categorize elements into groups or to rate whether or how well unusual elements belong to a group (e.g., Isen & Daubman, 1984). In other studies, participants generated ideas, which could be counted and analyzed for the proportion of unusual ideas (idea generation studies; e.g., Hirt, Melton, McDonald, & Harackiewicz, 1996). In past research, in both categorization studies and idea generation studies, cognitive breadth has been assessed quantitatively (how many elements per category or how many ideas) and qualitatively (how unusual are the elements in a category or the ideas). The unusualness of ideas or category elements was determined by researcher ratings, based on pre-tests, past research, or computations from the sample. Table 2.1 provides information for the distribution of outcome variables across comparisons and reports.

Categorization and idea generation are related to research on creativity more broadly. However, this analysis was specific to idea generation and categorization, and did not include studies of creativity tasks in general, such as Duncker's candle task (1945), or studies with remote associates tasks. Solutions in the latter tasks are either correct or incorrect, so that it is not possible to differentiate between the quality and quantity of responses. Also, studies of social categorization / stereotyping were not examined. Social categorization tasks are different form nonsocial categorization because of the valence of category elements (e.g., traits; Isen, Niedenthal, & Cantor, 1992), whereas in non-social categorization tasks the elements are typically neutral in valence (e.g., furniture; Isen & Daubman, 1984).

A sample of 20 studies published in the English language resulted from these efforts. Two articles were dropped, because the measurements of cognitive breadth were not sufficiently similar to the rest of the sample. Specifically, Ramon, Doran, and Faust (2007) measured reaction times to unusual category members. In this study, no significant differences were found between positive and neutral, and neutral and negative emotion groups. A second article (Conway & Hassebrauck, 1997) assessed cognitive breadth only as the number of categories built from a given set of elements instead of the number of elements integrated into one category. Here, positive emotions resulted in fewer categories than either neutral or negative emotions. Thus, a total of 18 reports containing 25 studies and 68 comparisons are analyzed in this meta-analysis. The majority of the studies had college students as the sample (see table 2.1). The median publication year was 1996 (1984, 2007).

To investigate potential moderators for the relationship between emotion and cognition, performance goals were coded in 5 categories: As ‘no goal,’ ‘achieve a self-set goal,’ ‘do enough,’ ‘do one’s best,’ and ‘do as long as you enjoy.’ For example, a ‘do one’s best goal’ was indicated when participants were instructed to ask themselves “Have I generated as many uses as I can?” and a ‘do as long as you enjoy’ goal when participants were instructed to ask themselves “Do I feel like continuing with this task?” (Martin et al., 1993; Sanna, Turley, & Mark, 1996).

Task difficulty was coded on a 3-point scale. In idea generation, low difficulty was coded when participants were asked to freely associate given a cue (e.g., the letter 'H;' Isen, Labroo, & Durlach, 2004), medium difficulty when they had to create a list according to a topic (e.g., things that fly; Gasper, 2004), and high difficulty when a text had to be created (e.g., an argument; Bohner & Schwarz, 1993). In categorization tasks, low difficulty was coded when both categories and exemplars were given and had to be sorted (e.g., Isen & Daubman, 1984), medium difficulty was coded when either categories or exemplars had to be created (e.g., creation of groups of similar TV shows; Murray, Sujan, Hirt, & Sujan, 1990), and high difficulty when both had to be created. The distribution of goals across samples and reports is given in Table 2.1.

All possible emotion group comparisons were performed: Positive versus neutral, neutral versus negative, and positive versus negative. Not all effect sizes are independent of each other, because 7 reports - which contributed 57% of all comparisons - contained 3 emotion groups.

Average effect sizes were estimated as Hedges g, an unbiased estimate, with the Comprehensive Meta-Analysis program. For studies that did not report sufficient statistics, several estimations were performed. Sample size was estimated by dividing the total sample by number of groups. Standard deviations were estimated using the information from F-tests or t-tests. For one positive-neutral emotion comparison (Barone, 2005, study 1), no standard deviation could be estimated in this way. As the author did not respond to an email inquiry, the standard deviations were estimated by taking the average of four standard deviations provided by Barone, Miniard, and Romeo (2000). Here, in two studies, positive and neutral emotions were aroused and their effect was measured with the same task, and yielding similar means, as in Barone (2005). The four standard deviations reported in Barone et al. (2000) have a small range (0.98, 1.2), so that I feel quite confident about this estimation procedure.

Results

As the effect of emotions on quantitative cognitive breadth can be quite different from qualitative breadth (Gasper, 2004; Hirt, Levine, McDonald, Melton, & Martin, 1997), the total sample of comparisons is split into those concerning the number of ideas generated and those concerning the unusualness of ideas and category elements.

The effects of positive, neutral, and negative emotions on quantitative cognitive breadth do not seem to stem from the same population, as the normal quantile-quantile plot, a plot of estimated versus actual data points that should result in a straight line if the sample stems from one normal distribution, shows deviations from a straight line and several comparisons that are outside the 95% confidence interval band (Figure 2.1). By splitting the comparisons into the different emotion group comparisons – positive-neutral, neutral-negative, and positive-negative – the distributions become somewhat closer to a normal distribution (Figures 2.2 – 2.4). The estimated effect sizes for quantitative cognitive breadth for each comparison can be seen in Table 2.2.

A meta-analysis of the effect of emotions on the numbers of ideas generated was first conducted on 14 comparisons of positive emotions with neutral emotions. The homogeneity test for a fixed effects model was significant, suggesting that the effects were heterogeneous and should be combined using a random effects model, Q (13) = 251.37, $p < .001$. Compared to neutral emotions, people in positive emotions generated more ideas and showed a propensity to include more elements into a category, $g_+ = 0.72$,

p = .04 (95% confidence interval [CI] = 0.02, 1.41 for a random effects model). The results of a fixed effects model are provided in Table 2.3. Boxplots of the standardized mean differences for each emotion group comparison are shown in Figure 2.5. Five outliers are visible, but they do not skew the results (see Table 2.3).

Combining the effects for a comparison of neutral with negative emotions, again, seems only possible in a random effects model, as the effects are not homogeneous, Q (9) = 232.58, $p < .001$. According to the Broaden and Build Theory of positive emotions, we would expect the average effect size to be positive. However, the average effect size is negative, $g_+ = -0.15$ (95% CI = -1.14, 0.85; random effects model), and the confidence interval includes zero. I paid special attention to the effect of one comparison for neutral versus negative emotions on quantitative cognitive breadth, because the boxplot (Figure 2.5) indicates an outlier on one side of the distribution, which might skew the results. Removing this outlier changes the direction of the effect size ($g_+ = 0.29$), but the confidence interval for the random effects model still includes zero (see Table 2.3). It seems that negative emotions do not necessarily reduce the number of ideas.

The question remains whether positive and negative emotions differ in their likelihood of increasing cognitive breadth. 17 comparisons of positive and negative emotions show an average effect size of $g_+ = 0.35$ (95% CI = -0.53, 1.24; random effects model). Again, this effect size is not homogeneous, Q (16) = 533.99, $p < .001$, suggesting that the effects should not be combined other than in a random effects model. Excluding two outliers based on the boxplot (Figure 2.5) does not change this result (Table 2.3). According to this analysis, negative emotions can broaden cognitive breadth as much as positive emotions.

All previous effects were heterogeneous, and it is possible to identify a moderator in the relationship between emotions and quantitative cognitive breadth. According to the Mood as Input Model (e.g., Martin et al., 1993), emotions should have different effects on performance, depending on how they are interpreted in the situation. According to the Mood as Input Model, doing one's best should result in a better performance with negative emotions, and doing as long as one enjoys the task should result in more ideas with positive emotions. Table 2.4 provides an overview of the results for each emotion group comparison and all emotion groups combined.

For positive compared to neutral emotions, performance goals only marginally moderated the positive average effect, Q (4) = 8.17, p = .09 (mixed effects model), and did not entirely reduce the heterogeneity in the effect size sample. Performance goals to 'do one's best,' or to 'do enough' yield negative effect sizes (g_+s = -0.89, -0.21, respectively) and to 'achieve a self-set goal,' 'no goal' or to 'do as long as you enjoy' or resulted in positive effect sizes (g_+s = 0.31, 0.69, 3.18, respectively).

For neutral compared to negative emotions, performance goals were a significant moderator, Q (4) = 9.88, p = .04 (mixed effects model). Although performance goals did not entirely explain the heterogeneity in the sample, goals to 'do one's best,' to 'do enough,' or to 'achieve a self-set goal' resulted in negative effect sizes (g_+s = -2.31 , -0.18, -1.05 respectively), and 'no goal' as well as 'do as long as you enjoy' in positive effect sizes (g_+s = 0.33, 1.44 respectively).

The results are similar for the comparison of positive and negative emotions. Performance goals do not entirely reduce the heterogeneity in the sample, but they significantly predict some of the variance, Q (4) = 21.87, p < .001 (mixed effects model).

Again, performance goals to ‘do one’s best,’ to ‘do enough,’ or to ‘achieve a self-set goal’ result in negative effect sizes (g_+s = -2.97, -1.78, -0.74, respectively), and ‘no goal’ as well as to ‘do as long as you enjoy’ resulted in positive effects (g_+s = 0.42, 4.17, respectively). The results do not change when one study at a time is removed, as seen in Figure 2.6.

As the results differ little across emotion group comparisons – positive/neutral, neutral/negative, and positive/negative – they can be combined (see Figure 2.7). Overall, performance goals significantly moderate the relationship between emotion and idea generation, Q (4) = 37.38, $p < .001$. The effect for ‘do best’ is g_+ = -2.16 (95% CI = -3.97, -0.36), for ‘do enough’ is g_+ = -0.88 (95% CI = -1.85, 0.10) and for ‘achieve a specific number’ is g_+ = -0.49 (95% CI = -1.30, 0.33). The effect sizes for ‘no goal’ is g_+ = 0.52 (95% CI = 0.06, 0.98) and for the goal ‘do as long as you enjoy’ is g_+ = 3.19 (95% CI = 1.93, 4.45). The motivation to do well increases idea generation with negative emotions. When enjoyment goals are salient or no goals are specified, positive affect results in more cognitive breadth. Yet a significant amount of heterogeneity remains in the sample. Unfortunately, task difficulty does not vary across the studies, and so its effect as a moderator cannot be examined.

To summarize the findings for quantitative cognitive breadth, the effect sizes of positive, neutral, and negative emotions on quantitative cognitive breadth are quite heterogeneous. This means that the influence of emotions on cognitive breadth is influenced by other variables. Not all of the heterogeneity can be explained by taking performance goals as a moderator into account. When the enjoyment of a task is the goal, positive emotions increase cognitive breadth more than neutral or negative emotions.

However, when high performance is the goal, negative emotions result in more creativity. This finding is robust to removing one study at a time. Accounting for the heterogeneity in a random effects model shows that positive emotions increase cognitive breadth compared to neutral emotions. Negative emotions, however, do not necessarily reduce quantitative idea generation performance.

For qualitative cognitive breadth, the distribution of the effect sizes is more normal than seen with the previous effects (Figure 2.8). The distribution has several bumps. For easy comparison to the previous results, the sample is split into three emotion group comparisons. The distribution of the effects for each particular emotion group comparison - similar to the effects of all three emotion group comparisons combined - on qualitative cognitive breadth seem normal, but have outliers and are bumpy (Figures 1.9 – 1.11), which indicates that important moderators might impact the effects. However, the sample size for the comparison of neutral versus negative, and positive versus negative are quite small, so conclusions must be drawn with caution. The effect size estimates for qualitative cognitive breadth are provided in Table 2.5.

To test the effect of positive compared to neutral emotions on unusualness of subjects' responses, a meta-analysis was conducted on 17 comparisons. Compared to neutral emotions, people experiencing positive emotions generated more unusual ideas, and showed a propensity to include unusual elements as category members, $g_{+} = 0.55$, $p < .001$ (95% CI = 0.44, 0.66, fixed effects model). The homogeneity test was nonsignificant, suggesting that the effects were homogeneous and could be combined, $Q(16) = 23.51$, $p = .10$. Table 2.6 shows that the results for a random effects model would be similar. A boxplot shows the distribution of the effect sizes for this and the following two emotion group comparisons (Figure 2.12). The results do not change if one study at a time is removed from the analysis (Figure 2.13).

Implied in past research is the idea that the more positive the feeling, the more creative the ideas and the more inclusive the categories. However, the average effect size of 4 studies comparing neutral and negative emotions is, similar to the findings for quantity of cognitive breadth, negative with $g_+ = -0.34$ (95% CI = -.59, -0.09; fixed effects model) and homogeneous, Q (3) = 4.54, p = .21. The results are similar with a random effects model (Table 2.6) and robust (Figure 2.13). It seems that, like positive emotions, negative emotions increase novel ideas.

The question remains whether positive and negative emotions differ in the likelihood to increasing cognitive breadth. Six comparisons of positive and negative emotions show an average effect size of $g_+ = 0.53$ (95% CI = 0.34, 0.71; fixed effects model). Again, this finding is similar for quantitative cognitive breadth. The effect size is not homogeneous, Q (5) = 36.12, $p < .001$, suggesting that the effects should not be combined. Figure 2.13 displays how the effect sizes change by removing one study at a time. A random effects model would be more appropriate.

Including task difficulty as a continuous moderator shows that the more difficult the task, the less the difference between positive and negative emotions in increasing idea generation and categorization breadth, b = -.49 (95% CI = -.78, -.22), $z = -3.55$, $p < .001$ (Figure 2.14). The slope is negative, indicating that with easier tasks, positive emotions improve performance over negative emotions. However, a significant amount of heterogeneity remains, Q (4) = 23.49, $p < .001$. For this particular comparison and dependent variable, no studies are included in the sample that allow an analysis of different performance goals.

As it is not possible to sufficiently reduce heterogeneity with these moderators, a random effects model is more appropriate for the comparison of positive and negative emotions. A random effects model results in an effect size of $g_+ = 0.50$. The 95% confidence interval is wide and includes zero (-0.02, 1.01). It therefore seems that negative emotions can operate quite similarly to positive emotions in increasing creativity in idea generation and category breadth for unusual category exemplars.

To summarize the findings for qualitative cognitive breadth, unusual idea generation seems more likely under positive than neutral emotion conditions. Similarly, negative emotions increase qualitative cognitive breadth compared to neutral emotions. These comparisons were homogeneous, suggesting that they are not moderated by other variables. These results are robust when using different models (fixed or random effects model), or excluding one study at a time. Comparing positive to negative emotions shows that positive emotions are as powerful as negative emotions in increasing the generation of unusual ideas and acceptance of unusual category members. However, this comparison is heterogeneous, and the direction of the effect therefore seems to depend on other variables. We found that the difference between positive and negative emotions is more pronounced with easy tasks, but other variables might additionally influence whether positive or negative emotions improve qualitative cognitive breadth.

Discussion

The results of this meta-analysis partially support the claims of the Broaden and Build Model, the Affect as Information Model, and the Dopaminergic Model concerning the broadening effect of positive emotions on cognition. Compared to neutral emotions, positive affect increases the number of ideas generated and the unusualness of ideas and category members. Regarding the unusualness of ideas and category members, the effect does not seem to be influenced by moderators. However, this finding only holds when comparing positive to neutral emotions. Contrary to the common belief, negative emotions can result in equal or more cognitive breadth compared to positive emotions. Regarding the quality of cognitive breadth, this effect does not seem to depend on situational variables.

When comparing positive to negative emotions, the Broaden and Build Model and the Affect as Information Model do not necessarily find support. In contrast to the implications of the previous research, negative emotions do not necessarily have the opposite effect of positive emotions. Indeed, negative emotions can be equally powerful as positive emotions in increasing cognitive breadth. The meta-analytic findings support the idea that positive and negative emotions are different processes with outcomes that do not lie on opposite ends of the same continuum.

When comparing positive to negative emotions, the outcomes for cognitive breadth seem to be influenced by different variables, as indicated by a high level of heterogeneity in the effect sizes. Performance goals can explain some of the variance for quantitative idea generation and categorization. With 'enjoy task' goals, positive emotions increase performance, and negative emotions decrease performance. With 'do you best' goals, however, negative emotions result in more ideas. Performance goals did not vary sufficiently among the comparisons of qualitative performance to estimate their effect on the relationship between emotions and unusualness of ideas and category members. The results support the Mood as Input Model.

A moderator of the emotions-cognition relationship for qualitative performance is task difficulty. With easy tasks, the difference between positive and negative emotions can be larger than with difficult tasks. As only few comparisons were used in this analysis, conclusions cannot be drawn with great confidence. Currently, the results support the Mood Behavior Model. Task difficulty did not vary for quantitative performance, so that it remains unclear how task difficulty affects the number of generated ideas.

After including performance goals and task difficulty, a significant amount of heterogeneity in the effect sizes remains, indicating that other moderators could impact the effect of positive and negative emotions on cognitive breadth. This suggests that the influence of positive compared to negative emotions on cognitive breadth is not robust, and may vary across situations. Moderators that appear in the literature, but that could not be examined meta-analytically due to a lack of sufficient studies, are the perceived desirability of creative responses (Gasper, 2004) and a focus on similarities or differences when generating ideas (Göritz & Moser, 2003; Murray, Sujan, Hirt, & Sujan, 1990).

Given that positive compared to negative emotions do not always increase associative flexibility, one could conclude that arousal rather than specific emotions increases creativity. However, Isen and Daubman (1984) assessed participants' arousal with two scales and found either no difference between the emotion and control group (alert-unaware scale), or differences that did not match the pattern of findings for performance (refreshed-tired scale). Also, it seems hard to attribute performance to arousal alone given that under the same circumstances, positive and negative emotions operate in different directions, as seen with the case of performance goals.

A variety of explanations for the underlying process of emotions on cognition have been suggested. For example, positive emotions might result in broader categories because positive affect cues a large amount of material, and the material is organized in more integrated categories to facilitate information processing (Isen & Daubman, 1984). This explanation seems to fit with the finding that positive emotions can increase the application of heuristics, which also facilitate information processing (Isen, Means, Patrick, & Nowicki, 1982). However, other research indicates that emotions do not affect the amount of available material, but rather how this material is used (Gasper, 2004).

Although the mechanisms for positive or negative emotions are not fully understood, many researchers agree that even if positive and negative emotions' outcomes are similar, the underlying processes might not be the same (Adaman & Blaney, 1995; Isen & Daubman, 1984; Tellegen, Watson, & Clark, 1999). For example, Ramon et al. (2007) show evidence that positive and negative emotions affect particular brain hemispheres, resulting in different categorization strategies. Recent research suggests that positive emotions improve creativity by increasing unusual associations, but negative emotions do so through persistence (De Dreu et al., 2008). Clearly, more work is required to understand the processes underlying the relationship of emotions on cognitive breadth. Likely, the processes for negative and positive emotions will be different from each other, and will allow for similar and different outcomes depending on the circumstances.

Conclusion

Past research has shown the many positive outcomes of positive affect (Lyubomirski et al., 2005). Implied in this research is the idea that negative affect has opposite effects. Some models explicitly predict that positive emotions broaden cognition and negative emotions narrow cognition (Fredrickson & Branigan, 2005). However, this meta-analysis shows that negative emotions do not result in a mirror image outcome of positive emotions. For the case of cognitive breadth in idea generation and categorization, the analysis confirmed that happy individuals come up with more, and more unusual, ideas, and include more unusual members in a category. However, the analysis also showed that negative emotions can broaden cognition in a similar way as positive emotions. When compared to neutral affect, the influence of positive as well as negative emotions on the unusualness of ideas and category members included in a category do not seem to vary with different situations. Thus, the outcomes of positive and negative emotions do not lie on one continuum, as often implied implicitly in the literature of positive emotions. Instead, the effect of positive and negative emotions on cognitive breadth can be similar to each other. Comparisons of negative and positive emotions show that which emotion increases cognitive breadth more is influenced by situational variables. Likely, positive and negative emotions trigger different processes that are responsible for similar or different outcomes, depending on the situation.

Table 2.1
Sample characteristics across comparisons and reports

Study characteristic	Out of 68 comparisons	Out of 18 reports
Emotion groups compared		
Pos vs. nt	46%	12 reports
Nt vs. neg	21 %	7 reports
Pos vs. neg	34%	11 reports
Specific emotion		
Pos, neg affect	53%	11 reports
'happy' and 'sad'	37%	Bohner & Schwarz, 1993; Davis et al., 2007; Gasper, 2004; Hirt et al., 1996; Hirt et al., 1997
'elated' and 'depressed'	6%	Adaman & Blaney, 1995
5 specific emotions	4%	Fredrickson & Branigan
Emotion induction		
Movie	44%	8 reports
Velten	32%	Goritz & Moser, 2003; Murray et al., 1990; Hirt et al., 1996
Essay	7%	Bohner & Schwarz, 1993; Gasper, 2004; Mikulincer & Sheffi, 2000
Music	6%	Adaman & Blaney, 1995
Candy	3%	Barone et al., 2000; Isen & Daubman, 1984
Refreshments	3%	Isen et al., 2004
Feedback	3%	Barone & Miniard, 2002; Barone et al., 2000
Illumination	2%	Baron et al., 1992
Control group		
No manipulation	38%	10 reports

Table 2.1 (continued)

Dependent variable		
Categorization	16%	6 reports
Idea generation	84%	12 reports
Quantity	60%	10 reports
Quality	40%	13 reports
Population, Setting		
Students, lab	91%	17 reports
Unknown, Internet	9%	Goritz & Moser, 2003
Goal		
No goal	62%	15 reports
Enjoy goal	12%	Hirt et al., 1996; Hirt et al., 1997; Martin et al., 1993; Sanna et al., 1996;
Do best	10%	Davis et al., 2007; Hirt et al., 1997; Sanna et al., 1996
Multiple goals	6%	Hirt et al., 1996; Hirt et al., 1997
Do enough	6%	Hirt et al., 1996; Martin et al., 1993
Self-set goal	4%	Davis et al., 2007
Task difficulty		
Easy	19%	7 reports
Medium	79%	10 reports
Hard	1%	Bohner & Schwarz, 1993

Notes. Pos = positive, nt = neutral, neg = negative.
Not all comparisons are independent, so that the sum of the percentages of comparisons can exceed 100, the number of reports exceed 18 respectively.

Table 2.2
Effect size estimates for quantitative cognitive breadth

Author	Year	N	Emotions	Hedges g	95% CI		Goal
Sanna, Turley, & Mark	1996	66	Pos-nt	-2.73	-3.39	-2.06	best
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos-nt	-0.21	-0.79	0.37	enough
Goritz & Moser	2003	68	Pos-nt	-0.18	-0.65	0.29	no goal
Murray, Sujan, Hirt, & Sujan	1990	78	Pos-nt	0.00	-0.44	0.44	no goal
Murray, Sujan, Hirt, & Sujan	1990	78	Pos-nt	0.17	-0.27	0.61	no goal
Davis, Kirby, & Curtis	2007	30	Pos-nt	0.30	-0.40	1.00	number
Murray, Sujan, Hirt, & Sujan	1990	41	Pos-nt	0.64	0.02	1.25	no goal
Adaman & Blaney	1995	48	Pos-nt	0.68	0.10	1.25	no goal
Davis, Kirby, & Curtis	2007	30	Pos-nt	0.97	0.23	1.71	best
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos-nt	0.99	0.37	1.61	no goal
Murray, Sujan, Hirt, & Sujan	1990	41	Pos-nt	1.00	0.36	1.63	no goal
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos-nt	1.54	0.88	2.21	enjoy
Fredrickson & Branigan	2005	98	Pos-nt	2.22	1.72	2.72	no goal
Sanna, Turley, & Mark	1996	66	Pos-nt	4.76	3.82	5.70	enjoy
Sanna, Turley, & Mark	1996	66	Nt-neg	-4.13	-4.99	-3.28	best
Davis, Kirby, & Curtis	2007	30	Nt-neg	-1.02	-1.76	-0.28	number
Adaman & Blaney	1995	48	Nt-neg	-0.98	-1.57	-0.39	no goal
Davis, Kirby, & Curtis	2007	30	Nt-neg	-0.43	-1.14	0.27	best
Hirt, Melton, McDonald, & Harackiewicz	1996	33	Nt-neg	-0.18	-0.88	0.53	enough
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Nt-neg	-0.06	-0.64	0.52	no goal
Goritz & Moser	2003	71	Nt-neg	0.25	-0.21	0.72	no goal

Table 2.2 (continued)

Sanna, Turley, & Mark	1996	66	Pos_neg	-6.86	-8.12	-5.60	best
Martin, Ward, Achee, & Wyer	1993	24	Pos_neg	-3.16	-4.34	-1.98	enough
Hirt, Levine, McDonald, Melton, & Martin	1997	30	Pos_neg	-2.54	-3.49	-1.59	best
Martin, Ward, Achee, & Wyer	1993	24	Pos_neg	-2.24	-3.23	-1.24	no goal
Davis, Kirby, & Curtis	2007	30	Pos_neg	-0.72	-1.44	0.00	number
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos_neg	-0.38	-0.97	0.20	enough
Gasper	2004	120	Pos_neg	-0.04	-0.39	0.32	no goal
Gasper	2004	108	Pos_neg	0.01	-0.36	0.39	no goal
Goritz & Moser	2003	77	Pos_neg	0.03	-0.41	0.47	no goal
Gasper	2004	124	Pos_neg	0.21	-0.14	0.56	no goal
Davis, Kirby, & Curtis	2007	30	Pos_neg	0.54	-0.17	1.25	best
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos_neg	0.91	0.29	1.52	no goal
Hirt, Melton, McDonald, & Harackiewicz	1996	44	Pos_neg	2.11	1.38	2.84	enjoy
Martin, Ward, Achee, & Wyer	1993	24	Pos_neg	2.59	1.53	3.66	enjoy
Fredrickson & Branigan	2005	98	Pos_neg	3.85	3.18	4.52	no goal
Hirt, Levine, McDonald, Melton, & Martin	1997	30	Pos_neg	4.77	3.38	6.17	enjoy
Sanna, Turley, & Mark	1996	66	Pos_neg	7.04	5.75	8.34	enjoy

Note. Pos = positive, nt = neutral, neg = negative.

Table 2.3
Average effect size estimate and 95% confidence interval for quantitative cognitive breadth by emotion group comparison for different models

Emotion groups	Model	Hedges g_+	95% CI	df	Homogeneity (Q_W)
Pos vs. nt	Fixed	0.54	0.38, 0.69	13	251.37***
		(0.60)	(0.44, 0.77)	(11)	(81.41***)
	Random	0.72	0.02, 1.41		
		(0.68)	(0.23, 1.13)		
Nt vs. neg	Fixed	0.22	0.02, 0.41	9	232.58***
		(0.45)	(0.26, 0.65)	(8)	(126.92***)
	Random	-0.15	-1.14, 0.85		
		(0.29)	(-0.51, 1.09)		
Pos vs. neg	Fixed	0.27	0.13, 0.42	16	533.99***
		(0.28)	(0.13, 0.43)	(14)	(306.22***)
	Random	0.35	-0.53, 1.24		
		(0.38)	(-0.35, 1.11)		

Notes. Pos = positive, nt = neutral, neg = negative.
Estimates when excluding outlier comparisons are given in parenthesis.
†$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$.

Table 2.4
Average effect size estimate, 95% confidence interval, and homogeneity test for quantitative cognitive breadth by emotion group comparison and by performance goal

Emotion groups	Goal	Between-classes effect (Q_B)	k	Hedges g_+	95% CI	Homogeneity within each class (Q_{Wi})
Pos vs. nt		8.17†				
	Do best		2	-0.89	-4.57, 2.80	52.66***
	Do enough		1	-0.21	-0.80, 0.38	n/a
	Self-set		1	0.31	-0.41, 1.03	n/a
	No goal		8	0.69	0.12, 1.26	64.61***
	Enjoy		2	3.18	-0.01, 6.36	29.66***
Nt vs. neg		9.88*				
	Do best		2	-2.31	-5.97, 1.36	42.43***
	Do enough		1	-0.18	-0.91, 0.55	n/a
	Self-set		1	-1.05	-1.81, -0.28	n/a
	No goal		4	0.33	-0.95, 1.61	68.93***
	Enjoy		2	1.44	-0.26, 3.14	15.33***
Pos vs. neg		21.87***				
	Do best		3	-2.97	-7.02, 1.08	104.69***
	Do enough		2	-1.78	-4.60, 1.04	17.20***
	Self-set		1	-0.74	-1.48, 0.001	n/a
	No goal		7	0.42	-0.46, 1.30	144.55***
	Enjoy		4	4.17	1.97, 6.34	47.96***
All		37.38***				
	Do best		7	-2.16	-3.97, -0.36	205.49***
	Do enough		4	-0.88	-1.85, 0.10	21.50***
	Self-set		3	-0.49	-1.30, 0.33	7.20*
	No goal		19	0.52	0.06, 0.98	283.24***
	Enjoy		8	3.19	1.93, 4.45	128.09***

Notes. Pos = positive, nt = neutral, neg = negative.
†p < .1, *p < .05, **p < .01, ***p < .001.

Table 2.5
Effect size estimates for qualitative cognitive breadth

Author	Year	N	Emotions	Hedges g	95% CI		Task difficulty
Barone	2005	109	Pos-nt	0.14	-0.23	0.52	1
Isen, Labroo, & Durlach	2004	46	Pos-nt	0.27	-0.42	0.96	1
Barone & Miniard	2002	166	Pos-nt	0.29	-0.01	0.59	1
Adaman & Blaney	1995	48	Pos-nt	0.37	-0.19	0.93	2
Isen & Daubman	1984	70	Pos-nt	0.43	-0.04	0.90	1
Mikulincer & Sheffi	2000	110	Pos-nt	0.44	0.07	0.82	1
Barone & Miniard	2000	67	Pos-nt	0.44	-0.04	0.92	1
Isen & Daubman	1984	70	Pos-nt	0.50	0.02	0.98	1
Barone	2005	158	Pos-nt	0.50	0.18	0.81	1
Goritz & Moser	2003	49	Pos-nt	0.51	-0.13	1.16	2
Isen, Labroo, & Durlach	2004	62	Pos-nt	0.59	0.09	1.09	1
Barone & Miniard	2000	71	Pos-nt	0.62	0.15	1.09	1
Hirt, Melton, McDonald, & Harackiewicz	1996	130	Pos-nt	0.80	0.44	1.15	2
Murray, Sujan, Hirt, & Sujan	1990	78	Pos-nt	0.90	0.44	1.36	2
Murray, Sujan, Hirt, & Sujan	1990	41	Pos-nt	0.98	0.34	1.62	2
Murray, Sujan, Hirt, & Sujan	1990	41	Pos-nt	1.06	0.42	1.71	2
Murray, Sujan, Hirt, & Sujan	1990	78	Pos-nt	1.13	0.65	1.60	2
Adaman & Blaney	1995	48	Nt-neg	-0.78	-1.36	-0.20	2
Goritz & Moser	2003	30	Nt-neg	-0.48	-1.20	0.24	2
Isen & Daubman	1984	55	Nt-neg	-0.46	-1.01	0.08	1
Hirt, Melton, McDonald, & Harackiewicz	1996	130	Nt-neg	-0.10	-0.44	0.24	2
Bohner & Schwarz	1993	88	Pos_neg	-0.06	-0.48	0.35	3
Isen & Daubman	1984	57	Pos_neg	0.03	-0.50	0.56	1
Goritz & Moser	2003	55	Pos_neg	0.03	-0.52	0.59	2
Hirt, Levine, McDonald, Melton, & Martin	1997	60	Pos_neg	0.59	0.08	1.10	2
Hirt, Melton, McDonald, & Harackiewicz	1996	130	Pos_neg	0.70	0.34	1.05	2
Baron, Rea, & Daniels	1992	92	Pos_neg	1.62	1.16	2.09	1

Notes. Pos = positive, nt = neutral, neg = negative.
Task difficulty ranges from 1 (easy) to 3 (difficult).

Table 2.6
Average effect size estimate, 95% confidence interval, and homogeneity test for qualitative cognitive breadth by emotion group comparison for different models

Emotion groups	Model	Hedges g_+	95% CI	df	Homogeneity (Q_W)
Pos vs. nt	Fixed	0.55	0.44, 0.66	16	23.51, n.s.
	Random	0.57	0.43, 0.70		
Nt vs. neg	Fixed	-0.34	-.59, -0.09	3	4.54, n.s.
	Random	-0.40	-0.72, -0.07		
Pos vs. neg	Fixed	0.53	0.34, 0.71	5	36.12***
	Random	0.50	-0.02, 1.01		

Notes. Pos = positive, nt = neutral, neg = negative.
†p < .1, *p < .05, **p < .01, ***p < .001.

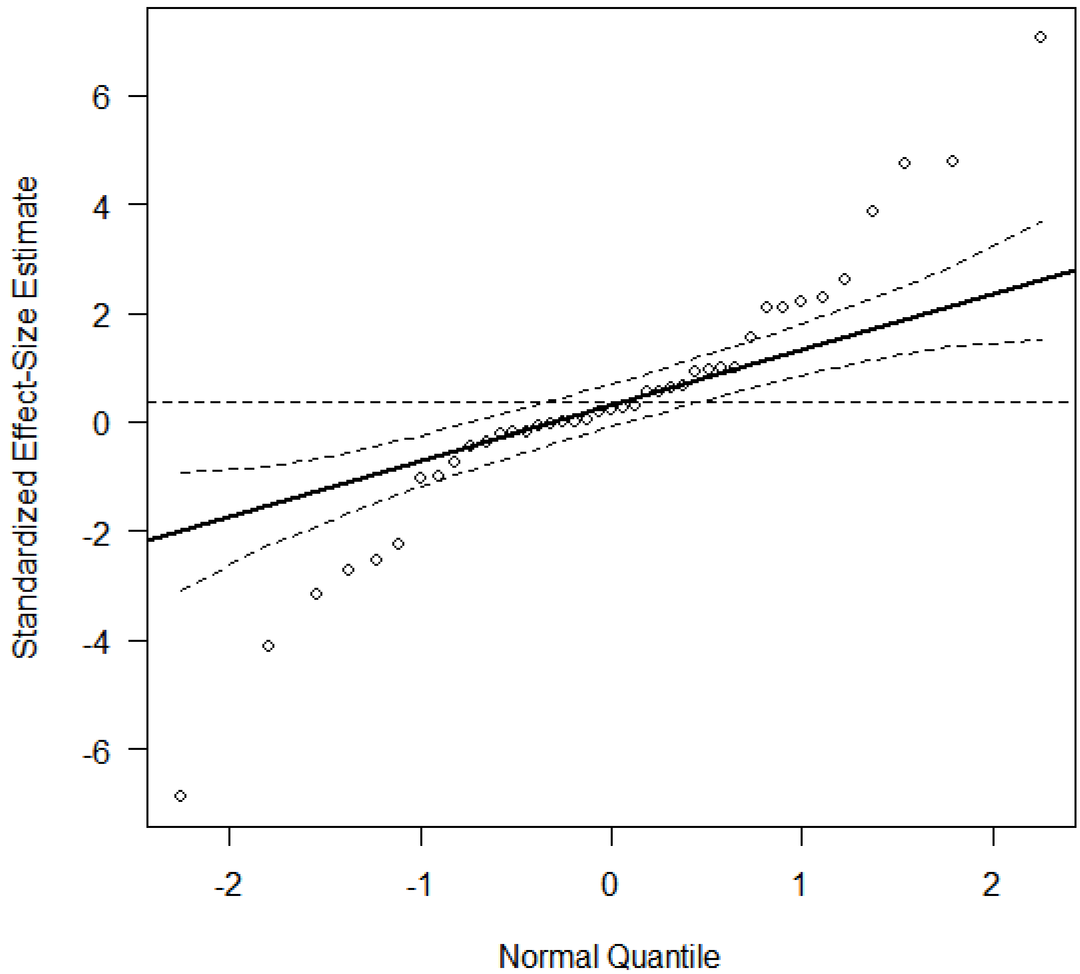

Figure 2.1. Normal q-q plot of standardized mean differences for quantitative cognitive breadth.

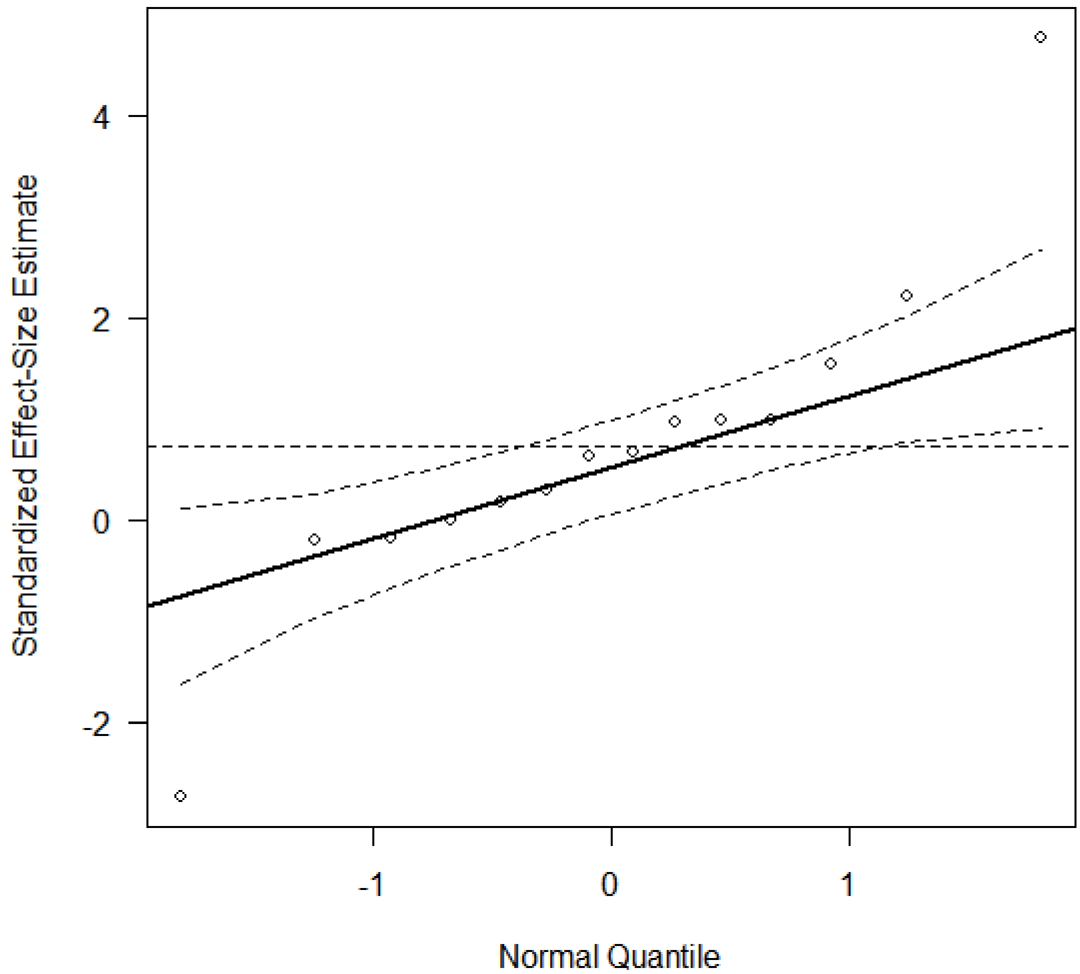

Figure 2.2. Normal q-q plot of standardized mean differences for quantitative cognitive breadth, positive vs. neutral emotions.

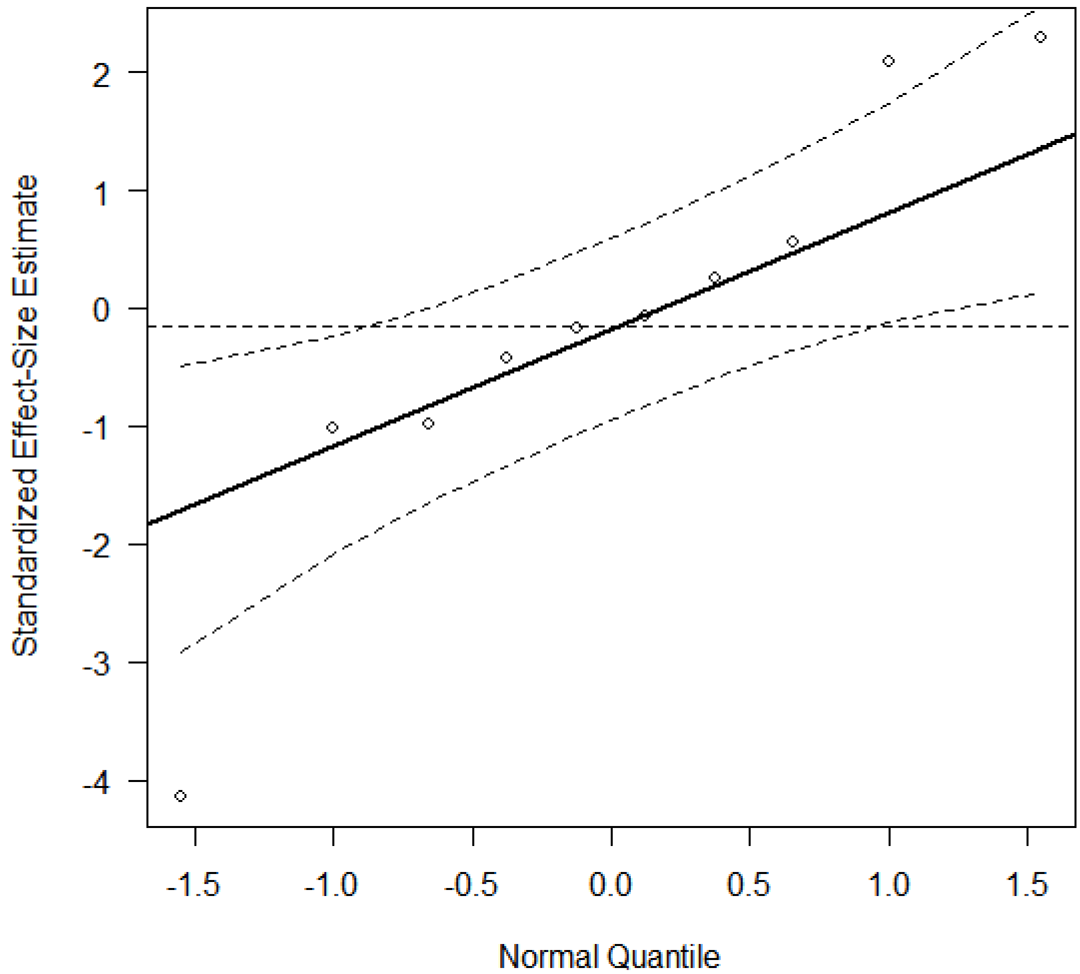

Figure 2.3. Normal q-q plot of standardized mean differences for quantitative cognitive breadth, neutral vs. negative emotions.

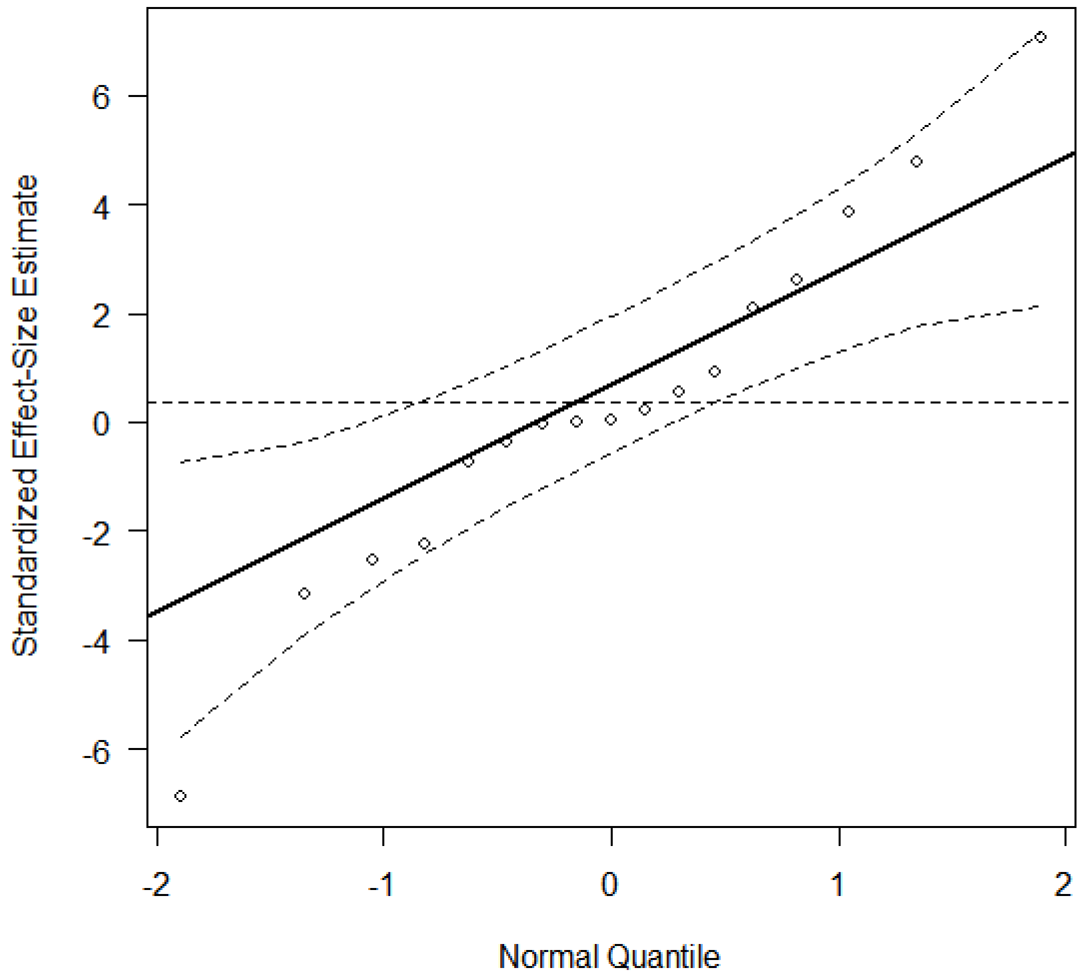

Figure 2.4. Normal q-q plot of standardized mean differences for quantitative cognitive breadth, positive vs. negative emotions.

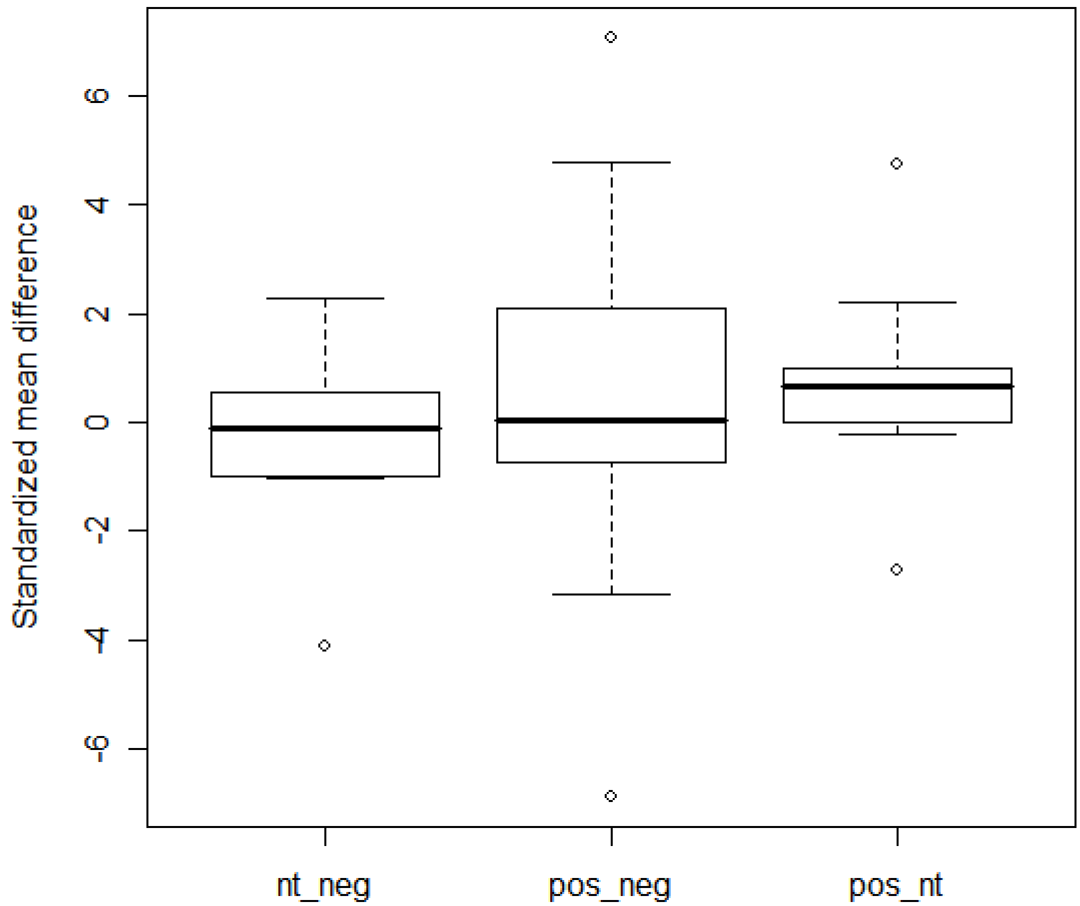

Figure 2.5. Boxplot of standardized mean differences for quantitative cognitive breadth. pos = positive, nt = neutral, neg = negative emotion.

Meta Analysis

Group by Goal	Report	valence	Comparison_ID	Point	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
1.00	14.000	1.000	14_1_3	-2.652	0.656	0.431	-3.938	-1.365	-4.040	0.000
1.00	14.000	2.000	14_1_4	-2.408	0.657	0.431	-3.695	-1.121	-3.667	0.000
1.00	14.000	3.000	14_1_6	-2.579	0.658	0.433	-3.868	-1.290	-3.921	0.000
1.00	9.000	1.000	9_1_2	-2.003	0.633	0.401	-3.244	-0.762	-3.164	0.002
1.00	9.000	2.000	9_1_1	-1.766	0.621	0.386	-2.984	-0.549	-2.843	0.004
1.00	9.000	3.000	9_1_3	-1.390	0.609	0.371	-2.583	-0.197	-2.283	0.022
1.00	10.000	3.000	10_1_2	-2.037	0.642	0.412	-3.296	-0.779	-3.172	0.002
1.00				-2.163	0.922	0.850	-3.970	-0.356	-2.346	0.019
2.00	15.000	3.000	15_1_1	-0.261	0.892	0.796	-2.010	1.488	-0.292	0.770
2.00	16.000	1.000	16_1_1	-1.213	0.931	0.867	-3.039	0.612	-1.303	0.193
2.00	16.000	2.000	16_1_4	-1.217	0.925	0.856	-3.031	0.596	-1.316	0.188
2.00	16.000	3.000	16_1_9	-1.151	0.930	0.865	-2.973	0.672	-1.237	0.216
2.00				-0.875	0.499	0.249	-1.853	0.103	-1.754	0.079
3.00	14.000	1.000	14_1_1	-0.892	1.126	1.269	-3.100	1.315	-0.792	0.428
3.00	14.000	2.000	14_1_2	-0.214	1.116	1.246	-2.402	1.974	-0.192	0.848
3.00	14.000	3.000	14_1_5	-0.367	1.120	1.255	-2.563	1.829	-0.327	0.743
3.00				-0.485	0.414	0.171	-1.296	0.326	-1.172	0.241
4.00	15.000	3.000	15_1_3	0.656	0.364	0.132	-0.056	1.369	1.805	0.071
4.00	16.000	1.000	16_1_3	0.484	0.371	0.138	-0.243	1.211	1.305	0.192
4.00	16.000	2.000	16_1_6	0.543	0.372	0.138	-0.186	1.272	1.461	0.144
4.00	16.000	3.000	16_1_11	0.489	0.371	0.138	-0.239	1.216	1.317	0.188
4.00	6.000	1.000	6_1_4	0.502	0.372	0.138	-0.228	1.231	1.348	0.178
4.00	6.000	2.000	6_1_3	0.595	0.368	0.136	-0.127	1.317	1.615	0.106
4.00	7.000	1.000	7_1_1	0.550	0.374	0.140	-0.183	1.283	1.472	0.141
4.00	7.000	2.000	7_1_2	0.526	0.375	0.141	-0.209	1.261	1.402	0.161
4.00	7.000	3.000	7_1_7	0.538	0.376	0.141	-0.198	1.274	1.434	0.152
4.00	12.000	1.000	12_2_1	0.484	0.371	0.137	-0.242	1.210	1.306	0.192
4.00	12.000	1.000	12_2_3	0.504	0.371	0.138	-0.224	1.232	1.357	0.175
4.00	12.000	1.000	12_3_1	0.531	0.376	0.141	-0.206	1.267	1.412	0.158
4.00	12.000	1.000	12_3_2	0.540	0.376	0.141	-0.196	1.276	1.438	0.150
4.00	17.000	3.000	17_1_1	0.542	0.380	0.144	-0.202	1.286	1.428	0.153
4.00	17.000	3.000	17_2_1	0.539	0.379	0.143	-0.203	1.281	1.424	0.154
4.00	17.000	3.000	17_3_1	0.528	0.381	0.145	-0.218	1.274	1.387	0.166
4.00	13.000	1.000	13_1_1	0.415	0.364	0.132	-0.298	1.128	1.141	0.254
4.00	13.000	2.000	13_1_2	0.422	0.365	0.133	-0.293	1.138	1.157	0.247
4.00	13.000	3.000	13_1_3	0.328	0.351	0.123	-0.360	1.016	0.935	0.350
4.00				0.518	0.234	0.055	0.059	0.978	2.211	0.027
5.00	15.000	3.000	15_1_2	3.237	0.604	0.365	2.053	4.421	5.359	0.000
5.00	16.000	1.000	16_1_2	3.413	0.612	0.375	2.213	4.613	5.575	0.000
5.00	16.000	2.000	16_1_5	3.568	0.618	0.381	2.358	4.779	5.778	0.000
5.00	16.000	3.000	16_1_10	3.323	0.608	0.370	2.131	4.514	5.466	0.000
5.00	9.000	1.000	9_1_5	2.927	0.586	0.344	1.778	4.077	4.992	0.000
5.00	9.000	2.000	9_1_4	3.300	0.606	0.367	2.112	4.488	5.445	0.000
5.00	9.000	3.000	9_1_6	2.647	0.576	0.332	1.517	3.776	4.592	0.000
5.00	10.000	3.000	10_1_1	2.949	0.594	0.353	1.785	4.113	4.967	0.000
5.00				3.191	0.642	0.412	1.933	4.449	4.971	0.000
Overall				0.262	0.178	0.032	-0.087	0.610	1.473	0.141

Statistics with study removed

Std diff in means (95% CI) with study removed

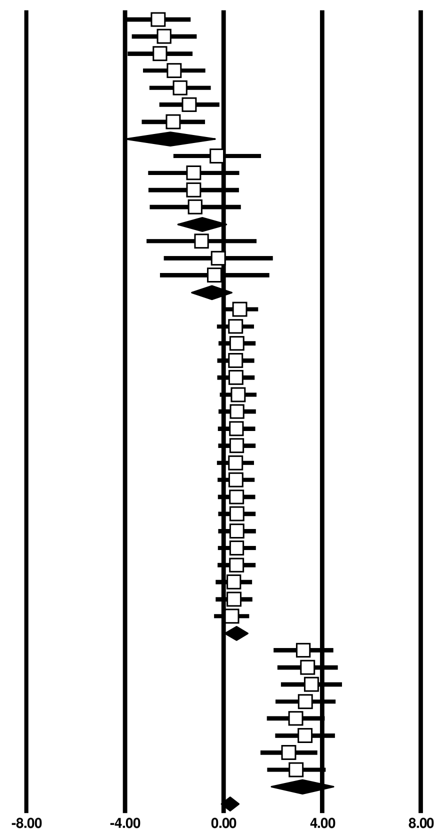

Figure 2.6. Average effect size estimates for quantitative cogn. breadth with one study removed. □ average effect size with one study removed, ♦ average effect size across goal group with one study removed. Goal 1 'best,' 2 enough,' 3 'self-set,' 4 'no goal,' and 5 'enjoy.'

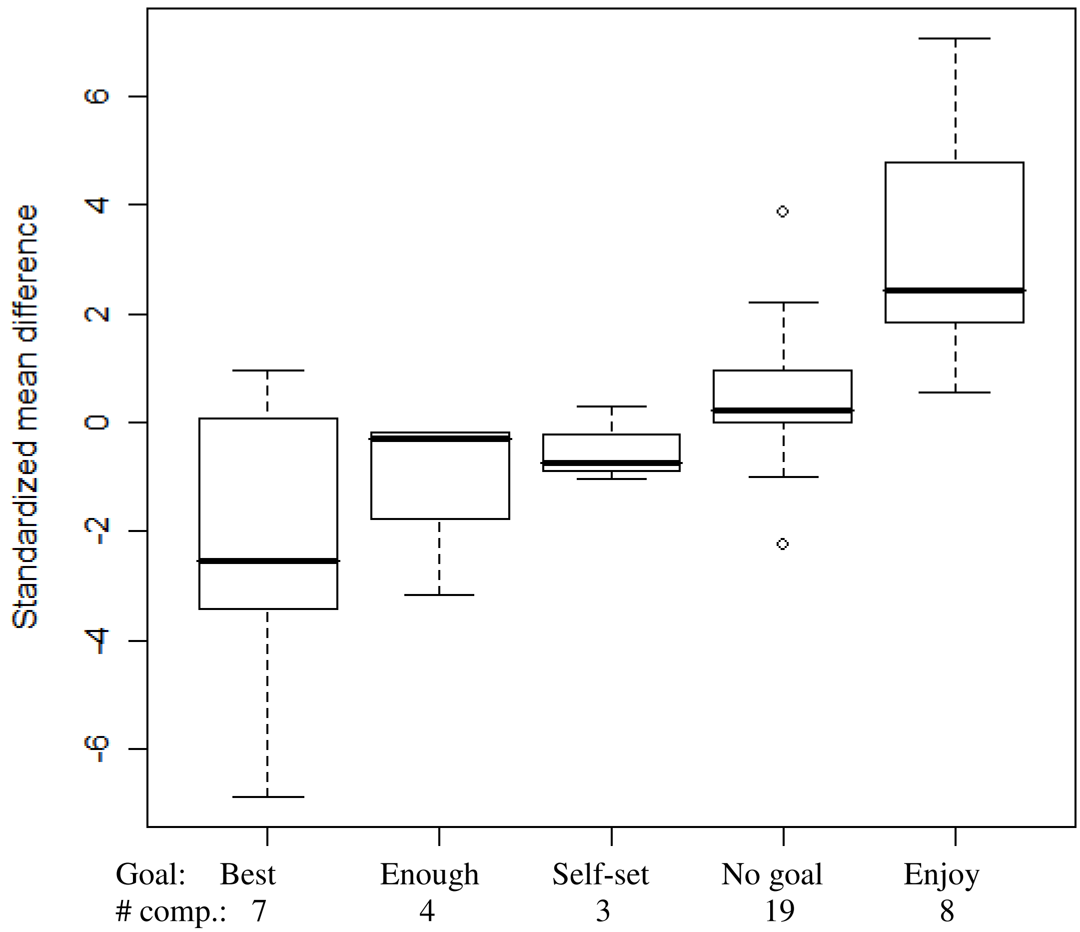

Figure 2.7. Boxplot of standardized mean differences for quantitative cognitive breadth by performance goals. The number of comparisons per goal group is indicated.
Best = do your best goal, enough = do enough goal, number = self-set number goal, and enjoy = enjoy task goal.

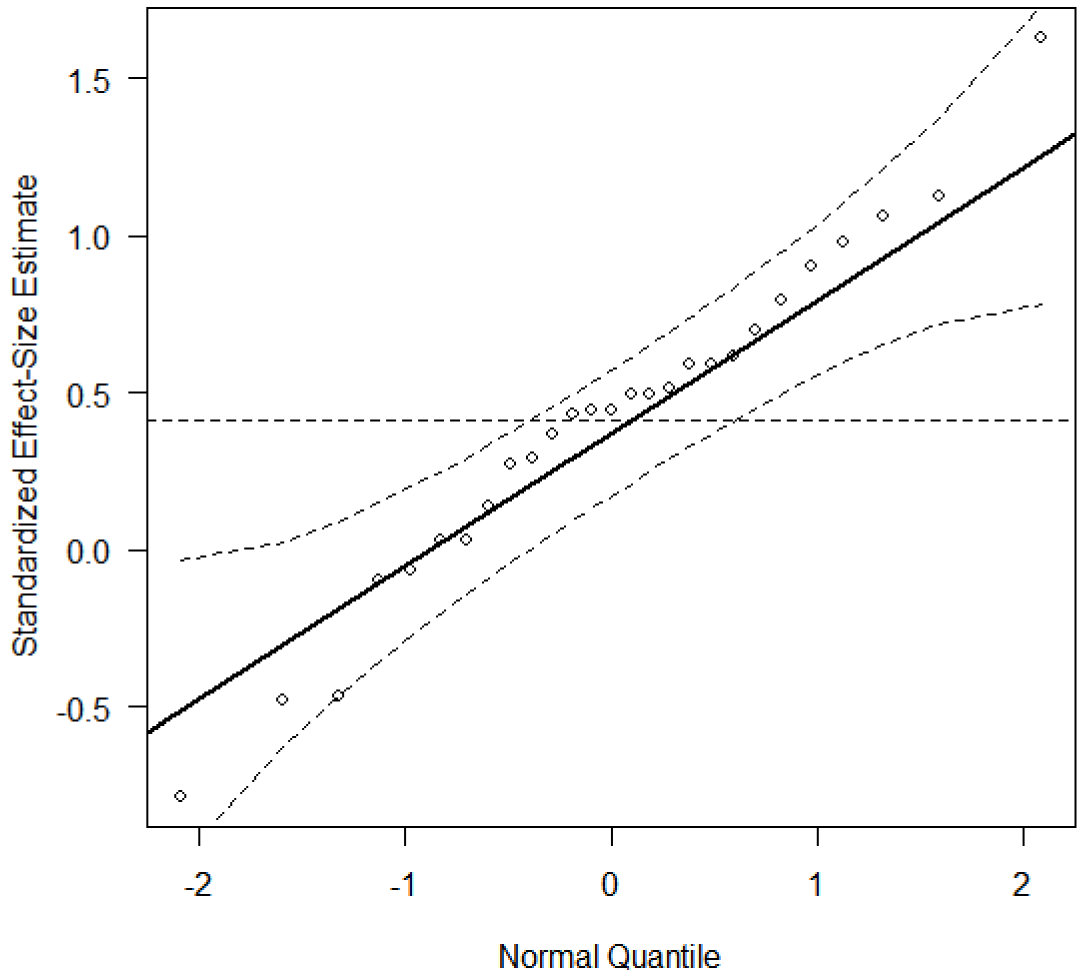

Figure 2.8. Normal q-q plot of standardized mean differences for qualitative cognitive breadth.

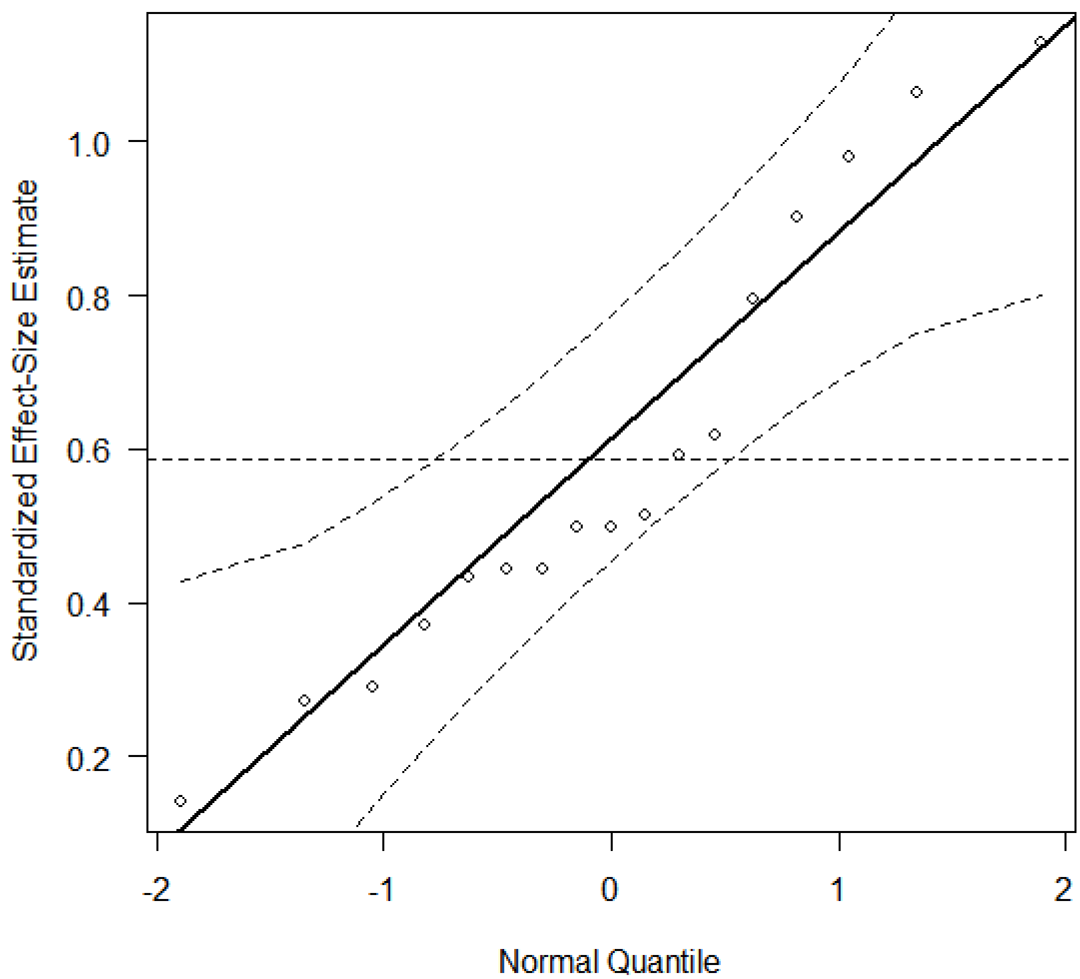

Figure 2.9. Normal q-q plot of standardized mean differences for qualitative cognitive breadth, positive vs. neutral emotions.

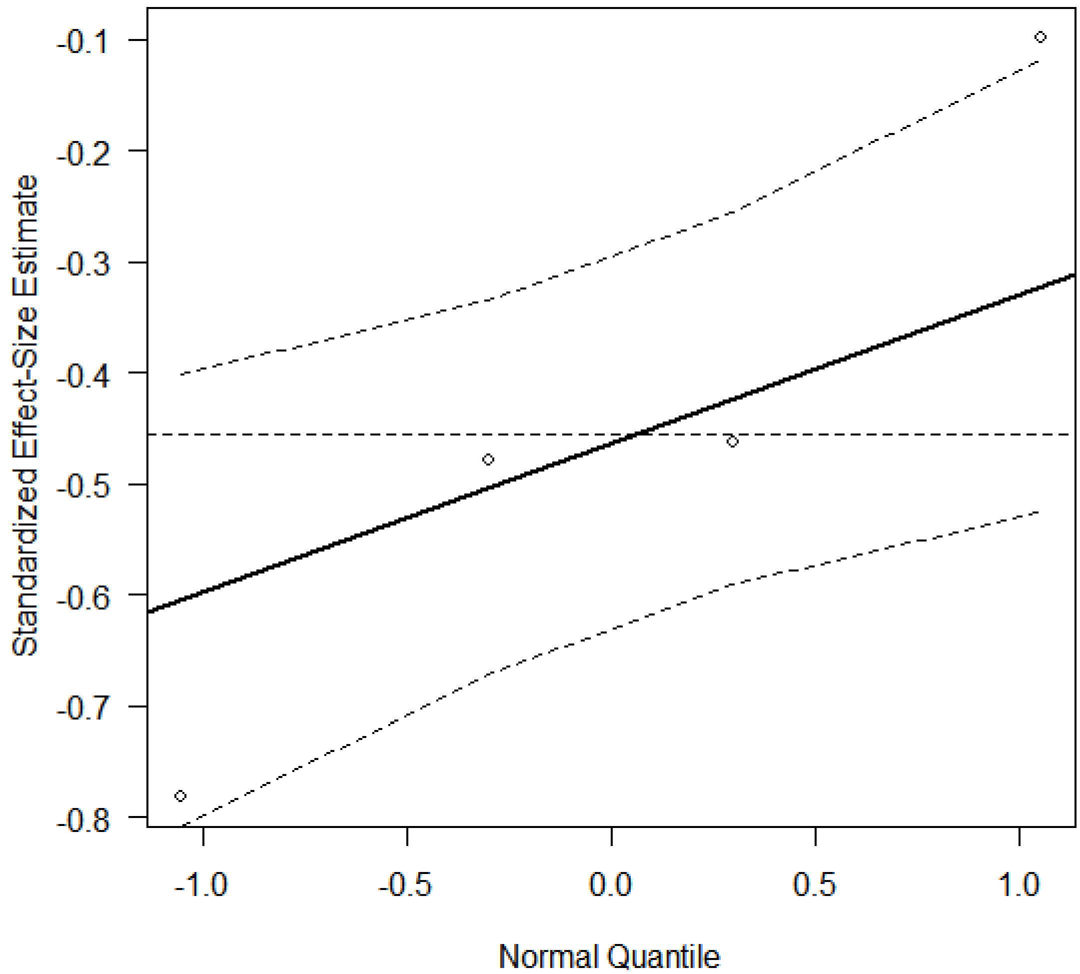

Figure 2.10. Normal q-q plot of standardized mean differences for qualitative cognitive breadth, neutral vs. negative emotions.

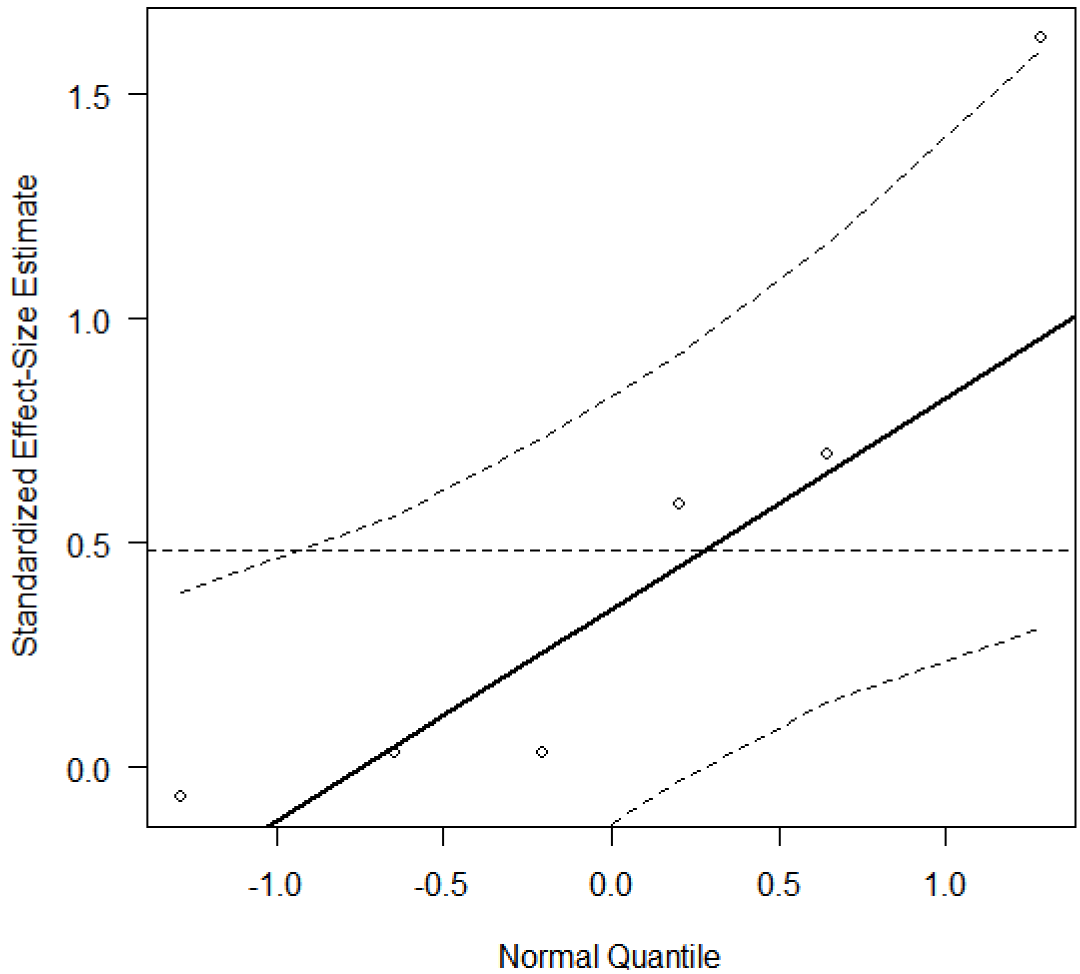

Figure 2.11. Normal q-q plot of standardized mean differences for qualitative cognitive breadth, positive vs. negative emotions.

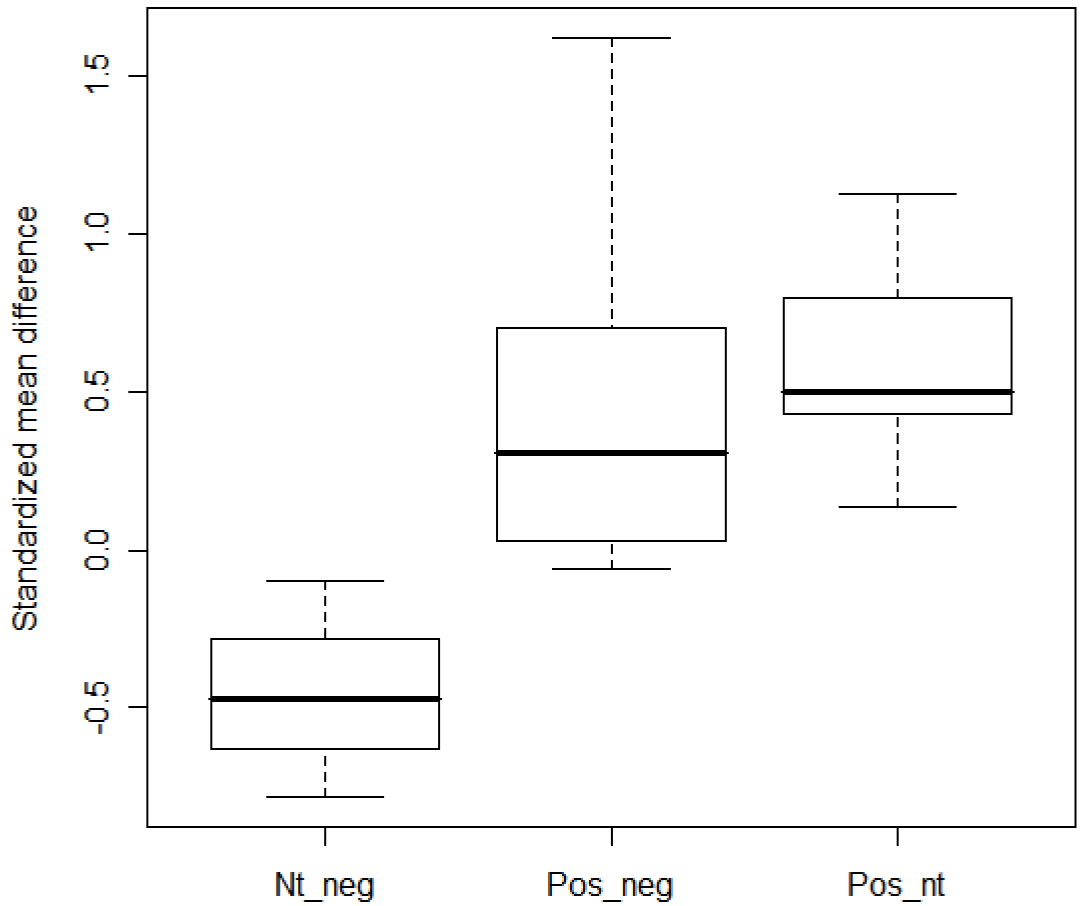

Figure 2.12. Boxplot of standardized mean differences for qualitative cognitive breadth. pos = positive, nt = neutral, neg = negative emotion.

Meta Analysis

Group by Subgroup within study	Report	valence	Comparison_ID	Point	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
1.00	18.000	1.000	18_1_1	0.585	0.059	0.004	0.469	0.702	9.876	0.000
1.00	6.000	1.000	6_1_2	0.555	0.056	0.003	0.444	0.665	9.830	0.000
1.00	1.000	1.000	1_1_1	0.558	0.058	0.003	0.444	0.671	9.640	0.000
1.00	2.000	1.000	2_1_1	0.554	0.057	0.003	0.442	0.665	9.738	0.000
1.00	2.000	1.000	2_2_1	0.544	0.057	0.003	0.433	0.656	9.562	0.000
1.00	11.000	1.000	11_1_1	0.551	0.057	0.003	0.439	0.662	9.688	0.000
1.00	11.000	1.000	11_2_1	0.555	0.057	0.003	0.443	0.666	9.741	0.000
1.00	7.000	1.000	7_1_5	0.549	0.056	0.003	0.439	0.659	9.774	0.000
1.00	12.000	1.000	12_2_2	0.535	0.056	0.003	0.425	0.646	9.526	0.000
1.00	12.000	1.000	12_2_4	0.533	0.056	0.003	0.423	0.643	9.491	0.000
1.00	12.000	1.000	12_3_3	0.516	0.057	0.003	0.405	0.628	9.075	0.000
1.00	12.000	1.000	12_3_4	0.528	0.057	0.003	0.416	0.639	9.259	0.000
1.00	16.000	1.000	16_1_7	0.523	0.058	0.003	0.409	0.637	8.988	0.000
1.00	19.000	1.000	19_1_1	0.555	0.059	0.003	0.439	0.670	9.406	0.000
1.00	19.000	1.000	19_2_1	0.585	0.058	0.003	0.472	0.699	10.112	0.000
1.00	3.000	1.000	3_1_1	0.546	0.057	0.003	0.435	0.657	9.627	0.000
1.00	3.000	1.000	3_2_1	0.555	0.056	0.003	0.445	0.665	9.896	0.000
1.00				0.548	0.055	0.003	0.440	0.657	9.896	0.000
2.00	6.000	2.000	6_1_1	-0.242	0.139	0.019	-0.514	0.029	-1.750	0.080
2.00	7.000	2.000	7_1_6	-0.320	0.133	0.018	-0.582	-0.059	-2.403	0.016
2.00	11.000	2.000	11_2_2	-0.307	0.141	0.020	-0.582	-0.031	-2.182	0.029
2.00	16.000	2.000	16_1_8	-0.592	0.180	0.032	-0.945	-0.239	-3.284	0.001
2.00				-0.339	0.126	0.016	-0.586	-0.093	-2.699	0.007
3.00	10.000	3.000	10_1_3	0.516	0.102	0.011	0.315	0.716	5.030	0.000
3.00	16.000	3.000	16_1_12	0.459	0.113	0.013	0.238	0.679	4.075	0.000
3.00	11.000	3.000	11_2_3	0.594	0.102	0.010	0.394	0.794	5.829	0.000
3.00	5.000	3.000	5_1_1	0.674	0.107	0.011	0.465	0.884	6.309	0.000
3.00	7.000	3.000	7_1_9	0.587	0.101	0.010	0.389	0.786	5.798	0.000
3.00	4.000	3.000	4_1_1	0.319	0.104	0.011	0.115	0.523	3.062	0.002
3.00				0.526	0.096	0.009	0.339	0.713	5.507	0.000
Overall				0.431	0.045	0.002	0.343	0.519	9.619	0.000

(Statistics with study removed)

Std diff in means (95% CI) with study removed

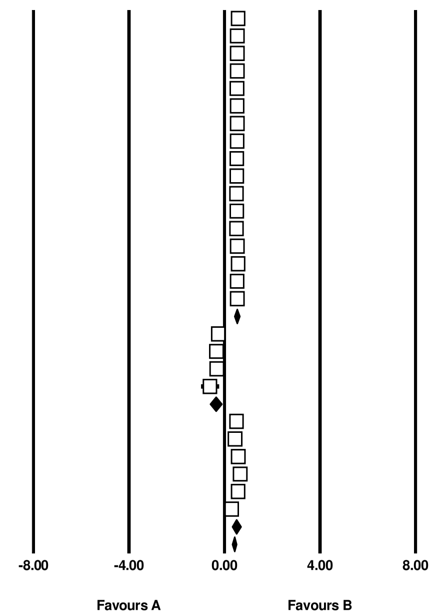

Figure 2.13. Average effect size estimate for qualitative cognitive breadth with one study removed. □ average effect size with one study removed, ♦ average effect size across emotion group comparison with one study removed.

Emotion group 1 ‘Positive vs. neutral,’ 2 ‘Neutral vs. negative,’ and 3 ‘Positive vs.negative.’

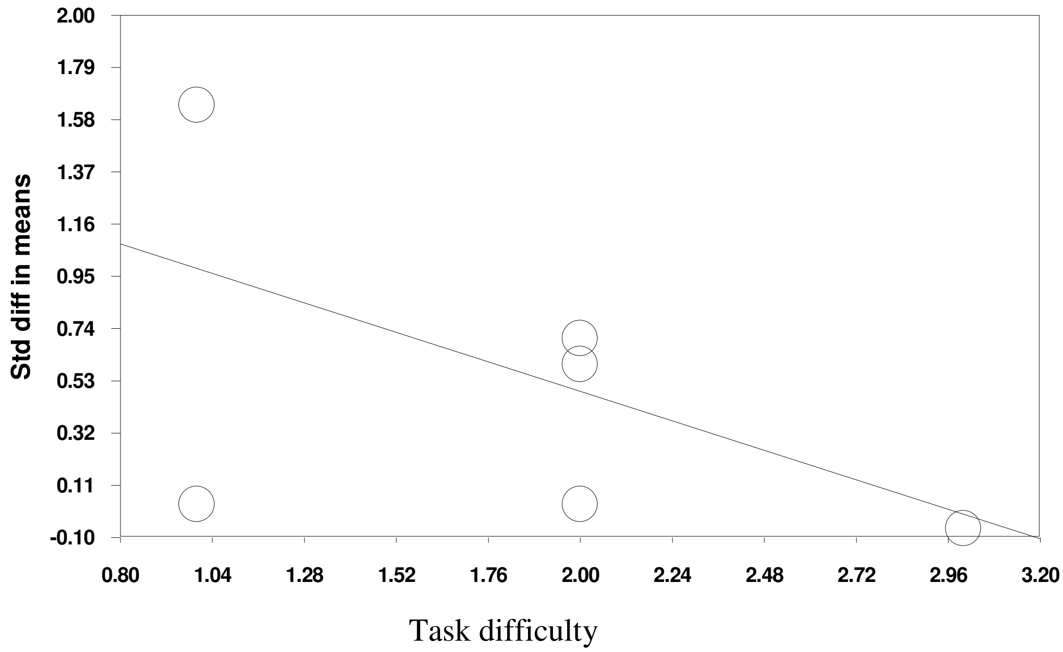

Figure 2.14. Regression of task difficulty on standardized mean differences. Task difficulty ranges from 1 (easy) to 3 (hard).

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Chapter 3

Happiness Impairs Cognitive Flexibility in Reversal Learning

Daily life involves dealing with change; the price of gas goes up, the grocery store no longer carries your favorite yogurt, your boss develops a new attitude about your performance. To deal with such events, individuals need to detect changes and adapt their behavior accordingly. In this study, we examine the role of emotions in the ability to learn changes in reward contingencies using a reversal learning paradigm. There is ample evidence that emotions aroused in one context can spill over to a different situation and influence behavior (so-called incidental emotions; Bodenhausen, 1993). For example, a large body of research on emotions and creative behaviors shows that positive affect generally improves flexibility in the creativity domain (Baas, De Dreu, & Nijstad, 2008; Davis, 2008). However, research on the influence of emotions on executive functions, such as reversal learning, is less advanced.

In a reversal learning paradigm, one of two stimuli is associated with a reward. The stimulus that is reinforced changes throughout the task (so-called reversals; e.g., Rolls, 2004). The ability to learn reversals is important for adapting to changes in rewards regarding basic behaviors, such as the acquisition of tasty foods, as well as social situations. For example, Kringelbach and Rolls (2003) studied reversal learning for changing facial expressions, which is associated with increased activity in the orbitofrontal and the anterior cingulate cortices.

To our knowledge, no study has investigated how reversal learning is influenced by incidental emotions. We consider predictions derived from several models: the Mood Behavior Model, Capacity Theories, and the Dopaminergic Model. We also propose a differentiation of the Dopaminergic Model (see Table 3.1). Models with predictions specifically regarding flexibility in the creativity domain (Broaden and Build Model; Fredrickson, 1998) are not considered.

According to the Mood Behavior Model (Gendolla, 2000), incidental emotions may not influence reversal learning because of the performance feedback inherent in the task. Although emotions can be used as a source of information about task performance and influence task effort (Schwarz & Clore, 1983), the informational value of incidental emotions is negligible when the task provides sufficient performance feedback (Gendolla, 2000).

According to Capacity Theories (e.g., Mackie & Worth, 1989), performance will be impaired after emotion induction because of the cognitive load produced by emotions. As an executive function task, reversal learning should be sensitive to reduced cognitive resources.

According to the Dopaminergic Model (Ashby, Isen, & Turken, 1999), positive affect generally enhances cognitive flexibility. Ashby et al. (1999) suggest that positive affect increases dopamine in the frontal cortex and the anterior cingulated cortex, with increased dopamine improving creativity, task switching, and flexibility. Therefore, reversal learning should be facilitated under positive affect.

We propose a differentiation of the Dopaminergic Model by taking into account different types of cognitive flexibility. Cognitive flexibility is not a unitary concept (e.g., Frick, Guilford, Christensen, & Merrifield, 1959). Controlled switching processes could be different from creative cognitive flexibility, which requires set-breaking and broad associations (Phillips, Bull, Adams, & Fraser, 2002). Reversal learning requires executive control, and emotions may have different consequences for executive function tasks than for creative behaviors (Mitchell & Philips, 2007). Furthermore, although dopamine is associated with positive affect and increased creativity (Ashby et al., 1999), dopamine impairs reversal learning (Cools, Lewis, Clark, Barker, & Robbins, 2007). Thus, a differentiated version of the Dopaminergic Model predicts that emotions facilitate different types of flexibility, e.g., emotions that typically improve flexibility in creativity tasks will reduce reversal learning.

In addition to differentiating among types of flexibility, the Dopaminergic Model may also require specification regarding the independent variable, positive emotion, because the influence of emotions of the same valence on flexibility might differ. For example, studies on flexibility in creative tasks show that emotions of different activation level differ in their effect on flexibility. Emotions can be differentiated according to the hedonic value (positive or negative) as well as the activation or arousal level (e.g., Posner, Russell, & Peterson, 2005). Although an emotion (e.g., happiness) could be more or less activating in different situations, an emotion might be more activating on average than a different emotion (e.g., relaxedness). For example, in a factor analysis of mood states, happiness, elation, and excitement loaded on a different factor than calm, relaxed, and at ease (De Dreu, Baas, & Nijstad, 2008). Generally, performance at medium levels of arousal may increase activity and performance (Yerkes & Dodson, 1908). However, at low levels of arousal, organisms may be inactive, and at very high levels of arousal, information processing capacities may also be reduced. According to the Dual Pathway to Creativity Model (De Dreu et al., 2008), medium levels of arousal caused by higher activation emotions may improve creativity in different ways depending on the valence of the emotion. For positive emotions, creativity is facilitated through flexibility in associations and for negative emotions through persistence (De Dreu et al., 2008). Low activation emotions, however, do not improve creativity (Baas, et al., 2008). Given the different influence of emotions of different activation levels on flexibility in the creativity domain, activation level may also be important for flexibility in other domains, such as learning reward contingencies.

In a recent meta-analysis on the influence of emotions on creativity (Baas et al., 2008), emotions were furthermore classified according to associated approach and avoidance tendencies. For example, successfully approaching an object or target is associated with happiness, but unsuccessfully approaching is associated with sadness. Successfully avoiding something results in relaxedness, but unsuccessfully avoiding something results in being tense (e.g., Higgins, Shah, & Friedman, 1997). That positive and negative emotions associated with approach/avoidance have different effects on cognitive flexibility in creativity has been explained with the attentional focus associated with approach and avoidance (e.g., Friedman & Förster, 2005). Promotion may enhance broad attention resulting in more flexibility in creativity tasks with promotion, whereas prevention may narrow attention and result in less creativity (Friedman & Förster, 2001).

Differences in approach/avoidance associated with an emotion may be relevant for flexibility in reversal learning as well.

Emotions of the same valence may also influence behavior in subsequent situations differently as a result of underlying appraisals associated with the emotions. For example, fear is associated with being less certain about the situation than with sadness or anger (Smith & Ellsworth, 1985). According to the Mood as Information Model (Schwarz & Clore, 1983; 2007), affective states signal which behavior is appropriate to meet the requirements of a situation. In the Appraisal Tendency Framework, this logic is applied to specific emotions (Lerner & Keltner, 2000). Differences in risk perceptions after anger or fear induction have therefore been attributed to associated differences in certainty appraisals (Lerner & Keltner, 2000). Various appraisals for various negative as well as positive emotions have been identified (e.g., Tong, 2008). Appraisals of control and certainty may be particularly relevant for reversal learning. With high control, individuals may not feel the need to identify reward contingencies. However, low control may indicate that it is important to increase predictability by understanding changes in reward contingencies. Therefore, we suggest that emotions of the same valence with different appraisals may also influence reversal learning differently.

Present Study

To examine the role of different positive and negative emotions on reversal learning, we conducted an experiment with four emotions (sadness, worry, happiness, and relief) and a control condition. The emotions differ in valence but also in activation level and associated approach/avoidance tendencies. Happiness and relief were selected as positive emotions; worry and sadness as negative. In line with previous research, happiness and worry can be classified as higher in activation and sadness as lower (compare De Dreu et al., 2008). Finally, happiness and sadness can be associated with approach, whereas relief and worry can be associated with avoidance (Carver, 2009; Higgins et al., 1997).

The emotions can also be differentiated according to underlying appraisals. Happiness is typically associated with pleasantness, certainty, and perceived control (e.g., Smith & Ellsworth, 1985). Happiness can additionally be characterized by believing that the world is good and fair, high self-regard, social appropriateness, and change (Tong, 2008). Relief may be characterized by ascribing agency to circumstances, perceiving little autonomy, and change (Tong, 2008). Sadness is associated with unpleasantness, little responsibility, and little situational control (compare Smith & Ellsworth, 1985). Worry is characterized by high unexpectedness, goal obstructiveness, external causation, and low coping ability (Scherer & Ceschi, 1997). Thus, the emotions differ on a variety of appraisals. As discussed in the previous section, differences in control appraisals may be particularly relevant for reversal learning, and happiness is relatively higher in perceived control than relief, sadness, and worry.

Differences in reversal learning profiles for combinations of happiness, relief, worry, and sadness may indicate which underlying dimension (activation, approach/avoidance) or appraisal (e.g., control) is relevant for reversal learning. This knowledge will be useful for generalizing the findings to other emotions and for theory building.

According to the Mood Behavior Model, the four emotion conditions will not differ from the control conditions, because emotions have little informational value when the task itself provides sufficient performance feedback. Capacity Theories predict that emotions will reduce regulative flexibility compared to the control condition, because emotions increase cognitive load. According to the Dopaminergic Model, happiness and relief will improve regulative flexibility because positive emotions generally improve cognitive flexibility, but the model does not make predictions for negative emotions. Finally, according to the Differentiated Dopaminergic Model, happiness will reduce reversal learning because, mediated by increased dopamine, happiness impairs controlled switching processes such as reversal learning; no predictions are made for the other emotion conditions.

Method

Participants

Seventy-seven participants[1] (40 female, M age = 18.9) from a large Midwestern university participated in the study for partial course credit. The majority of the participants were Caucasian (75%), and some were Asian/Asian-American (16%), Latino/a (4%), African-American (1%), and of other ethnicities (4%).

Procedure

Participants were told:

“This study has two parts. First, we are interested in characteristics of you, such as gender and age, and your performance on a creative writing task. In the second part, we will ask you to do a reaction time measure on the computer.”

Participants were randomly assigned to one of the emotion conditions (happy, relieved, sad, or worried) or the control condition. Participants had ten minutes to complete demographic questionnaires and to write an emotion arousing essay (participants could not precede until ten minutes passed). A feeling thermometer was then administered to assess current emotions, followed by the computerized Reversal Learning Task (15 minutes). The experimenter stayed with participants during the practice trials of the task to answer questions. At the end of the study, participants were debriefed.

Measures

Emotion Arousal. We employed the method of life event essays to induce emotion. The instructions for the happy condition read “Remember a recent event in your life that made you feel HAPPY and POSITIVE. Visualize the event in your mind, imagine the event vividly. Try to re-experience the original perceptions, sensations, and affective reactions. Write down the imagined event and elaborate on your thoughts and feelings.” ‘Happy’ was replaced with ‘relieved,’ ‘worried,’ or ‘sad,’ and, in the worried and sad condition, ‘positive’ was replaced with ‘negative.’ Control condition participants were asked to write about going to the drug store.

Mood assessment. After the emotion arousal, participants were asked to indicate how they felt, at this moment, on five 9-point items anchored with “very bad - very good,” “irritable – pleased,” “happy – sad,” “depressed – relieved,” “calm – worried,” respectively.

Reversal Learning Task. In the Reversal Learning Task, participants saw two stimuli and selected the one that had a higher chance of being ‘correct.’ Unknown to participants, the probability of a stimulus being correct was 80%. Participants learned which stimulus was correct through feedback (rule learning). The stimulus that was correct changed twice (first and second reversal learning). Participants were told that the correct stimulus can change, but not how often or when. We used the E-prime script of Waltz and Gold (2007). Stimuli were grey-scale fractals. Participants needed to select the correct stimulus in nine trials out of ten (programmed in blocks of five) before the pattern changed. If the participant did not reach this criterion, the pattern changed after the 50^{th} trial. The program allowed up to two reversals. Participants repeated the task three times with different stimulus pairs.

Results

Manipulation Check

Participants differed in their emotion ratings across conditions.[2] A mixed analysis of variance with the five feeling thermometer items as repeated measures and emotion condition as the between factor showed a main effect of condition, $F(4, 71) = 4.36$, $p = .003$, that was qualified by an interaction with rated emotion, $F(16, 284) = 1.89$, $p = .022$. Participants in the positive conditions felt more positive (6.65) than participants in the negative (5.41) conditions, $t(58) = 3.39$, $p = .001$. The difference between the negative and the neutral (6.23) conditions approached significance, $t(41) = 1.75$, $p = .088$. The neutral condition did not result in significantly less positive feelings than the positive conditions, $t(47) = 1.09$, $p = .281$.

Participants in the happy condition felt as happy (‘sad’ was reverse coded) as in the relieved condition (6.19; 6.29), $t(31) = 0.12$, $p = .902$, and also as relieved (6.50; 6.65), $t(31) = 0.29$, $p = .774$. Participants in the sad condition felt as sad as in the worried condition (4.83; 5.47), $t(25) = 0.04$, $p = .968$, and as worried (3.33; 3.67), $t(25) = .42$, $p =$

.677. Thus, at the level of specific emotions, the manipulation was less successful than at the level of positive compared to negative emotions according to self-reported feelings.

Hypothesis Test

We computed the number of trials that participants took to learn a rule/reversal as a dependent measure. For those subjects who did not reach a reversal within 50 trials and thus had no value for the reversal, missing data were replaced by the sample mean plus two standard deviations (a score of 49)[3]. The number of trials for rule/reversal learning was averaged across the three repetitions, so that each subject had one score for each rule, first reversal, and second reversal learning ranging from 10 (good performance) to 50 (poor performance).

A mixed analysis of variance with rule/reversal mean number of trials as a within factor and condition as a between factor showed a significant main effect of rule/reversals, $F(2, 144) = 83.64$, $p < .001$. Rules were initially learned faster (22.40) than first and second reversals (31.55; 31.64), $t(76) = 9.55$, $p < .001$ and $t(76) = 9.44$, $p < .001$; see Figure 3.1. A main effect of emotion condition, $F(4, 72) = 3.35$, $p = .014$, was qualified by an interaction of condition with rule/reversal learning, $F(8, 144) = 2.21$, $p = .038$. In the happy condition, participants learned rules about as fast as the control participants (26.56; 20.83), $t(30) = 1.52$, $p = .140$, but took longer to learn first reversals (37.88; 28.81), $t(30) = 2.01$, $p = .054$, and second reversals (38.25; 28.79), $t(30) = 2.19$, $p = .037$. The other emotion conditions did not differ from the control for rule or reversal learning, all *p*s > .05. Compared to relieved participants (18.82; 23.45; 24.14), happy participants took longer to learn rules, $t(31) = 2.43$, $p = .021$, first reversals, $t(31) = 3.43$, $p = .002$, and second reversals, $t(31) = 3.28$, $p = .003$.

To examine whether poorer performance in the happy condition was due to faster reaction times, we ran a mixed measures analysis of reaction times in rule/reversal learning as the within factor and emotion condition as the between factor. This analysis showed a main effect of rule/reversal learning, $F(2, 80) = 23.04$, $p < .001$, and no other effect. Reaction times were longer for rule learning than first and second reversal learning, (694; 593; 594), $t(54) = 5.13$, $p < .001$, $t(44) = 4.89$, $p < .001$. Including the average reaction time as a covariate in the main analysis did not change the results for the interaction between emotion conditions and rule/reversal learning, $F(8, 142) = 2.13$, $p = .037$.

Post-hoc Analysis of Essays

The essays were content coded to verify condition assignment. One rater coded all essays and one rater coded 66 essays, both blind to condition. They achieved an acceptable level of rater agreement (Cohen's kappa = .75; in case of disagreements, the codes of the rater who rated all essays were used). In the happy, sad, and control condition, essay codes reflected condition assignment for all but one, one, and two participants, respectively. However, in the relieved and worried condition, the essays of five and six participants, respectively, could not be identified by the coders. When selecting only those participants whose essays reflected their condition assignment, the pattern of the results remained the same. Happy participants did not differ from control participants for rule learning (27.56; 22.14), $t(27) = 1.38$, $p = .118$, but took longer to learn first reversals (39.29; 30.55), $t(27) = 1.92$, $p = .066$, and second reversals (39.69; 30.29), $t(27) = 1.25$, $p = .041$. The other emotion conditions did not differ from the control for rule or reversal learning, all *p*s > .05. Also, happy participants took longer to learn rules and reversals than relieved participants (20; 24.75; 27.11), $t(25) = 2.06$, $p = .05$; $t(25) = 3.00$, $p = .006$; $t(25) = 2.63$, $p = .015$.

Discussion

A Reversal Learning Task was used to study the effect of different positive and negative emotions on cognitive flexibility. We found that happiness impaired reversal learning but relief did not impair reversal learning. The effect cannot be attributed to faster reaction times in the happy condition. A limitation of our study is that the manipulation checks did not differentiate between positive (negative) emotions. However, the analysis of the essays suggests that condition assignment was generally successful. Given the significant effects on performance, it is possible that the manipulation checks were insensitive to the differences between positive emotions. Future research should differentiate between these emotions more clearly.

As happiness differed from another positive emotion (relief), the influence of happiness cannot be attributed to positive valence. Also, the activation level associated with the emotions does not seem useful to explain the findings, since happiness and worry differed in their effect. Similarly, happiness and sadness differed in the influence on reversal learning, suggesting that differences in approach/avoidance orientation did not explain the effect.

However, the underlying appraisals of happiness, relief, sadness, and worry may be important for reversal learning. Appraisals associated with an emotion may signal which behavior is most required (Lerner & Keltner, 2000; Schwarz & Clore, 2007). Happiness differs from the other three emotion conditions on several appraisals. For example, control might play a role for performance. Specifically, good performance in the reversal learning task might be a function of increased attempts to regain control, after an event where one lacked control and autonomy signals the need to reestablish control. When feeling happy, however, the individual is already provided with a sense of control, and there is no need to establish control. However, if perceptions of control drive the influence of emotions on reversal learning, sadness, worry, and relief should improve performance compared to the control condition. This was not the case in the present study. However, stronger mood manipulations might have resulted in a difference of a control compared to a relief, worry, and sadness condition. Thus, further research is required to rule out the importance of control appraisals. Alternatively to control, the belief in a good and fair world might drive the effect. This belief goes beyond perceiving that a situation is not problematic. It entails the idea that things are not only fine, but at their best. As a result, perceptions that the world is good and fair do not require an individual to understand the logic of changes in reward-contingencies, and may not induce attempts to increase predictability. A belief in a good world should be more prominent with happiness than relief, worry, sadness, or a control. Future research should examine the importance of control appraisals and beliefs in a good world for performance in reversal learning.

The prediction from the Mood Behavior Model that incidental emotions affect performance when performance feedback is given was not supported. Similarly, the predictions from Capacity Theories that emotions impair performance were not supported. According to the Dopaminergic Model, happiness and relief should improve cognitive flexibility. However, we found that positive emotions differ in how they influence reversal learning: Happiness impaired flexibility, and relief showed a tendency to improve it.

The results are in line, however, with a Differentiated Dopaminergic Model. According to this model, positive emotions have differential effects on different types of cognitive flexibility. We found that happiness is particularly hurtful for reversal learning. However, past research has shown that happiness improves flexibility in the creativity domain (De Dreu et al., 2008). Thus, our study indicates that happiness can have facilitating or impairing effects on different types of flexibility.

We suggest that flexibility in creativity and in reversal learning belong to different types of flexibility. We distinguish between *associative* and *regulative* flexibility and suggest that emotions influence these two types of flexibility in opposing ways. Also, we propose a taxonomy of related tasks. Associative flexibility involves breaking a set of typical associations and creating new associations. Associative flexibility is characterized by originality and an affinity to the new and unusual. It is based on associative networks that are activated unconsciously and effortlessly. Tasks measuring primarily associative flexibility are remote associates tasks (e.g., Mednick & Mednick, 1967), insight problem solving tasks (e.g., Duncker, 1945), categorization tasks (e.g., Isen & Daubman, 1984), and idea generation tasks (e.g., Torrance, 1974). In remote association tasks, unusual connections result in finding a concept common to given stimuli. In insight problem solving tasks, making associations between objects and unusual uses facilitates finding a solution. In categorization tasks, perceived connections between objects and concepts result in more inclusive categories. Similarly, in brainstorming or fluency tasks, solutions are seen as belonging to the pool of answers based on unusual associations.

Regulative flexibility is an executive function relevant to changing rules. It refers to the ability to adjust to different stimulus-reward associations (reward-based control; Rogers et al., 1999). Examples of reward-based tasks are the Reversal Learning Task (e.g., Clark, Cools, & Robins, 2004; Waltz & Gold, 2007) and the Regime Change Task (Massey & Wu, 2005). Having high regulative flexibility does not result in being original and creative, but in being able to adjust to lasting changes in the environment. The ability to identify new rules, to inhibit perseverance of old rules, and to maintain new rules are characteristics of regulative flexibility. Performance on executive tasks is effortful and decreases when cognitive load is increased (e.g., Phillips, 1997). The specific task requirements and the degree of task difficulty are fruitful avenues for future research on the influence of emotions on cognitive flexibility.

An explicit taxonomy of tasks complements the distinction between associative and regulative flexibility that has similarly been suggested by others (Phillips et al., 2002). Our goal is to integrate the existing research on flexibility types (Phillips et al., 2002) with research distinguishing among positive and negative emotions. Existing research has shown that valence, activation level, and regulatory focus of an emotion are relevant predictors for associative flexibility (e.g., Baas et al., 2008), but has not yet addressed other types of flexibility. Research on the appraisals associated with emotions has examined outcome variables such as social judgments, but not flexibility (e.g., Lerner & Keltner, 2000). Future research is needed to test the prediction that regulative and associative flexibility are differently affected by different positive and negative emotions.

Future research could also connect research on the influence of emotions on reversal learning with research on the influence of emotions on other behaviors, such as gambling behavior. Cognitive flexibility in reversal learning refers to the ability to learn changes in reward situations. It is related to decision making concerning risks, e.g. in gambling decisions (Clark, Cools, & Robins, 2004). Previous research shows that in early stages of the Iowa Gambling Task, positive affect improves performance (Vries, Holland, & Witteman, 2008). This is consistent with research showing that happiness heightens the sensitivity for losses, and results in reduced risk taking (e.g., Isen, Nygren, & Ashby, 1988). However, increased levels of dopamine in medicated Parkinson's patients increase pathological gambling (Voon & Fox, 2007). How can the notion that happiness improves gambling performance but impairs reversal learning be reconciled? We suggest that happiness might lead to improved gambling behavior when risk aversion is beneficial, but not when successful performance requires recognizing changes in reward contingencies. Understanding the factors that influence risk taking has both theoretical interest and applied relevance. For example, risk taking in gambling decisions is associated with increased drug abuse (e.g., Passetti, Clark, Mehta, Joyce, & King, 2008). Therefore, understanding the influence of emotions on flexibility in different domains has important applications.

Our study provides evidence that happiness, an emotion that typically increases associative flexibility, decreases regulative flexibility in a reversal learning task. The Dopaminergic Model, Capacity Theories, and the Mood Behavior Model cannot account for this finding. However, the findings support a Differentiated Dopaminergic Model where different emotions and types of flexibility are taken into account. The model suggests that emotions can have antagonistic effects on tasks that belong to the regulative flexibility category, such as the reversal learning task, or to the associative flexibility category, such as many creativity tasks. The integration of research identifying types of flexibility (Phillips et al., 2002), features of emotions (e.g., De Dreu et al., 2008; Tong, 2008), and underlying neural mechanisms (e.g., Ashby et al., 1999; Rogers et al., 1999) is a fruitful avenue for future research. We hope that the suggested taxonomy of tasks will help inspire and guide this process.

Footnotes

[1]Thirteen participants were suspicious about the purpose of the study and four female participants did not understand the task even after practice trials as indicated by never achieving successful reversal learning; these participants were excluded from the analysis. Including these participants in the analysis did not change the significant interaction of emotion condition and rule/reversal learning, but only the mean comparisons of happy versus relieved for learning reversals remained significant.

[2]One participant did not complete the manipulation check items.

[3]This score was given to 25.5% of all reversals across participants and at least once to 51% of participants. In a repeated measures analysis without accounting for missing data, the interaction between emotion condition and rule/reversal learning was not significant due to lack of power. However, individual comparisons (happy versus control, happy versus relieved) still resulted in significant mean differences.

Table 3.1 Predictions by different models for reversal learning performance impairment (↓) or improvement (↑) under positive and negative emotions

☺	☹	**Model**
0	0	Mood Behavior Model (Gendolla, 2000)
↓	↓	Capacity Theories (Mackie & Worth, 1989)
↑		Dopaminergic Model (Ashby et al., 1999)
↓H		Differentiated Dopaminergic Model

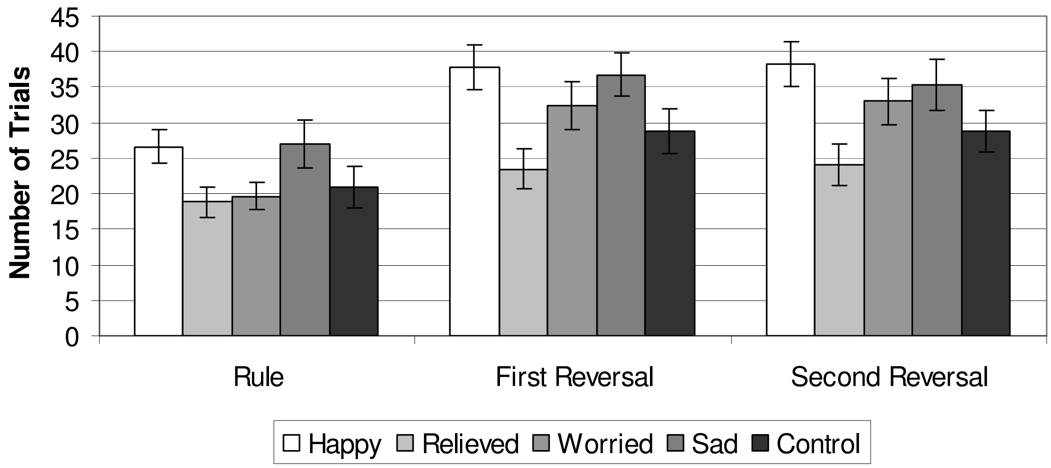

Figure 3.1. Mean number of trials to learn rules and reversals in different emotion conditions.

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Chapter 4

The Influence of Happiness and Relief on Different Types of Cognitive Flexibility

What is common to brain-storming ideas for a wedding gift, alternating checking your email with reading the news, and adapting to the fact that your teenage children give you dirty looks when you want to spend time with them after all the years of craving constant care and attention from you? All these behaviors require cognitive flexibility. Like other cognitive tendencies, cognitive flexibility is influenced by emotions (e.g., Isen, 1990).

Previous research has shown that positive affect aroused in one situation improves flexibility on a variety of tasks (Isen and colleagues). In fact, some believe that it “is now well recognized that positive affect leads to greater cognitive flexibility” (Ashby, Isen, Turken, 1999, p. 530). However, flexibility is not a unitary concept (e.g., Frick, Guilford, Christensen, &Merrifield, 1959), and whether positive affect improves flexibility may depend on the type of flexibility (Sacharin & Gonzalez, 2009). Also, positive emotions may differ in their influence on cognitive tendencies (e.g., De Dreu, Baas, & Nijstad, 2008). In the current paper, we suggest that not all positive and negative emotions influence all types of flexibility in the same way. We propose a distinction between different types of flexibility, and test the idea that they are differentially influenced by different positive emotions (study 1). We also attempt to identify mediators in the relation between emotions and cognitive flexibility (study 2).

Because the emotions are aroused prior to the performance situation and are not an integral part of it, they are called incidental emotions (as opposed to integral emotions; Bodenhausen, 1993). Emotions can be defined as a syndrome of a subjective feeling (e.g., pleasant, aroused), a judgment about the situation (e.g., you are responsible), behavioral tendencies that encompass cognition (e.g., global versus local; flexible versus inflexible) and action (e.g., approaching versus avoiding), physiological changes (e.g., heart rate), and sometimes an emotion label (e.g., happy). As briefly reviewed in the following section, research on the influence of emotions on cognitive flexibility in some domains (e.g., creativity) is well established, and several theories exist to explain the effect of emotions.

Previous Research on Emotions and Flexibility

Positive affect improves performance on a variety of tasks involving creativity. For example, individuals in a happy mood categorize more inclusively (Isen & Daubman, 1984), generate more ideas in brain-storming tasks (Isen, Labroo, & Durlach, 2004), and solve remote associate problems better (Isen et al., 2004). Recent meta-analyses (Baas, De Dreu, & Nijstad, 2008; Davis, 2009) confirm that happiness generally improves creativity in these types of tasks. Several models have been proposed to explain why emotions influence cognitive tendencies (e.g., Broaden and Build Theory, Fredrickson, 1998; Mood as Information Model, Schwarz & Clore, 1983). According to the Dopaminergic Model (Ashby et al., 1999), the influence of positive emotions on cognitive tendencies is a function of increased levels of dopamine. However, for several reasons, a further specification of this model may be necessary.

Although the Dopaminergic Model assumes that dopamine improves all types of flexibility, there is some indication that dopamine does not always facilitate flexibility. For example, in Parkinson's patients, medication-induced increases of dopamine reduce flexibility in rule learning (Cools, Lewis, Clark, Barker, & Robbins, 2007). Recent research shows that "dopamine and dopamine receptor agonists have contrasting effects on the expression of function depending on, among other factors, the brain region that is implicated by the process under study, the baseline levels of dopamine in that brain region and receptor specificity" (Cools, 2008, p. 383).

An additional challenge for existing theories on the relation between positive emotions and flexibility is that they do not account for instances where positive affect impairs flexibility. For example, positive affect increases response times in a switching Stroop task (Phillips, Bull, Adams, & Fraser, 2002). Also, happiness impairs flexibility in reversal learning (Sacharin & Gonzalez, 2009). Thus, positive affect is beneficial for certain types of flexibility but not for others. Specifically, flexibility in the creativity domain could be different from controlled switching processes (Phillips et al., 2002). Even flexibility in executive functions can refer to different types of control, such as reward-based or attention-based (Rogers et al., 1999, Slamecka, 1968). Thus, a differentiation of the Dopaminergic Model regarding different types of flexibility seems necessary.

A further specification of the Dopaminergic Model concerns the category 'positive affect' because emotions of the same valence may influence the same type of flexibility differently. For example, flexibility in the creativity domain is influenced differently by different positive emotions. Specifically, in a recent meta-analysis positive emotions classified as activating (e.g., happiness) increased idea generation, but emotions classified as de-activating (e.g., relaxedness) did not (Baas, De Dreu, & Nijstad, 2008). Also, flexibility in learning changes in reward contingencies is differentially influenced by positive emotions. Here, the pattern of results for happiness was opposite to the findings for flexibility in the creativity domain. Specifically, happiness impaired performance in reversal learning, but relief did not (Sacharin & Gonzalez, 2009).

These different outcomes of happiness could be explained by the appraisals underlying different positive emotions. For example, happiness is typically associated with pleasantness, certainty, and perceived control (e.g., Smith & Ellsworth, 1985), and can additionally be characterized by a belief that the world is good and fair, high self-regard, social appropriateness, and change (Tong, 2008). Relief may be characterized by ascribing agency to circumstances, perceiving little autonomy, and being less certain than with happiness (Tong, 2008). Also, the perceived pleasantness of a situation changes from negative to positive. Thus, happiness is relatively higher in perceived control, certainty, and beliefs in a good and fair world than relief. These differences may be important for subsequent cognitive flexibility. For example, perceptions of control may provide a safe base for exploring unusual ideas and thereby increase flexibility in creative tasks (Fredrickson, 1998; Schwarz & Clore, 2007). However, perceiving little control might induce behaviors to regain control, such as carefully monitoring reward-contingencies. On the other hand, when feeling happy, individuals may already be provided with a sense of control and feel no need to establish control, thereby reducing performance in tasks that require monitoring changes in reward contingencies, such as reversal learning.

Although a large body of research suggests that positive affect facilitates flexibility, it seems necessary to consider more precisely which positive emotions might improve or impair which types of cognitive flexibility. We propose a differentiation of the Dopaminergic Model that takes into account different positive emotions as well as different types of flexibility. In the next section, we differentiate between associative, regulative, and attentional flexibility.

Types of Flexibility

We propose a distinction between associative, regulative, and attentional flexibility, and suggest that emotions influence these types of flexibility in different ways. Distinguishing among different types of flexibility is not a new idea. In 1959, Frick et al. published a factor analytic study of flexibility and a related taxonomy of tasks. They distinguished between "spontaneous" and "adaptive" flexibility. They defined spontaneous flexibility as "the ability to produce a diversity of ideas in a relatively unstructured situation," and adaptive flexibility as "the ability to change set in order to meet requirements imposed by changing problems" (p. 471). Similarly, Phillips et al. (2002) differentiate spontaneous from controlled flexibility. Furthermore, reward-based and attention-based control processes seem to differ (Rogers et al., 1999; Ravizza & Carter, 2008). Reward-based control refers to "learning revised stimulus-reward linkages" and attention-based control to "the reallocation of attention towards newly-relevant features of environment stimuli" (Rogers et al., 1999, p. 488). Therefore, we differentiate three types of flexibility: associative flexibility ("spontaneous"), regulative flexibility (controlled, reward-based), and attentional flexibility (controlled, attention-based, "adaptive").

Associative flexibility involves breaking a set of typical associations and creating new associations. Associative flexibility is characterized by an affinity to the new and unusual, as well as inclusiveness. Novel ideas are perceived as part of the universe of possible solutions to a problem. It is based on associative networks that are activated unconsciously and effortlessly.

With regulative and attentional flexibility, the changes are not created by the individual, but imposed by the environment. Regulative flexibility refers to the ability to adjust to different stimulus-reward associations (reward-based control; Rogers et al., 1999). For example, in social interactions, the mood of others might change. Regulative flexibility is necessary to learn when the mood of a person changes, and when somebody who used to be happy is now in a negative mood, and vice versa (e.g., Kringelbach & Rolls, 2003). For regulative flexibility, the ability to identify new reward-contingencies and inhibit perseverance of old contingencies is crucial. This is what defines the flexibility. Additionally, regulative flexibility is characterized by the ability to maintain new contingencies (in contrast to a mere affinity to things new). Regulative flexibility is associated with activity in the ventral striatum and orbiofrontal cortex (Cools, Barker, Sahakian, & Robbins, 2001).

Attentional flexibility refers to the ability to switch attention between different types of stimulus features or stimuli (attentional control; extra-dimensional set-shifting; Rogers et al., 1999). For example, books in a shelf can be arranged according to publisher or according to color. When cleaning a room one could pay attention to the clothes that need to be folded or to the papers scattered on the floor. Attentional flexibility is associated with the dorsal striatum and the dorso-lateral prefrontal cortex (Cools et al., 2003).

Regulative flexibility and attentional flexibility are executive functions. Executive processes are involved in conscious, effortful control and regulation of cognition and behavior (Phillips, 1997). As a result, performance on executive tasks decreases when cognitive load is increased (e.g., in a dual-task paradigm; Phillips, 1997). However, regulation strategies that are initially effortful can become automatic, and are then no longer considered an executive process (Phillips, 1997; Rabbitt, 1997). Like other executive functions, such as working memory, continuous inhibitions, and planning, regulative and attentional flexibility are likely to be correlated with the broader concept of fluid intelligence (Rabbitt, 1997).

Although associative flexibility is prevalent in creativity, and regulative and attentional flexibility are prevalent in executive functions, we refrain from calling the flexibility types "creative" flexibility and "executive function" flexibility. Creativity can also be achieved by other means, such as persistence (e.g., De Dreu et al., 2008), and acknowledging something as 'creative' depends on the environment (e.g., Sternberg, 2006). In fact, past research shows that positive affect does not facilitate performance on some types of creativity tasks (e.g., Akinola & Mendes, 2008). Also, response latencies in insight problem solving can be impaired under positive affect (Kaufmann & Vosburg, 1997). Similarly, executive function refers to several abilities that are influenced by emotions, such as planning. For example, positive affect impairs performance on the Tower of London task (Oaksford, Morris, Grainger, & Williams, 1996). However, planning involves primarily working memory (Oaksford et al., 1996) rather than flexibility. Instead of differentiating creative behavior and executive functions more broadly, the purpose of the present framework is to differentiate between different types of flexibility which may or may not play a role in creativity and in different executive functions.

Assessment of Associative, Regulative, and Attentional Flexibility

An explicit taxonomy of tasks (Table 4.1) complements the distinctions between associative, regulative, and attentional flexibility that have been suggested by others (Phillips et al., 2002; Rogers et al., 1999; Slamecka, 1968). Tasks primarily measuring associative flexibility are insight problem solving tasks (e.g., Duncker, 1945), categorization tasks (e.g., Isen & Daubman, 1984), idea generation tasks (e.g., Torrance, 1974), and remote associates tests (e.g., Mednick & Mednick, 1967). In insight problem solving tasks, making associations between objects and unusual uses facilitates finding a solution. In categorization tasks, perceived connections between objects and concepts result in more inclusive categories. Idea generation and remote associates tasks are used in the current study, and thus deserve more detailed introduction.

In idea generation, brainstorming, or fluency tasks, participants are asked to generate a lists of solutions to a certain problem, such as a list of things that can fly (e.g., Gasper, 2004), uses of a brick (e.g., Davis, Kirby, & Curtis, 2007; Guilford, 1960), or words starting with a certain letter of the alphabet (e.g., Isen et al., 2004). A formal version of the task is The Torrance Test of Creative Thinking (Torrance, 1974), which provides standardized instructions for this type of task, as well as normative data. Responses to idea generation tasks can be analyzed for quantity (fluency), unusualness of responses (originality), amount of detail in responses (elaboration), and number of different categories of answers (flexibility; Guilford, 1967; Torrance, 1974). Fluency in idea generation tasks is not a pure measure of associative flexibility, because individuals can use systematic strategies to perform well in fluency tasks (Phillips, 1997); however the degree to which individuals use associations versus strategies can be assessed by measuring the flexibility and originality of answers in this type of task. Past research shows that happiness increases fluency, category flexibility, and originality (e.g., Murray, Sujan, Hirt, & Sujan, 1990). In line with the Dopaminergic Model (Ashby et al., 1999), Parkinson's patients with depleted dopamine (off medication) show reduced performance on fluency tasks (Gotham, Brown, & Marsden, 1988).

The remote associates test was developed by Mednick (1962) to measure creative thinking. In this task, participants see three stimulus words and have to create a solution that meaningfully relates to all stimuli. In some remote associates tests, the way the solution relates to the stimulus words differs; e.g., in the triad "same-tennis-head," the solution "match" relates to one word as a synonym (same-match), builds a compound word with another word (match head), and is a semantic association with the third word (tennis match; Bowden & Jung-Beeman, 2003). Bowden and Jung-Beeman (2003) created remote associate items where solutions build compound words with each stimulus word, and describe normative data for the difficulty of items under different time constraints. In remote associates tests, unusual connections between concepts result in finding a solution. Performance on remote associates tests is improved with happiness (e.g., Isen et al., 2004). Both idea generation and remote associates tasks belong in the category of associative flexibility.

Another type of flexibility, regulative flexibility can be assessed with reversal learning tasks (e.g., Clark, Cools, & Robins, 2004; Waltz & Gold, 2007) and the Regime Change Task (Massey & Wu, 2005). A reversal learning task is used in the current study, and is described below in more detail.

In a reversal learning paradigm (e.g., Rolls, 2004), participants are asked to select one of two stimuli and learn through feedback whether the stimulus is 'correct.' First, participants learn the rule that one stimulus has a higher chance of being correct. However, the stimulus that is reinforced changes throughout the task. Flexibility is required to learn these rule reversals. The ability to learn reversals is important for adapting to changes in rewards regarding basic behaviors, such as the acquisition of tasty foods, as well as social situations (e.g., Kringelbach & Rolls, 2003). Previous research shows that happiness, but not relief, impairs performance on reversal learning (Sacharin & Gonzalez, 2009). In line with a differentiated Dopaminergic Model, Parkinson's patients with higher levels of dopamine (on medication) show reduced performance on this task (Cools et al., 2007).

Examples of attentional flexibility tasks are the Wisconsin Card-Sort Task (Berg, 1948; Heaton, 1981), the Implicit Association Task (Greenwald, McGhee, & Schwartz, 1998), Task Switching Tasks (e.g., Monsell, 2003), and the California Card Sorting Test (CCST; Delis, Squire, Bihrle, & Massman, 1992). For the Wisconsin Card-Sort Task and the CCST, individuals have to figure out what they need to attend to themselves. In the Implicit Association Task (Greenwald et al., 1998) and Task Switching Tasks (e.g., Monsell, 2003), the relevant feature that requires attention is indicated by the task. A CCST is used in this study and will be described in more detail.

The CCST consists of three stimulus sets with six stimuli. For each set, three sub-tasks are administered. In the Free Sorting sub-task, participants are asked to sort the items repeatedly into two equal piles and state a sorting rule for each pile. Items can be sorted according to three verbal criteria (e.g., land versus water animals), or according to three non-verbal criteria (e.g., black versus white triangle). This sub-task measures the ability to generate sorts, verbalize sorting principles, and inhibit perseverative sorts and descriptions. In the Structured Sorting sub-task, participants are presented with different sorts, and are asked to identify the sorting rule for each pile. This sub-task measures the ability to verbalize sorting principles and inhibit perseverance in sorting descriptions. In the Cued Sorting sub-task, participants are asked to sort the items according to cues given by the experimenter. This sub-task measures the ability to comprehend sorting rules. The procedure repeats with each stimulus set.

The task appears similar to the Wisconsin Card Sorting Test (Heaton, 1981). However, psychometric analyses show that it does not measure the very same abilities (Greve, Farrell, Besson, & Crouch, 1995). Also, the CCST allows for more refined analyses (Delis et al., 1992). For example, verbal and nonverbal concept formation can be differentiated in the CCST. Also, the task allows differentiating between deficits in knowing sorting rules and enacting sorting rules. Furthermore, the CCST does not provide performance feedback, and is thus potentially less aversive for respondents, compared to the Wisconsin Card Sorting Test and the reversal learning task.

To our knowledge, there are no data on the influence of emotions on performance on the CCST. On the one hand, some evidence suggests that positive affect might increase performance. For example, children switch sorting criteria (e.g., sort faces by gender or by age) more easily when happy face stimuli are used than sad face stimuli (Qu & Zelazo, 2007). The paradigm used in this study is similar to the Cued Sorting sub-task of the CCST. However, the results could be due to the fact that sad faces capture attention more than happy faces, and reduce the ability to perform additional cognitive tasks (Eastwood, Smilek, & Merikle, 2003). Research on medicated Parkinson's patients is mixed. On the one hand, Parkinson's patients show impairments in set-shifting (Cools et al., 2001; Downes et al., 1989). On the other hand, dopamine medication does not seem to change performance (Lewis, Slabosz, Robbins, Barker, & Owen., 2005), suggesting that decreased performance by patient groups is not due to changes in dopamine levels. Finally, switching between different sorting criteria (e.g., color of word versus word meaning) in a Stroop task is impaired with happiness (Phillips et al., 2002). Thus, the existing evidence for the influence of emotions on attentional flexibility is inconclusive.

Study 1

The goal of this paper is to integrate the existing research on flexibility types (Swainson et al., 2000; Phillips et al., 2002) with research distinguishing among emotions of the same valence (e.g., De Dreu et al., 2008; Lerner & Keltner, 2000). We aim to test the prediction that associative, regulative, and attentional flexibility are differently affected by different positive emotions, specifically happiness and relief.

There exists evidence for differential outcomes of different emotions on different types of flexibility. Past research shows that the influence of different positive and negative emotions varies for tasks from the associative flexibility category (e.g., Baas et al., 2008). Also, happiness and relief influence regulative flexibility in reversal learning differently (Sacharin & Gonzalez, 2009). However, to our knowledge no study has compared the influence of emotions on regulative and associative flexibility. The simultaneous assessment of both types of flexibility is necessary to rule out confounding effects. For example, it is possible that the happiness condition used in previous research on reversal learning (Sacharin & Gonzalez, 2009) differed from that used in research on associative flexibility tasks in a systematic way, and therefore resulted in reduced performance on subsequent tasks, regardless of whether they were associative or regulative flexibility tasks. To compare performance on associative and regulative flexibility directly, both types of flexibility need to be assessed in the same study.

The additional benefit of a within-subjects design with associative and regulative flexibility is that it can provide more specific insights. For example, does happiness improve associative flexibility and reduce regulative flexibility merely at a group level, or do individuals show negative correlations between those types of flexibility? The relation between variables need not necessarily reflect group differences in these variables (see Figure 4.1). For example, in dyads, trust and satisfaction might be positively related, because couples where trust is high are also more satisfied. However, on the individual level, trust and satisfaction might not be high if an individual's trust is not reciprocated (Gonzalez & Griffin, 2001). More generally, differences between groups on two continuous variables, A and B, do not provide information on the relation between variables A and B in individuals. Intuitively, if group H (happiness) is high on variable A (e.g., associative flexibility) and low on variable B (e.g., regulative flexibility), and group C (control) is low on variable A and high on variable B, one expects a negative relation between A and B corresponding to line 1 in figure 4.1. Generalizing from the group level of analysis to the individual level is called the "ecological correlation fallacy" (Robinson, 1950). Although a correspondence between levels of analysis is the easiest relation to comprehend, it is not the only way A and B could be related. For example, in Figure 4.1, the variables A and B might show a negative (1) or positive (2) linear relation, or no linear relation (3), regardless of group differences between group H and C. Discussions of empirical cases where group differences are not reflected in individual differences are provided by Robinson (1950). It is therefore an empirical question whether variables are related in individuals in a way similar to group differences.

Another advantage of the simultaneous assessment of different types of flexibility is that it is possible to examine whether the effects of emotions are stronger for one type of flexibility than for the other. According to the Mood Behavior Model (Gendolla, 2000), incidental mood can be used as information that influences associations and cognitive processing. The model emphasizes that mood is but one piece of information about a situation. Information given by the task itself, for example, about how difficult it is or via direct performance feedback, can reduce the effect of incidental mood as information. Given that executive function tasks are inherently effortful (Phillips, 1997), the informational value of emotions might be relatively higher for associative flexibility tasks than for regulative and attentional flexibility tasks resulting in a smaller influence of emotions on the latter two.

Hypotheses

In the current study, we simultaneously compare the influence of happiness, relief, and a control condition on associative, regulative, and attentional flexibility. Associative flexibility is assessed with an idea generation and a remote associates task, regulative flexibility with a reversal learning task, and attentional flexibility with a

CCST. Based on the literature review, we expect that happiness will increase performance for idea generation and remote associates, and decrease performance for reversal learning. For relief, we expect no difference relative to the control condition based on previous research on reversal learning (Sacharin & Gonzalez, 2009). The influence of emotions on performance on the CCST will be explored. The influence on attentional flexibility will be explored, because previous research and theory do not provide sufficient ground to derive a hypothesis (see Table 4.2).

Method

Participants

Sixty-two women (mean age 19) participated in the study for partial course credit. They were largely Caucasian (73%), with a minority of Asians/Asian-Americans (15%), African-Americans (5%), Latinas (5%), and others (3%). From an originally larger sample of eighty-three, eight suspicious participants were excluded, as well as thirteen participants who did not perform one of the four tasks due to computer errors and several fire alarms, or because the study went over the allotted time and had to be discontinued prematurely.[1]

Procedure

Participants were told that we were conducting two studies: One on the effect of length of essay writing on feelings, and a second on the relation between various cognitive tasks. After signing a fake consent form for each study, participants were randomly assigned to a happy, relieved, or control condition. After participants provided two events where they felt happy, relieved, or selected two weekdays (Monday – Thursday), we asked participants to write about the first event (weekday) for 9 minutes.

After a manipulation check where participants indicated their current feelings, the first block of cognitive tasks was administered. Then, we induced moods again by asking, participants to write a longer essay about the second event (weekday) for 9 minutes, followed by a second manipulation check, and a second block of cognitive tasks. In one cognitive task block, regulative flexibility was assessed with a reversal learning task that measures reward-based control. In the other block, attentional control was assessed with a CCST (Delis et al., 1992), and associative flexibility was assessed with a remote associates test (Bowden & Jung-Beeman, 2003), and an idea generation task. The order of these tasks was counter-balanced. The order of the blocks was also counterbalanced. Participants provided demographic information before they were probed for suspicion, debriefed, and asked to sign the consent form for the entire study. The duration of the study was about one hour.

Measures

Emotion arousal. We employed the method of life event essays to induce emotion. The instructions for the happy condition read "Remember a recent event in your life that made you feel HAPPY and POSITIVE. Visualize the event in your mind, imagine the event vividly. Try to re-experience the original perceptions, sensations, and affective reactions. Write down the imagined event and elaborate on your thoughts and feelings." In the relieved condition, 'happy' was replaced with 'relieved.' Control condition participants were asked to write about a regular week-day.

Mood assessment. After the emotion arousal and again at the end of the study, participants were asked to indicate how they felt, at this moment, on five 9-point items anchored with "very bad - very good," "very unhappy – very happy," "not at all relieved

– very relieved,” “very calm – very active,” and “very certain / not confused – very uncertain / confused.”

Idea generation task. Participants were asked to generate as many different ideas as possible for uses of a brick. They had a total of five minutes to generate ideas. In addition to recording participants’ responses, we also recorded response times to compute the number of ideas within the first minute, the first two minutes, and five minutes. Ideas were counted (so-called fluency), and coded for number of different categories used (category flexibility), and unusualness of ideas (originality).

While computing the fluency score is relatively straightforward, determining the category flexibility and the originality score requires some explanation. Two coders blind to emotion condition coded for 18 content categories, plus one category of inadequate responses (see Table 4.3 for examples). Coder agreement was good with Cohen’s kappa = .88. Disagreements were resolved through discussion. Category flexibility was determined by the sum of different categories used (regardless of the number of ideas within each category). Unusualness was based on the frequency of the answers within the sample. We identified categories that contained fewer than 1% of all ideas (Identifier, Gift, Heating, Study Material, Ground Brick, Hiding Place, Fix), and summed all ideas from these categories, as well as from the category “Other,” to build an unusualness score. Thus, more elaborate ideas that fell into a more common category (e.g., from the category Build, “To build a fort for a little kid”) were not included in this score.

Remote associates test. We selected 30 items from Bowden and Jung-Beeman (2003). Based on the norms provided by these authors, two items were of low difficulty (66% - 80%) of participants reached a solution in 15 seconds), 27 items of moderate difficulty (39 – 61 %), and one item of high difficulty (22%). Items were presented in random order. The program proceeded to the next stimulus item as soon as participants had typed their solution and hit ‘enter,’ or after 15 seconds passed. Before participants started the task, they were given instructions with two example items. We recorded participants’ solution words as well as their response time. The maximum score for correct solutions was 30.

Reversal learning task. In the reversal learning task, participants saw two stimuli and selected the one that had a higher chance of being ‘correct.’ Unknown to participants, the probability of a stimulus being correct was 80%. Participants learned which stimulus was correct through feedback (rule learning). The stimulus that was correct changed twice (first and second reversal learning). Participants were told that the correct stimulus could change, but not how often or when. We used the E-prime script of Waltz and Gold (2007). Stimuli were grey-scale fractals. Participants needed to select the correct stimulus in 9 trials out of 10 (programmed in blocks of 5) before the pattern changed. If the participant did not reach this criterion, the pattern changed after the 50th trial. The program allowed up to 2 reversals. Participants repeated the task three times with different stimulus pairs.

We computed the number of trials that participants took to learn a rule/reversal as a dependent measure. For those subjects who did not reach a reversal within 50 trials and thus had no value for the reversal, missing data was replaced by a score of 50 (the maximum score; the mean plus two standard deviations was used in previous research by Sacharin & Gonzalez, 2009, but this value exceeded the maximum score in the current sample). Number of trials for rule/reversal learning was averaged across the three repetitions, so that each subject had one score for each rule, first reversal, and second reversal learning ranging from 10 (good performance) to 50 (poor performance). To facilitate an analysis of reversal learning performance with performance on the other tasks used in this study, we subtracted the number of trials to learn rules from the average of the number of trials to learn reversals as a measure of reversal learning. Higher scores indicate poor performance.

California Card Sorting Test. The CCST consists of three stimulus sets, but the correlation between a stimulus set and the overall CCST score has been judged sufficiently high to justify using one stimulus set as a short version of the task (Greve, Williams, & Crouch, 1995). Therefore, we used one of the three stimulus sets described by Delis et al. (1992). The verbal sorting criteria for the set are land versus water animals, large versus small animals, and pets versus man-eating animals. The non-verbal sorting criteria are black versus white triangle, triangle above versus below the word, and background lines slope left versus right.

We developed a computerized version of the Free and the Structured Sorting sub-tasks. The Cued Sorting sub-task was not used in this study due to time constraints. Also, Grewe, Farrell, et al., (1995) reported ceiling effects for this sub-task with college students, suggesting that it might be less valuable than the other sub-tasks with a college sample.

To familiarize participants with the task, instructions with example sorts for a different stimulus set were given. Participants then had three minutes for the Free Sorting and 60 seconds for each trial of the Structured Sorting, similar to the time constraints in past research with college students (Greve, Williams, et al., 1995).

Results from the CCST yield several scores (compare Greve, Williams, et al., 1995; Greve, Farrell, et al., 1995) for the sorts and descriptions. The following scores were applied in this study for sorts:

1. Total Attempts is the total number of all attempted sorts (correct and incorrect sorts).
2. Correct Sorts is the number of different sorts that corresponds to one of the six sorting rules (maximum score is 6), with a verbal (3 points) score and a non-verbal (3 points) score.
3. Perseverative Sort is the number of correct, repeated sorts.
4. Incorrect Sorts is the number of incorrect sorts (the sum of correct and incorrect sorts can be smaller than the number of all attempted sorts due to repetitions of answers). It consists of Nontarget and Unequal Sorts.
    a. Nontarget Sorts is the number of sorts with equal piles that do not correspond to a sorting rule.
    b. Unequal Sorts is the number of sorts with unequal piles.

The following scores were applied for descriptions of sorting rules:

1. Correct Descriptions are the number of different correct rule descriptions. 2 points are given when each pile has an identifying rule (e.g., fish, mammals), and 1 point is given when pile descriptions refer to only one pile (e.g., fish, not fish). The maximum score is 12 points, and can be broken down into a verbal (6 points) and a nonverbal (6 points) score.
2. Perseveration Descriptions is the total number of correct repeated descriptions.

3. Incorrect descriptions consist of Nonrule Descriptions and Nonmatch Descriptions.
    a. Nonrule Descriptions are descriptions that do not correspond to any sorting rule.
    b. Nonmatch Descriptions are descriptions that correspond to a sorting rule, but that do not apply to the current sort.

Results

Manipulation Check

Repeated measures ANOVA with mood at time 1 and at time 2 showed significant effects of emotion condition. For feeling good, the only significant effect was a main effect of emotion condition, $F(2, 59) = 3.14$, $p = .05$, with a marginal effect of time, $F(1, 59) = 3.33$, $p = .07$. At time 1, participants in the happy condition felt as good as control participants (7.08; 6.89), $t(41) = 0.40$, $p = .69$, and as relieved participants (7.08; 6.68), $t(41) = 0.91$, $p = .37$. At time 2, happy participants felt better than control participants (7.25; 6.11), $t(41) = 3.18$, $p = .003$, and than relieved participants (7.25; 6.16), $t(41) = 3.13$, $p = .003$. Control and relieved participants reported similar levels of feeling good at both time points.

For feeling happy, a similar pattern emerged. There was no main effect of emotion condition emerged, but a marginal effect of time, $F(1, 59) = 3.55$, $p = .06$, that was qualified by a marginally significant interaction with emotion condition, $F(2, 59) = 2.86$, $p = .07$. At time 1, participants in the happy condition felt no more happy than control participants (7.00; 7.15), $t(41) = 0.38$, $p = .71$, or than relieved participants (7.00; 6.63), $t(41) = 0.90$, $p = .37$. At time 2, participants in the happy condition felt happier than control participants (7.17; 6.26), $t(41) = 2.30$, $p = .027$, and than relieved participants (7.17; 6.32), $t(41) = 2.30$, $p = .027$. Control and relieved participants reported similar levels of feeling happy at both time points. For feeling relieved, certain, or active, no effects emerged. Given the differential effects of mood on self reported feelings for different task blocks, we included block order as a variable in all following analyses.

Idea Generation

Three different measures were created from the idea generation task: Fluency as the number of ideas, flexibility as the number of different categories, and originality as the number of unusual ideas. To assess how fluency differed across emotion conditions, a repeated measures ANOVA with number of cumulative ideas generated at different time points (1, 2, or 5 min.) as a within factor, and emotion condition, block order (first or second block) and task order (first, second, or third within block) as between factors was conducted. More ideas were generated as time progressed, $F(2, 90) = 119.96$, $p < .01$. The only other significant effects were an interaction of block and task order, $F(2, 45) = 3.21$, $p = .050$, and an interaction of emotion condition with task order, $F(4, 45) = 2.60$, $p = .048$, that was qualified by a three-way interaction of emotion condition, task order, and time for idea generation, $F(8, 90) = 2.32$, $p = .026$. To understand the three-way interaction, we conducted separate analyses by task order. Repeated measures analyses with time as a within factor and emotion condition and block order as between factors showed that emotion condition had an effect on idea generation only when the task was placed last, $F(2, 16) = 4.31$, $p = .032$. A main effect of block order emerged as well, $F(1, 16) = 5.78$, $p = .029$, but no interaction of block order with emotion condition.

When the task was placed last, happy participants generated more ideas than relieved participants in one minute (6.50; 3.75), $t(14) = 2.43$, $p = .029$, two minutes (11.63; 5.50), $t(14) = 2.49$, $p = .026$, and five minutes (15.88; 9.25), $t(14) = 2.17$, $p = .047$ (see Table 4.2). Scores of control participants lay in between and did not differ significantly from either emotion condition.

To assess the influence of emotions on the number of different categories used by participants, we conducted an ANOVA with emotion condition, task order and block order as factors. A significant interaction of emotion condition and task order emerged, $F(4, 45) = 3.59$, $p = .013$. No other effects were significant. Follow-up analyses by task order showed that a significant effect emerged only when the idea generation task came last. A main effect of emotion condition, $F(2, 16) = 9.12$, $p = .007$, as well as a main effect of block order emerged, $F(1, 16) = 9.78$, $p = .007$.

When the task was placed last, happy participants generated ideas from more different categories than control participants (8.25; 5.00), $t(12) = 2.05$, $p = .063$, and more than relieved participants (8.25; 4.38), $t(14) = 3.22$, $p = .006$. Other mean differences were not significant.

Category flexibility was positively correlated with fluency (see Table 4.4). The effect of emotions on flexibility could thus be the result of increased fluency. When controlling for fluency by including fluency as a covariate in the model, the influence of emotions on flexible category use was still significant when the task came last, $F(2, 15) = 4.12$, $p = .037$, despite a significant effect of fluency, $F(1, 15) = 8.60$, $p = .01$. Thus, category flexibility was not a function of fluency.

An ANOVA with emotion condition and task order and block order on originality showed a marginally significant interaction of emotion category and task order, $F(4, 45) = 2.20$, $p = .085$. Follow-up analyses by task order showed that emotions influenced originality only when the task came last, $F(2, 16) = 5.24$, $p = .018$. When the task came last, happy participants produced more unusual ideas than control participants (2.13; 0.33), $t(12) = 1.20$, $p = .073$. Other mean differences were not significant.

The unusualness of ideas was positively associated with fluency (see Table 4.4). The effect of emotions on originality was not significant when including fluency as a covariate in the model of emotion condition on unusual responses. Thus, the effect of emotions on originality was driven by fluency.

Remote associates test

An ANOVA with emotion condition, task order and block order as factors on the number of correctly solved remote associate items showed several effects: A main effect of task order, $F(2, 44) = 4.65$, $p = .015$, an interaction of emotion condition with task order, $F(4, 33) = 4.25$, $p = .005$, and an interaction of emotion condition with block order, $F(2, 44) = 3.58$, $p = .036$. Follow-up analyses by task order showed that there was a marginal effect of emotion condition on remote associates both when the task came first, $F(2, 13) = 3.34$, $p = .068$, and when the task came last, $F(2, 20) = 3.29$, $p = .058$. However, the direction of the effects was opposite (see Table 4.2): When the task came first, happy participants solved fewer remote associate items than control participants (7.86; 14.71), $t(12) = 4.19$, $p = .001$, but when the task came last, they produced more (15.27; 11.25), $t(17) = 2.74$, $p = .014$. When the task came last, relieved participants also solved more items than control participants (14.00; 11.25), $t(13) = 2.18$, $p = .049$. Other mean differences were not significant.

Reversal learning task

An ANOVA with emotion condition and block order as factors showed a main effect of emotion condition, $F(2, 56) = 3.09$, $p = .05$, and no other effects. Participants in the happy condition took longer to learn reversals, relative to learning rules. The difference to the control condition was not significant, (11.28; 7.41), $t(41) = 1.55$, $p = .129$, but the difference to the relieved condition was significant (11.28; 5.22), $t(41) = 2.19$, $p = .034$. Control and relieved condition participants did not differ significantly, $t(41) = 0.89$, $p = .381$. There were no general performance differences across blocks, $t(60) = 0.52$, $p = .603$.

California Card Sorting Test

The California Card Sorting Test contains the sub-tasks Free Sorting and Structured Sorting. The means and standard deviations for the scores used in the analysis are provided in table 4.5. Table 4.4 shows that overall, performance for sorting the stimuli and for identifying sorting rules were correlated for each of the verbal and the non-verbal sorts, with stronger associations in the nonverbal domain. Also, performance on the verbal and nonverbal domain were either uncorrelated (e.g., Structured Sorting descriptions), or negatively correlated (e.g., Free Sorting descriptions). In the Free Sorting Task, the number of attempted sorts, correct sorts in the nonverbal domain, perseverance, as well as erroneous sorts (nontarget and unequal sorts) was not influenced by emotion condition, task, and block order.

For the number of correct sorts in the verbal domain, an ANOVA with emotion condition, task order and block order as factors showed a significant interaction of emotion condition and block order, $F(2, 45) = 4.38$, $p = .018$. Follow-up analyses showed that the only significant effect emerged when the CCST task occurred within the first block of the experiment (see Table 4.2). Then, emotions significantly influenced correct sorts in the verbal domain, $F(2, 25) = 3.75$, $p = .038$. Happy participants performed worse then control participants (1.44; 2.00), $t(19) = 2.20$, $p = .040$, and than relieved participants (1.44; 2.23), $t(20) = 2.50$, $p = .021$. Other mean differences were not significant. Figure 4.3 illustrates that when the CCST task occurred in the first block, happy participants produced generally fewer correct sorts (including verbal, nonverbal, and perseverance) than relieved participants (3.22; 4.69), $t(20) = 2.67$, $p = .015$, and control participants (3.22; 4.08), $t(19) = 2.24$, $p = .037$. When aggregating across emotion conditions, general performance in Correct Sorts, verbal, was marginally worse in the first compared to the second block (1.94; 2.25), $t(60) = 1.74$, $p = .088$.

In contrast to the production of sorts, there was no influence of emotions on the number of descriptions for sorting rules in the Free Sorting sub-task or in the Structured Sorting sub-task. The number of correct descriptions (with and without perseverance) and erroneous descriptions (nontarget and nonmatch descriptions) in the Free Sorting task was not influenced by emotion condition, task or block order. Similarly, in the Structured Sorting task, a repeated measures ANOVA with emotion condition, task order and block order as between factors and domain (verbal/nonverbal) as a within factor on number of correctly recognized sorting rules showed no effects. General performance for these measures also did not differ across blocks.

Relation between flexibility tasks

We expected a positive association between tasks from the associative flexibility domain, and a negative correlation between tasks from the associative and the regulative flexibility domain. Regulative and attentional flexibility could be correlated since both are executive functions.

Associative flexibility was measured with an idea generation and a remote associates test. However, there was no correlation between scores from the idea generation task and from the remote associates test. Given the task order effects in previous analyses, we analyzed the association between these tasks separately by task order. Fluency within the first minute was positively associated with remote associates test performance when the idea generation task came first, $r(16) = .69$, $p = .003$, or when the remote associates task came last, $r(26) = .42$, $p = .035$. There were no other significant relations.

Regulative flexibility was assessed with a reversal learning task and attentional flexibility with a California Card Sorting task. Reversal learning was not associated with any of the CCST scores in the sample total or with analyses by block order.

We analyzed the relation between associative and regulative flexibility tasks. Idea generation scores and remote associates test performance were not correlated with reversal learning.

We also explored the relation between associative and attentional flexibility tasks. There were several relations between idea generation and performance on the CCST. Correct Sorts from the verbal domain in the CCST was positively correlated with Fluency in the first minute, $r(62) = .26$, $p = .046$. Also, Sorting Perseverance was positively associated with Fluency in five minutes, *r*(62) = .28, *p* = .026, Category Flexibility, *r*(62) = .29, *p* = .022, and Originality, *r*(62) = .28, *p* = .030. When both tasks occurred in the first block, the relation between idea generation and CCST scores varied across task order. For example, when the idea generation task occurred first, the relations of idea generation scores and Correct Sorts, verbal, were positive, but when the idea generation task came last, the relations were negative. When both tasks occurred in the second block, Correct Sorts, verbal, showed overall positive correlations with idea generation scores.

The remote associates test was correlated with two scores from the CCST. Specifically, Correct Sorts as well as Correct Descriptions from the nonverbal domain correlated with remote associates test, *r*(62) = .32, *p* = .012, and *r*(62) = .34, *p* = .006. When the remote associate and the CCST task came in the first block, Correct Sorts and Descriptions from both the verbal and nonverbal domain of the CCST showed positive relations to remote associates test performance across task order, though only one correlation was significant. However, when the tasks occurred in the second block, the (nonsignificant) relations between scores varied across task order. Overall, there were positive associations between fluency, remote associates test, and performance on the CCST, but the relations were sensitive to block and task order.

Discussion

The goal of the present study was to test the influence of different positive emotions on different types of flexibility. Specifically, we introduced the distinction between associative flexibility as the ability to generate unusual associations, regulative flexibility as the ability to adapt to changing reward contingencies, and attentional flexibility as the ability to shift attentional sets. Based on previous research showing different effects of positive affect on performance on a variety of flexibility tasks, we predicted that happiness, but not relief, would improve associative flexibility, but impair regulative flexibility.

Associative flexibility was measured with an idea generation task and a remote associates test. In line with previous research, we found that happiness improved fluency, category flexibility, and originality in the idea generation task. However, the effect was sensitive to task order, and only occurred when the idea generation task came later in the study. Task order also moderated how emotions influence performance on a remote associates test. Here, the results were ambiguous, since happiness impaired or improved performance depending on task order. Thus, we were not able to replicate previous research on the influence of positive affect on remote associates test performance.

Regulative flexibility was assessed with a reversal learning task. We replicated previous research (Sacharin & Gonzalez, 2009) and found that happiness impaired flexibility in reversal learning, but relief did not impair performance.

Attentional flexibility was assessed with the CCST. For this task, no previous research on the influence of current emotions existed. We found that happiness impaired performance for initiating sorts from the verbal domain. However, this effect was sensitive to order effects, and only occurred when the task came in the first block of the study. Performance for the nonverbal domain and the ability to generate sorting rules were not affected by emotions. Thus, there was some indication that happiness impaired performance on the CCST similarly to the executive function in regulative flexibility, but the evidence was relatively weak.

Compared to previously published data (Greve, Williams, et al., 1995), our sample performed relatively poorly in the CCST. This could be due to a lack of motivation in our sample, to the computerized version of the test, or to other factors. The computerized version differs from an administration by an experimenter in several ways. First, the experimenter is not present to monitor and encourage sorts. Second, with an experimenter, the subjects have additional time to think or take a break while the experimenter re-organizes the cards (compare Beatty & Monson, 1990). In the computerized version we developed, respondents do not receive this extra time. However, it would be possible to introduce a monitoring system, feedback, or extra time between sorts. Future research is necessary to judge the value of changing different parameters in a computerized version of the CCST.

One goal of the study was to show that the impairment of reversal learning with happiness is not due to confounding factors. Although our results were influenced by order effects, we showed that the happiness manipulation used in our paradigm did not impair performance generally, but was specific to reversal learning. We also showed that performance on other tasks such as fluency in idea generation was improved with happiness.

Furthermore, our results are consistent with the prediction that happiness influences different types of flexibility differentially. Specifically, we showed that happiness improved associative flexibility in the idea generation task, impaired regulative flexibility in the reversal learning task, and somewhat impaired attentional flexibility in the CCST task. The effects of the CCST task were sensitive to order effects and, given that there was no pre-existing research assessing the influence of emotions on this task, replication is important. It is possible that the influence of emotions is different for reward-based flexibility and attention-based flexibility. We found support for the differentiation of the influence of happiness on associative and regulative flexibility, but more research is necessary regarding attentional flexibility. Overall, our results suggest that the influence of emotions on flexibility is no weaker or stronger for associative than for regulative flexibility.

Unlike happiness, relief did not improve associative flexibility and reduce regulative flexibility. We had suggested that differences in underlying appraisals may explain the differential effect of happiness and relief. Specifically, happiness can be characterized as higher in perceptions of control and beliefs in a good and just world compared to relief or a neutral state (Tong, 2008). Perceptions that the world is good and fair do not require an individual to understand the logic of changes in reward-contingencies, and may not induce attempts to increase predictability. The same belief may also improve associative flexibility because the safety signal from this belief could increase exploratory and creative behavior (Fredrickson, 1998; Schwarz & Clore, 2007). Thus, the belief in a good and fair world may decrease regulative flexibility and increase associative flexibility.

With our design, we were able to examine performance on different associative tasks and a regulative flexibility task at the individual level. We found weak associations between associative flexibility tasks (idea generation and remote associates test). The relations between the two tasks measuring associative flexibility and other types of flexibility were mixed. Specifically, we did not find that group differences between happy, relieved, and control participants' performance on regulative and associative flexibility were reflected in individual differences. Associative and regulative flexibility may not be correlated on an individual level if, for example, a third variable influences performance. For example, smart individuals may perform well on reversal learning and fluency tasks. When grouping individuals by intelligence, fluency and reversal learning may be positively associated across groups. However, for the grouping variable emotion, fluency and reversal learning may be negatively associated across groups. With smart individuals in either emotion group, individual differences would not correspond to either group difference. Future research is required to understand which variables explain differences between variable relations at the group and the individual level.

Given that we used multiple measures within one study, it is not surprising to find task order effects. However, it is important to examine whether these effects are merely noise, or if there is a systematic pattern in the results. Future research could examine how performance on one task facilitates or impairs performance on a subsequent task. The effects of task order within a block may also be the result of distraction or a general lag effect, and block order effects may be a result of fatigue. We found different types of order effects for the influence of emotions on associative and attentional flexibility tasks.

For both associative flexibility tasks, we found primarily task order effects: Our prediction that happiness would facilitate performance was confirmed only when the task came last within a block of tasks. Based on the findings, we speculate that the influence of emotions on creativity tasks might require a time lag to show. There is some indication from past research that this might indeed be the case. In several studies, filler tasks are administered before an associative flexibility task (e.g., Hirt, Levine, McDonald, Melton, & Martin, 1997; Martin, Ward, Achee, & Wyer, 1993; Sanna, Turley, & Mark, 1996).

However, in other studies, no filler tasks were used or reported and happiness did have an effect on idea generation (e.g., Bohner & Schwarz, 1993; Isen, Johnson, Mertz, & Robinson, 1985).

According to the Mood as Input Model, mood manipulations might not have an effect on immediately following tasks because participants might discount the information provided by their mood if they are aware of the mood induction (Martin et al., 1993). However, it is not clear why this would only affect associative flexibility and not regulative flexibility. Alternatively, thoughts generated by remembering a happy event may lead to a preoccupation with the happy event, and diminish the advantage of positive affect on associative flexibility until the distracting thoughts vanish after some time. This idea is in line with capacity theories that predict that emotions increase cognitive load (Mackie & Worth, 1989). Manipulations that facilitate or inhibit the termination of thoughts related to the happiness experience would be useful to test this idea. Alternatively, happiness might increase the accessibility of cognitive material so much that associations become chaotic and response generation is impaired. According to this view, happiness is akin to manic or schizophrenic states in which thoughts cannot be organized well. Not until emotion decreases after some time can optimal levels of free associations be reached and generate ideas. This explanation could be tested by designing a task where ideas can be generated in a more or less structured way (e.g., mere free association versus brain-storming solutions to complex problems). Finally, beliefs in a good and fair world associated with happiness (Tong, 2008) might initially result in maintenance of the pleasant status quo (compare Schwarz & Clore, 2007) and only later lead to creative and explorative behavior (compare Fredrickson, 1998). These explanations are quite speculative. Further research is required to establish the sensitivity of associative flexibility to order effects by replicating our results, and to understand its underlying cause.

Block order did not affect associative flexibility tasks, suggesting that these tasks are not sensitive to fatigue or preceding events. However, for the CCST, emotions only made a difference when the task came in the first block. If block order effects are an indicator of fatigue, then performance on executive function tasks should generally be lower when they occur in the second block. However, performance on the CCST and the reversal learning task was not generally lower in the second block of the task, even though in the second block, emotions did not result in performance *differences* on the CCST. This indicates that fatigue did not play a major role in these executive function tasks, and the block effect for the CCST cannot be explained that way.

Besides order effects, a major limitation of the study was that self-reported feelings did not differentiate well between different emotion conditions. Participants in the happy condition differed from control and relieved participants significantly only at time 2. Although happiness can generally be characterized as feeling certain and in control more than relief (Tong, 2008), self-reported feelings of certainty/confusion did not differ across emotion conditions. Given the significant effects on performance, it is possible that the manipulation checks were insensitive to the differences between emotions. Also, relieved and control participants did not differ on self-reported feelings, and also did not differ on most of the dependent variables. Thus, it is possible that participants in the relief condition did not feel particularly emotional at all. Interestingly, for idea generation and reversal learning, the difference between the happy and the relieved condition was stronger than between the happy and the control condition (like Sacharin & Gonzalez, 2009). Future research replicating the finding that difference in cognitive performance with happiness and relief may occur without changes in subjective feeling is necessary to show that rather than emotions, conceptualizations of emotional experiences evoked by remembering happy and relief stories are responsible for the influence of emotional story on cognitive flexibility.

A further limitation was that several subjects were excluded from the analysis because they were suspicious or because they were run during break and showed a different pattern of results than the remainder of the sample. The first problem could be ameliorated in future research by using a better cover story. However, understanding and dealing with the ‘break effect’ seems more complicated. A systematic analysis of changes in participants’ motivation, cognitive abilities, and general mood during break could shed some light on this issue. Regardless of the underlying reasons, the fact that emotions do not influence regulative flexibility during break time indicates that the effects are not robust. Future research is required to better understand which variables change the relation of emotion and cognitive flexibility, and why.

Study 1 showed that manipulating happiness and relief – as emotion or an emotional conceptualization - had different outcomes for cognitive flexibility. Specifically, happiness, but not relief, facilitated associative flexibility in idea generation, and impaired regulative flexibility in reversal learning.

An important question is how these differences can be explained. To develop a parsimonious theory for the influence of emotions on cognitive tendencies, identifying mediators in the relation between emotion and flexibility could be useful. Different variables could be mediators. For example, happiness and relief differ with regard to several underlying appraisals. Specifically, beliefs in a good and just world under happiness might facilitate subsequent creativity (Fredrickson, 1998; Schwarz & Clore, 2007), and reduce the need to monitor reward contingencies. Also, increases in dopamine levels may differ with happiness and relief. Increased dopamine facilitates associative flexibility (Ashby et al., 1999) but reduces regulative flexibility (Cools et al., 2007). Furthermore, associative flexibility has often been attributed to, or closely related with, global processing (e.g., Fredrickson, 1998; Isen et al., 1985; Schwarz & Clore, 2007) and with unfocused or distracted processing (Dreisbach & Goschke, 2004; Dreisbach, 2006). However, as an executive function regulative flexibility may require attention to detail and focused thinking. If associative flexibility is mediated by global and unfocused thinking, and regulative flexibility requires local and focused thinking, the influence of emotions could be described as a function of increases and decreases of global and focused thinking. This possibility will be examined in study 2.

Study 2

Study 1 showed that happiness has different effects on different types of flexibility. An explanation of these results may be informed by the identification of mediators. The goal of study 2 is to identify whether the influence of happiness and relief on regulative flexibility is mediated by goal maintenance and global processing. Both processes are central in theorizing about associative flexibility, and may inform a theory explaining the influence of emotions on flexibility more generally. However, to our knowledge, there is no research on the relation of regulative flexibility, goal maintenance, and global processing. Therefore, another goal of study 2 is to contribute to the knowledge on the relation between these cognitive processes.

Goal maintenance refers to the ability to persevere in goal pursuit when faced with distracters. Synonyms are “focused thinking” and “perseverance,” and an antonym is “distractibility.” Mediated by dopamine, cognitive flexibility may be antagonistic to stable maintenance (e.g., Dreisbach & Goschke, 2004). Individuals may be able to adjust the balance between flexibility and maintenance depending on the context (Dreisbach & Goschke, 2004). While distractibility may be beneficial for associative flexibility, distraction may be detrimental to performing well on executive tasks, such as regulative flexibility tasks.

Goal maintenance can be assessed with a continuous performance paradigm, where information that precedes a stimulus in time (so-called context information) is necessary to react appropriately to the stimulus (Dreisbach, 2006). Whether more or less goal maintenance will result in good performance depends on the task. For example, for some tasks the ability to detach from previously relevant information is required to perform well (e.g., Dreisbach & Goschke, 2004). Goal maintenance does not therefore reflect an individual’s motivation or ability to “perform well” on a task, but rather reflects the tendency to maintain prior goals.

In addition to goal maintenance, global processing has also been suggested as important for understanding the influence of emotions on associative flexibility. Global processing refers to a tendency to process information based on an overall schema or Gestalt, rather than on individual elements of knowledge. More specifically, global processing refers to a perception of a pattern based on its global configuration, while local processing refers to attention to the local elements that make up the Gestalt. For example, a large letter L can be constructed from small Ts. When asked which letter is shown, identifying the letter "L" demonstrates a global focus, and identifying the letter "T" a local focus. Similarly, a square-shaped Gestalt can be constructed from triangular elements (Kimchi & Palmer, 1982).

Global processing can be interpreted as an indicator of broad thinking, and broad thinking is perceived to facilitate flexibility (e.g., Fredrickson & Branigan, 2005; Isen et al., 1992). For example, Isen and colleagues suggest that "positive affect cues a broad set or range of material . . . and the happy person . . . may see a different set of relations among items" (Isen et al., 1985, p. 1414) resulting in better performance in idea generation (Isen et al., 1985) and broader categorization (Isen, Niedenthal, & Cantor, 1992). Similarly, the Broaden and Build Theory suggests that "positive emotions broaden a person's momentary thought-action repertoire. Accordingly, experiences of certain positive emotions prompt individuals . . . to pursue novel, creative, and often unscripted paths of thought and action" (Fredrickson, 1998, p. 304). Global processing can also be interpreted as an indicator of schema driven, or top-down processing (e.g., Schwarz & Clore, 2007). Top-down processing has been seen as advantageous for solving associative flexibility in remote associate problems and other creativity tasks (Schwarz & Clore, 2007). However, a bottom-up or data driven processing style indicated by local processing may be beneficial for performance in an executive function, such as regulative flexibility. Overall, broad perceptual attention indicated by global processing and associative flexibility are perceived as closely related (Friedman & Förster, 2005).

Based on the importance of goal maintenance and global processing for associative flexibility, the goal of study 2 is to identify whether goal maintenance and global processing mediate the relation of emotions and regulative flexibility. Previous research provides information on how happiness influences these cognitive tendencies. One goal of study 2 is to replicate this research. To our knowledge, no research has examined the influence of relief on attention and global processing, which will be explored in this study.

A necessary condition for a mediation model is that the variables be related to each other in a consistent way. For example, if goal maintenance mediates the influence of happiness on regulative flexibility, then goal maintenance and regulative flexibility must be positively related. Thus, a second goal of study 2 is to examine the relation between reversal learning, global processing, and goal maintenance. To our knowledge, no paper has focused directly on the relation of these three cognitive tendencies. Although information on group differences exists, group differences do not necessarily provide information about the relation among variables at the individual level. While happiness might result in poor reversal learning and reduced goal maintenance, reversal learning and goal maintenance might not necessarily be positively correlated. However, this correlation is necessary for mediation. Existing literature on group differences regarding reversal learning, global processing, and goal maintenance will be used to derive predictions for a mediation model.

Emotions and Reversal Learning, Global/Local Processing, and Goal Maintenance

Knowledge about how emotions influence reversal learning, global processing, and goal maintenance is generally limited, but exists for happiness. Study 1 showed that happiness impairs reversal learning. Other research shows that happiness is associated with global and distracted thinking. For example, happy individuals use global rather than local criteria for decision making (Gasper & Clore, 2002). Also, positive affect reduces goal maintenance on a continuous performance task (Dreisbach, 2006) and decreases perseverance on a variant of the task switching task (Dreisbach & Goschke, 2004). Positive affect also increases distractibility due to novel stimuli in a task switching task (Dreisbach & Goschke, 2004). A lack of goal maintenance is also indicated by increased variety seeking (Kahn & Isen, 1993) with positive affect.

Group differences in reversal learning and in goal maintenance have also been found in research on patient groups and medicated healthy individuals. Parkinson's disease is associated with reduced levels of dopamine, and medication of Parkinson's patients generally increases dopamine levels. Parkinson's patients on medication (with higher levels of dopamine) show impaired performance on a reversal learning task (Cools et al., 2001). In line with this, administration of a dopamine agonist (which resembles dopamine in its effect as opposed to an antagonist which blocks the dopamine effect) impairs reversal learning performance in healthy participants (Mehta, Swainson, Ogilvie, Sahakian, & Robbins, 2001). Also, the ability to ignore distracters is decreased in medicated Parkinson's patients with higher dopamine (Moustafa, Sherman, & Frank, 2008). Thus, higher levels of dopamine are associated with worse reversal learning and goal maintenance, suggesting a positive relation between these abilities.

Similarly, schizophrenic patients show impaired performance on reversal learning (Waltz & Gold, 2007). Goal and context maintenance are also impaired in schizophrenic patients (Servan-Schreiber, Cohen, & Steingard, 1996). Thus, the performance profile of schizophrenic patients suggests that poor performance on reversal learning could be associated with reduced goal maintenance.

The Relation of Reversal Learning, Global Processing, and Goal Maintenance

To our knowledge, no paper has described the relation of performance on reversal learning, global processing, and goal maintenance directly. To examine if global processing and goal maintenance mediate the differences between groups of happy, relieved, and control participants, individual differences should mirror group differences. Although group-level differences are not necessarily reflected in individual differences, predictions about the relation between these variables can be based on the hypothesis that cognitive tendencies co-occur in a systematic way to facilitate optimal processing, and that relations between variables can be explained in a parsimonious way. If specific conditions such as emotional or pathological states cause specific cognitive tendencies, the tendencies might co-occur under different conditions as well and might be related to each other in a similar fashion to the differences between emotion groups reviewed in the previous section.

Theoretically, a case can be made for a positive association between regulative flexibility and goal maintenance, and for a negative association between regulative flexibility with global processing. The following theoretical discussion covers both associative and regulative flexibility. I suggest that associative flexibility will increase when thinking is unfocused and open to novelty, allowing a spread of activations to unusual associations (compare Phillips et al., 2002). Distraction leads to quickly jumping from one topic to another, from one category to another. Because of lack of focus, associative flexibility is effortless. Associative flexibility will also increase when thinking is broad, connective, inclusive, and global, rather than detail-oriented, discriminative, exclusive, and local, because it is based on accepting and including different elements in the universe of possible solutions to a problem.

Regulative flexibility will increase when thinking is focused rather than unfocused because it requires the maintenance of a goal (compare Phillips, Bull, Adams, & Fraser, 2002). Having a goal reduces distractibility (Müller et al., 2007). Because of goal-maintenance, regulative flexibility is an executive function. Regulative flexibility will also increase when thinking is analytic, detail-oriented, and local, because it requires the ability to identify changes in the environment and discriminate different rules. Because of bottom-up processing, regulative flexibility can be distinguished from other executive functions (e.g., working memory, continuous inhibition as in the Stroop task, planning).

In contrast to goal maintenance and reversal learning, where the relation between variables is expected to resemble group differences, we expect top-down and focused thinking to be independent (Table 4.6). Thus, various combinations of these processes could be identified with different emotional states, and lead to different predictions for the effect of an emotion on cognitive flexibility.

Hypotheses

We expect that happiness will increase global processing, and reduce goal maintenance and reversal learning. The influence of relief on global processing and goal maintenance will be explored. Also, we expect that good reversal learning performance will be positively correlated with goal maintenance and negatively with global processing. Finally, we expect that global processing and lack of goal maintenance mediate the influence of happiness on reversal learning (see Figure 4.4).

Method

Participants

One hundred and thirty-three students (69 women; mean age = 18) participated in the study for partial course credit. The majority of the participants were Caucasian (74 %), some were African-American (10%) and Asian-American (10%) or of other ethnicities (6%).

Procedure

The procedure was similar to the procedure in study 1. Participants were told that we were conducting two studies: One on the effect of length of essay writing on feelings, and a second on the relation between various cognitive tasks. After signing a fake consent form for each study, participants were randomly assigned to a happy, relieved, or control condition. After participants provided two events where they felt happy or relieved, or selected two weekdays (Monday – Thursday), we asked participants to write about the first event (weekday) for 9 minutes. After a manipulation check where participants indicated their current feelings, the first block of cognitive tasks was administered. Then, we induced moods again by asking participants to write a longer essay for 9 minutes about the second event (weekday), followed by a second manipulation check, and a second block of cognitive tasks. In one task block, participants performed the reversal learning task. In the other block, a continuous performance task to measure goal maintenance (Dreisbach, 2006) and a global/local task to measure top-down processing (Kimchi & Palmer, 1982) were administered. The order of these tasks was counterbalanced. The order of the blocks was also counterbalanced. Participants provided demographic information before they were probed for suspicion, debriefed, and asked to sign the consent form for the entire study. The duration of the study was no longer than one hour.

Measures

Emotion arousal. We employed the method of life event essays to induce emotion. The instructions for the happy condition read “Remember a recent event in your life that made you feel HAPPY and POSITIVE. Visualize the event in your mind, imagine the event vividly. Try to re-experience the original perceptions, sensations, and affective reactions. Write down the imagined event and elaborate on your thoughts and feelings.” In the relieved condition, ‘happy’ was replaced with ‘relieved.’ Control condition participants were asked to write about a regular week-day.

Mood assessment. After the emotion arousal and again at the end of the study, participants were asked to indicate how they felt, at this moment, on five 9-point items anchored with “very bad - very good,” “very unhappy – very happy,” “not at all relieved – very relieved,” “very calm – very active,” and “very certain / not confused – very uncertain / confused.”

Reversal learning task. In the reversal learning task, participants saw two stimuli and selected the one with a higher chance of being ‘correct.’ Unknown to participants, the probability of a stimulus being correct was 80%. Participants learned which stimulus was correct through feedback (rule learning). The stimulus that was correct changed twice (first and second reversal learning). Participants were told that the correct stimulus could change, but not how often or when. We used the E-prime script of Waltz and Gold

(2007). Stimuli were grey-scale fractals. Participants had to select the correct stimulus in 9 trials out of 10 (programmed in blocks of 5) before the pattern changed. If the participant did not reach this criterion, the pattern changed after the 50^{th} trial. The program allowed up to 2 reversals. Participants repeated the task three times with different stimulus pairs.

We computed the number of trials that participants took to learn a rule/reversal as a dependent measure. For those subjects who did not reach a reversal within 50 trials and thus had no value for the reversal, missing data was replaced by a score of 50 (the maximum score; the mean plus two standard deviations was used in previous research by Sacharin & Gonzalez, 2009, but this value exceeded the maximum score in the current sample). Number of trials for rule/reversal learning was averaged across the three repetitions, so that each subject had one score for each rule, first reversal, and second reversal learning ranging from 10 (good performance) to 50 (poor performance). To facilitate a joint analysis of reversal learning performance with performance on the other tasks used in this study, we subtracted the number of trials to learn rules from the average of the number of trials to learn reversals as a measure of reversal learning. Higher scores indicate poorer performance.

Goal maintenance: We used an AX-Continuous performance task, in which participants see letter strings of black and red letters. The task is to focus on the black letters and to press the right key, whenever the cue 'X' is followed by the probe 'A,' and to press the left key when a cue other than 'X' is followed by any letter, or a different cue precedes the probe 'A.' In this task, errors on A-*not*X tasks indicate too much goal maintenance, and errors on *not*A-X trials indicate too little goal maintenance (compare

Dreisbach, 2006). A difference score of A-notX and notA-X trial error rates was used as a measure of goal maintenance (compare Moustafa et al., 2008). Higher scores indicate more goal maintenance.

Global/local task: In the Kimchi & Palmer (1982) task, participants see a top figure and two bottom figures. They have to determine which of the bottom figures is more similar to the top figure, either based on local or global features of the stimulus. The sum score of the stimuli that are selected based on global features is the index for global processing, with a maximum value of 24. Higher scores indicate more global processing.

Results

Manipulation Check

Feelings were assessed twice during the study, following each emotion induction. At time 1, self-reported feelings on five items differed, $F(4, 464) = 113.00$, $p < .01$. We found a significant interaction of emotion condition, gender, and feeling item at time 1 $F(8, 464) = 2.28$, $p = .021$. Specifically, in the happy compared to the control condition women felt better (7.10; 6.27), $t(40) = 2.11$, $p = .041$, happier (7.20; 6.42), $t(44) = 2.05$, $p = .047$, and more active (5.20; 3.81), $t(44) = 2.94$, $p = .005$, and in the happy compared to the relieved condition, they felt happier (7.20; 6.17), $t(41) = 2.01$, $p = .051$, and less uncertain (3.00; 3.96), $t(37) = 2.12$, $p = .040$. Other mean differences were not significant.

Men, however, did not show significant differences between the happy and control condition, but men reported more happiness in the relief than in the control condition (6.94; 5.81), $t(37) = 2.43$, $p = .020$. Other mean differences were not significant.

At time 2, the gender difference was not significant. Differences between feeling items, $F(4, 464) = 50.35$, $p < .01$, and between emotion conditions, $F(2, 116) = 4.44$, $p = .014$, were qualified by a significant interaction of feeling items by condition, $F(8, 464) = 2.23$, $p = .024$. Across genders, participants in the happy condition felt better (6.83; 5.70), $t(83) = 3.27$, $p = .002$, happier (6.78; 5.66), $t(90) = 3.22$, $p = .002$, and more active (5.00; 4.11), $t(90) = 2.20$, $p = .030$, than the control, and happier (6.78; 5.85), $t(84) = 2.62$, $p = .011$, than the relief condition. Other mean differences were not significant.

To show comparisons with the time 1 data, we also looked at feelings reported separately by gender at time 2. Women in the happy condition felt better (7.05; 5.64), $t(40) = 2.87$, $p = .007$, and happier (6.85; 5.69), $t(44) = 2.25$, $p = .030$, than in the control condition and happier (6.85; 5.61), $t(41) = 2.08$, $p = .044$, than in the relief condition. Other mean differences were not significant. For men, at time 2, participants in the happy condition reported more happiness (6.72; 5.62), $t(44) = 2.27$, $p = .028$, than the control, and the happy and relief conditions did not differ on self-reported feelings. Other mean differences were not significant. Given the gender differences in emotion induction, I included gender as a variable in subsequent analyses.

The Influence of Emotions on Reversal Learning

An ANOVA with task order, gender, and emotion condition as factors showed that the influence of emotions on reversal learning was qualified by an interaction with gender, $F(2, 121) = 3.54$, $p = .032$. Other effects were not significant. Emotions had a significant effect on reversal learning for women, $F(2, 57) = 3.18$, $p = .049$. Women showed reversal learning impairments in the happy condition compared to the relief (15.58; 9.23), $t(41) = 2.17$, $p = .036$, and control condition (15.58; 10.45), $t(44) = 2.46$, p

= .056. The latter two conditions did not differ from each other. For men, emotions did not influence reversal learning, $F(2, 52) = 0.47$, $p = .631$. There were no other effects. Thus, women showed the predicted impairment of reversal learning with happiness, but men did not.

The Influence of Emotions on Global Processing

No significant effects of emotions or gender on global processing emerged; all *p*s > .05.

The Influence of Emotions on Goal Maintenance

An ANOVA with task order, gender, and emotion condition as factors showed a significant interaction of emotion condition with gender emerged, $F(2, 109) = 3.62$, $p = .030$. For women, emotion condition predicted goal maintenance, $F(2, 57) = 4.21$, $p = .020$. Women in the happy condition did not differ from the control (7.25; 0.81), $t(44) = 1.24$, $p = .222$, or the relief condition, (7.25; 13.26), $t(41) = 1.06$, $p = .294$. However, women in the relief condition showed more goal maintenance than the control participants (13.26; 0.81), $t(47) = 2.12$, $p = .039$. For men, there was no significant effect of emotion condition. Thus, the influence of emotion on goal maintenance was not as anticipated for women, and was absent for men.

The Relation between Reversal Learning, Global Processing, and Goal Maintenance

We had predicted that good reversal learning performance would be positively related to goal maintenance, and negatively to global processing. As a higher score in the reversal learning task indicated poor performance, we expected that the reversal learning score would be negatively correlated with the goal maintenance score, and positively with the global score.

The reversal learning score (indicating poor performance) was negatively correlated with goal maintenance, $r(133) = -.21$, $p = .018$. This means that better reversal learning was positively associated with goal maintenance. Contrary to predictions, the reversal learning score was negatively correlated with global processing, $r(133) = -.21$, $p = .015$. This means that better reversal learning was positively associated with global processing. Global processing and goal maintenance were not correlated in the sample total, $r(133) = .04$, $p = .69$, or for the sub-samples of men or women.

A regression of reversal learning on global processing, goal maintenance (both standardized), and the interaction of global processing and goal maintenance showed an overall significant model, $p < .001$. Global processing was negatively related to the reversal learning score, beta = -.174, $p = .037$. Also, goal maintenance was negatively associated with the reversal learning score, beta = -.225, $p = .007$. The effects were qualified by an interaction, beta = .239, $p = .005$. Thus, global processing and goal maintenance improved reversal learning (resulted in a small reversal learning score). The combination of local processing and distraction was particularly hurtful for reversal learning.

Separate analysis by gender showed that for women, a regression of reversal learning on global processing and goal maintenance as well as the interaction (all independent variables standardized) was overall significant, $p = .008$. Global processing showed no main effect, beta = -.114, $p = .32$, and goal maintenance showed a significant effect, beta = -.226, $p = .051$, qualified by an interaction, beta = .325, $p = .006$. Low goal maintenance hindered reversal learning particularly in combination with local processing (see Figure 4.5).

For men, the regression model was significant, *p* = .051, but none of the predictors reached ordinary levels of significance. Global processing was negatively associated with the reversal learning score, beta = -.231, *p* = .076 (see Figure 4.6).

The Mediation Model

Since there was no effect of emotion condition on reversal learning for men, the mediation model was examined for women only. For women, including goal maintenance and global processing as covariates in an ANCOVA with emotion condition and task order as factors on reversal learning did not reduce the effect of emotion on reversal learning, $F(2, 61) = 3.35$, $p = .042$. However, including the interaction of global and goal maintenance in the model showed a main effect of the interaction term, $F(1, 60) = 4.58$, $p = .037$, and reduced the significance of emotion condition to $p = .102$.

If the interaction of goal maintenance and global processing mediated the influence of emotions on reversal learning, emotions would influence the interaction term, which was not examined in the previous analysis of goal maintenance and global processing. An ANOVA with emotion condition and task order as factors showed a significant main effect of emotion on the goal maintenance-global interaction, $F(2, 57) = 3.60$, $p = .034$, with no other effects. Participants in the happy condition showed a higher interaction score than the control participants (.23; -.34), $t(44) = 2.46$, $p = .018$. The score of participants in the relief condition was in between (-.04) and did not significantly differ from the happy and control condition.

To understand the meaning of the interaction score, we computed grouping codes based on the four combinations of negative and positive z-scores to distinguish between participants with combinations of low/high goal maintenance and low/high global processing. In the previous analysis, a combination of low goal maintenance and low global processing was particularly hurtful for reversal learning, and happiness was hurtful for reversal learning. If low goal maintenance and low global processing mediate the influence of happiness on reversal learning, then there should be more low/low participants in the happy condition, and excluding the low/low group should reduce differences between the emotion groups.

Although the happy and control condition differed in the distribution of groups (low/low; low/high; etc.), Chi-Square (3, 46) = 9.38, p =.025, the difference was not in the low/low group but in the other groups (see Table 4.7). After excluding the low/low group from the analysis, an ANOVA with emotion condition as a factor on reversal learning, the influence of emotions remained significant, with or without controlling for goal maintenance, global processing, and the interaction. Contrary to the expectation based on a mediation model, the p value improved when taking out the low/low group. An ANOVA with emotion condition and task order on reversal learning showed a significant effect of emotion, $F(2, 40) = 5.70$, $p = .007$, and when additionally controlling for goal maintenance, global processing, and the interaction, the effect of emotion was $F(2, 37) = 3.93$, $p = .028$. Thus, the influence of happiness on reversal learning was not explained by the relation of low goal maintenance and low global processing with reversal learning. Instead, emotions influence reversal learning independent of the influence of a particular combination of goal maintenance and global processing (Figure 4.7).

Post-hoc Analysis of Essays

We found unexpected gender differences in the manipulation checks and task performance on this study. To examine the gender difference, we analyzed the essays written by participants in the emotion induction. Specifically, the question was whether men failed to follow the instruction to write about an event causing happiness or relief when instructed to do so, and instead wrote about happy events in the relief condition and vice versa. To assess if men wrote shorter and potentially less powerful essays, we computed the word count of each essay. Also, two coders blind to actual condition assignment rated the essays at time 1 and time 2 for suspected condition assignment to examine if the condition assignment was reflected in the essay. Rater agreement for condition assignment was good, Cohen's kappa = .81, $p < .01$. In a different coding approach, we blanked out 'happy' and 'relief' words from the essays, and one coder rated condition assignment.

Word count. Participants were instructed to write more for the second essay than the first essay. The word count ranged between 10 and 1863 words, with a median of 250 for the first essay, and 300 for the second essay. A mixed analysis with essay at time 1 and at time 2 as repeated measures factor and emotion condition and gender as between subjects factors showed a main effect of time, $F(1, 111) = 8.13$, $p = .005$. Essays at time 2 were longer than at time 1 (315; 267), $t(150) = 3.96$, $p < .01$. There was no gender difference, suggesting that men did not write shorter essays.

Identification of essay condition. To examine condition assignment at the level of essays, ratings were first combined across raters so that only essays that were unambiguously identified as happy or relief essays by both raters were used in analysis of gender differences. At time 1, raters could not identify three essays (one from the happy condition, two from the relieved condition), and thought that three essays from the relieved condition were ‘happy.’ At time 2, raters could not identify one essay from the relieved condition, and thought that four essays from the relieved condition were ‘happy,’ and that one essay in the happy condition was ‘relieved.’ To examine effects at the level of subjects, only participants whose essays at time 1 and time 2 reflected condition assignment were included (42 for happy, 33 for relieved, 47 for control). For these participants, one participant in the relieved condition was classified as happy, and 42 happy and 32 relieved participants were correctly identified. Thus, there were overall only a few miss-classifications of emotion condition, and the gender differences in emotion induction could not be attributed to ‘wrong’ essays.

To examine if ‘wrong’ condition assignment explained the gender difference, we selected only those participants whose condition assignments could be correctly identified. However, an ANOVA with task order, emotion condition, and gender on reversal learning still showed the interaction of emotion with gender, $F(2, 109) = 3.52$, $p = .033$. For women, emotions influenced reversal learning, $F(2, 57) = 3.22$, $p = .048$. Women in the happy condition performed worse than in the relief condition (15.17; 8.38), $t(35) = 2.14$, $p = .039$, and marginally worse than in the control condition, (15.17; 10.45), $t(43) = 1.78$, $p = .082$. For men, emotions did not influence reversal learning.

When coding ‘blanked’ essays, the results were similar. Agreement in assigned condition for essays at time 1 and time 2 was only absent for two essays from the happy condition and eight essays from the relieved condition. When only analyzing the essays for which time 1 and time 2 ratings were consistent, three essays from the relieved condition were wrongly classified as happy, while 40 happy and 30 relieved essays were correctly identified. When analyzing only those participants for whom classified and actual condition assignment matched, happiness reduced reversal learning compared to relief for women (15.18; 8.38), $t(35) = 2.14$, $p = .039$, but not for men, consistent with previous analyses. Overall, the results of the post-hoc analysis indicate that the gender differences in reversal learning could not be attributed to a failure to follow the instructions by writing short essays or essays that were not about a happy or relieved event.

Discussion

The goal of study 2 was to examine the role of global processing and goal maintenance as potential mediators in the relation of emotions with reversal learning. Based on past research showing an association of happiness with poor reversal learning, global processing, and distractibility, we expected that reversal learning would be negatively associated with global processing and positively associated with goal maintenance. Also, we expected to replicate the findings from study 1.

As in study 1, we found that happiness reduced reversal learning, but relief did not. However, an unexpected gender difference emerged, and men's reversal learning was not influenced by emotions. The gender difference could be due to differential emotion arousal, because at time 1 men reported feeling the most happy in the relieved condition and not in the happy condition. This indicates that men and women might have responded differently to the emotion induction.

Unlike in study 1, women in the happy condition reported feeling more certain/less confused than in the relieved condition, suggesting that feelings of certainty and control might matter for the difference between happiness and relief. If this were the case, control participants should also report reduced certainty. However, happy participants did not show more certainty than control participants. Instead, other appraisals may be more relevant to the difference between happiness, relief, and control condition. For example, the belief in a good and fair world should be more prominent with happiness than relief or a control (compare Tong, 2008). Believing in a good and fair world may be related to performance in reversal learning. For example, perceptions that the world is good and fair might reduce an individual's motivation to understand the logic of changes in reward-contingencies in an attempt to gain predictability. Future research should examine the importance of beliefs in a good world for performance in reversal learning.

To examine if gender differences in emotion induction were due to a failure to follow the instruction, we conducted a post-hoc analysis of the essays written to arouse emotions. However, only few stories could not correctly be classified as happy or relieved stories indicating that - at the level of condition identification - no fundamental difference in the essays written by men and women existed. Future research is required to better understand why men did not respond to the mood manipulation in the same way as women.

Based on the effects of happiness from past research on reversal learning, global processing, and goal maintenance, we had predicted that reversal learning would be improved under goal maintenance and local processing. Indeed, our results show that reversal learning is improved with goal maintenance. Unexpectedly, global processing is positively associated with reversal learning. Future research is needed to examine whether global processing was advantageous in the particular reversal learning paradigm we employed, where fractal patterns have to be distinguished from each other. It is possible that a global focus facilitated the perception of differences in fractal patterns, but would not facilitate reversal learning were different stimuli to be used. With the current paradigm, we found that the combination of distraction and local processing is particularly hurtful for reversal learning.

A mediation analysis showed that this specific processing combination of distraction and local processing does not explain the influence of emotions on reversal learning. It seems that happiness impairs reversal learning independent of a low level of goal maintenance and top-down processing.

A limitation of the study was that we were not able to replicate specific group differences between the happy and the control condition for goal maintenance and global processing. Although emotions influenced goal maintenance, we did not find that happiness reduced goal maintenance compared to the control. However, relief resulted in increased goal maintenance for women.

Despite this limitation, we were able to examine the relation between reversal learning, goal maintenance, and global processing. Although in past research, happiness has resulted in global processing, distractibility, and poor reversal learning, we found that the group differences between happiness and a control were not reflected in the association of these cognitive tendencies. This indicates that the influence of happiness on reversal learning cannot be explained by a lack of goal maintenance. This study showed the importance of examining the relation between variables at the individual level in addition to the group level.

General Discussion

In this paper, we introduced the distinction between three types of flexibility. Associative flexibility is the ability to generate unusual associations, regulative flexibility the ability to adapt to changes in reward contingencies, and attentional flexibility the ability to shift attentional sets. Contrary to the popular belief that positive affect generally improves cognitive flexibility (e.g., Ashby et al., 1999), we found that happiness and relief had different outcomes for different types of flexibility. Specifically, we found that happiness, but not relief, facilitated associative flexibility in idea generation, and impaired regulative flexibility in reversal learning. The evidence that happiness impaired attentional flexibility was somewhat weak and further research is required before conclusions can be drawn.

To establish the base for a parsimonious explanation for the influence of emotions on flexibility, we sought to identify mediator variables. In study 2, we examined the role of global processing and goal maintenance as potential mediators in the relation of emotions with regulative flexibility. However, a mediation analysis showed that happiness impaired reversal learning independently of global processing and goal maintenance.

Future research is required to understand why happiness and relief differ in their effects, but relief and control do not. For example, happiness and relief differ on a variety of appraisals (Tong, 2008). Beliefs in a good and fair world might explain why happiness impairs regulative flexibility, because this belief does not motivate an individual to learn and understand reward-contingencies. Belief in a good and fair world is higher with happiness than relief (Tong, 2008), and presumably also a control. A belief in a good and just world might also improve associative flexibility. For example, the safety signal from this belief could increase exploratory and creative behavior (Fredrickson, 1998).

The current research in combination with previous research on Parkinson's patients suggests that dopamine might play a central role as a neural correlate of the emotion-cognition link. Of particular relevance are the D1 and D2 receptors that control tonic (long-term) and phasic (short-term) changes in dopamine and balance the functions of maintenance and up-dating of information (Cohen, Braver, & Brown, 2002). Higher tonic dopamine levels reduce the effects of phasic changes, because of a reduced contrast (Cohen et al., 2002). Too much dopamine can then result in a reduced contrast and perseverance, and too little dopamine in an increased contrast and impulsivity (Cohen et al., 2002). However, the specific brain regions involved also matter. For example, attentional flexibility is associated with the dorsal striatum and the dorso-lateral prefrontal cortex, and regulative flexibility with the ventral striatum and orbiofrontal cortex (Cools et al., 2001). Thus, a more direct test of the Dopaminergic Model's prediction should assess dopamine levels. Also, a careful analysis of the brain areas involved in performance in different flexibility task would be useful for understanding differential outcomes of dopamine on flexibility.

However, the results from study 1 suggest that different processes may mediate the relation of emotions with regulative and with associative flexibility. Specifically, although happiness impaired regulative flexibility and facilitated associative flexibility, regulative and associative flexibility were not correlated. This finding indicates that the identification of a mediator variable that could explain the effects on both associative and regulative flexibility might be complicated by other variables, such as intelligence. More research is required before conclusions regarding the reliability of the independence of associative and regulative flexibility can be drawn with certainty.

In summary, this paper shows that it is important to examine the relation between variables at different levels of analysis separately, because results at one level of analysis do not necessarily translate to another level of analysis. In study 1, the relation between associative and regulative flexibility at the individual level did not correspond to differences at the group level. In study 2, the relation between regulative flexibility, global processing, and goal maintenance did not reflect differences between different emotion groups on these cognitive tendencies.

Understanding the underlying mechanisms of the emotion-cognition links requires further integration of research on emotions, cognitive tendencies, and underlying neural mechanisms. Also, the value of the distinction of associative, regulative, and attentional flexibility cannot be fully established without further research. We hope that the suggested taxonomy of tasks will be useful for understanding the interplay of emotion and cognition.

Footnote.

[1]We also excluded fourteen participants who performed the task during midterm and finals week. Break was defined as the week before spring break, Thanksgiving, and finals. Participants during break performed significantly worse in the reversal learning task than not during break (14.64; 8.24), $t(74) = 2.51$, $p = .014$. The 'break' effect cannot be examined well with only 14 participants. Therefore, we created a sample from all participants in studies 1 and 2, as well as from Sacharin and Gonzalez (2009) resulting in a sample of 258 participants with a happiness, relief, or control manipulation. 8 out of 49 participants were run during break time in the Sacharin & Gonzalez (2009), 14 out of 76 in the study 1 sample, and 29 out of 133 in the study 2 sample. Repeated measures with rule and reversal learning as within factor and emotion condition and time (break/no break) as between factors showed a main effect of rule/reversal learning, $F(2, 504) = 160.56$, $p < .01$, a three-way interaction of rule/reversal learning, emotion condition, and time, $F(4, 504) = 2.46$, $p = .044$, and no other effects. Follow-up analysis by time showed that emotions influenced rule/reversal learning only when the study was not run during break time, $F(4, 408) = 3.96$, $p = .004$. During break time, the interaction of time and emotion condition was not significant, $F(4, 96) = 0.64$, $p = .639$, although the groups were sufficiently large (happiness 18, relief 13, control 20) to detect effects. When not run during break, participants in the happy condition performed worse than control participants (reversal learning scores 11.98; 8.73), $t(136) = 2.22$, $p = .028$, and relief participants (11.98; 7.40), $t(137) = 3.04$, $p = .003$. However, during break, there was an opposite, non-significant trend in comparisons of happy with control (9.45; 12.88), $t(36) = 1.10$, $p = .28$, and relief participants (9.45; 12.56), $t(29) = 1.10$, $p = .28$. Figure 4.2 shows the mean reversal learning scores in the samples for men and women run during break or not during break. In study 1 reported in this paper, the influence of emotions on poor reversal learning was not significant without excluding 'break' participants. When excluding 'break' participants in study 2, the effect of emotions on reversal learning was significant even without controlling for task order, and the test statistics changed from $F(2, 66) = 2.82$, $p = .067$ to $F(2, 51) = 3.90$, $p = .026$. In the sample from Sacharin & Gonzalez (2009), the interaction effect of happiness, relief, and control on rule/reversal learning improved when taking out break participants from $F(4, 92) = 2.47$, $p = .050$ to $F(4, 76) = 4.33$, $p = .003$. Break and non-break participants did not differ with regard to self-reported feelings.

Table 4.1
Tasks associated with different types of flexibility

Associative Flexibility	Regulative Flexibility	Attentional Flexibility
Remote associates task (e.g., Mednick & Mednick, 1967)	Reversal rule learning task (e.g., Waltz & Gold, 2007)	Task switching task (e.g., Monsell, 2003)
Insight problem solving task (e.g., Duncker, 1945)	Regime change task (e.g., Massey & Wu, 2005)	Implicit association task (Greenwald et al., 1998)
Categorization task (e.g., Isen & Daubman, 1984)		Wisconsin card-sort (Heaton, 1981)
Idea generation task (e.g., Torrance, 1974)		California card-sort (Delis et al., 1992)

Table 4.2 Predictions and results for the influence of happiness on various tasks

	Idea Generation	Remote Associates	Reversal Learning	CCST
Prediction	↑	↑	↓	?
Direction of effect	↑	mixed	↓	↓
Block order effect?	no	no	no	yes
Block 1				-
Block 2				n.s.
Task order effect?	yes	yes	n.a.	no
Task first	n.s.	↓		
Task second	n.s.	n.s.		
Task last	↑	↑		

Notes. ↑ = happiness improves performance, ↓ = happiness impairs performance; n.s. = emotion effect is not significant; n.a. = effect is not applicable

Table 4.3
Frequency of responses in the idea generation task for unusual uses of a brick

Category	**Example items**	**Frequency (n (ideas))**
Build	To build a house	17.2 %
	To make a temple to the gods	(308)
Weight	To weight something down	5.8 %
	Iron man contest	(104)
Structure	To sit on	3.2 %
	For short people to stand on when taking pictures	(58)
Art	Decoration	3.1 %
	Paint it to make it look deceptively light and then laugh when somebody tries to pick it up	(55)
Weapon	To murder	3.0 %
	For hazing (making pledges carry around bricks)	(54)
Stopper	As a doorstopper	2.7 %
	Stop your car (by putting it behind the back wheels)	(49)
Smash	To smash	1.9 %
	Nut cracker or shell cracker	(34)
Utensil	To hammer	1.8 %
	Place holder	(32)
Throw	Throw	1.4 %
	Throw out of a window because you’re mad	(25)
Play	Game	1.0 %
	Make a game of who can throw the brick the farthest	(18)
Fix	Level	0.8 %
	To fix a missing brick in a brick sidewalk	(14)
Ground Brick	Break it up and to make pebbles	0.6 %
	Grind into sand and use sand to make glass	(10)
Study material	Experiment	0.4%
	To show erosion	(8)
Gift	Donate it	0.3%
	Birthday present for a carpenter	(6)
Heating	Oven	0.2 %
	Heat up and use as bed warmer	(4)
Identifier / Marker	Marking a spot	0.2%
	Tombstone for a pet	(3)
Hiding place	Hiding place	0.1%
	Hide an extra key under	(2)
Other	To inspire a poem	1.7 %
	Use to represent something strong	(30)
Inadequate responses	Do nothing	0.6%
	I’m out of ideas	(11)

Table 4.4

Correlations between idea generation, remote associate, CCST, and reversal learning tasks

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Fluency, 1 min														
2	Fluency, 2 min	.82**													
3	Fluency, 5 min	.64**	.87**												
4	Category Flexibility	.50**	.64**	.79**											
5	Originality	.31*	.47**	.57**	.77**										
6	Remote Associates	.14	.01	.09	-.01	-.12									
7	Poor Reversal Learning	.10	.04	-.03	-.08	-.05	-.03								
8	Correct Sorts, verbal	.26*	.10	.18	.25	.04	.22	-.03							
9	Correct Sorts, nonverbal	-.16	-.19	-.11	-.22	-.24	.32*	.00	-.23						
10	Sorting Perseverance	.20	.24	.28*	.29*	.28*	.01	-.24	.03	-.34**					
11	FS Correct Descriptions, verbal	.23	.08	.07	.14	-.05	.14	.01	.65**	-.49**	.24				
12	FS Correct Descriptions, nonverbal	-.10	-.17	-.12	-.13	-.21	.34**	.02	-.06	.87**	-.41**	-.30*			
13	FS Description Perseverance	-.09	-.14	-.06	.04	-.02	.15	.03	.14	.17	.33**	.25	.31*		
14	SS Correct Descriptions, verbal	.15	.23	.18	.22	.17	-.08	-.02	.08	-.32*	.20	.32*	-.18	.23	
15	SS Correct Descriptions, nonverbal	.10	.19	.23	.10	-.04	.21	-.16	-.09	.48**	.09	-.15	.46**	.16	.06

Notes. ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Tasks are: Idea Generation (Fluency, Category Flexibility, and Originality), Remote Associates, Poor Reversal Learning, and Sorting as well as Descriptions scores (verbal, nonverbal, perseverance) from the California Card Sorting task (FS = Free Sorting, SS = Structured Sorting

Table 4.5
Means and standard deviations of scores of the CCST

Score	M	SD
Attempted Sorts	5.05	1.42
Correct Sorts	3.58	1.05
- Verbal	2.08	0.71
- Nonverbal	1.50	0.95
Sorting Perseverance	0.73	0.98
Nontarget Sorts	0.03	0.25
Unequal Sorts	0.31	0.93
Correct Descriptions, Free Sorting	2.92	0.98
- Verbal	1.65	0.63
- Nonverbal	1.27	0.96
Description Perseverance, FS	2.79	1.53
Nonrule Descriptions	0.97	1.15
Nonmatching Descriptions	0.15	0.51
Correct Descriptions, Structured Sorting	2.95	2.16
- Verbal	1.71	1.61
- Nonverbal	1.24	1.34

Table 4.6
Regulative and associative flexibility performance resulting from combinations of goal maintenance and global processing

Processing style		Regulative flexibility	Associative flexibility
Unfocused	Top-down	low	high
	Bottom-up	medium	medium
Focused	Top-down	medium	medium
	Bottom-up	high	low

Table 4.7
Distribution of women in different emotion conditions according to combinations of goal maintenance and global processing

		Low goal maintenance		High goal maintenance	
		Local	Global	Local	Global
Emotion Condition	Happy	6	3	3	8
	Control	6	12	6	2

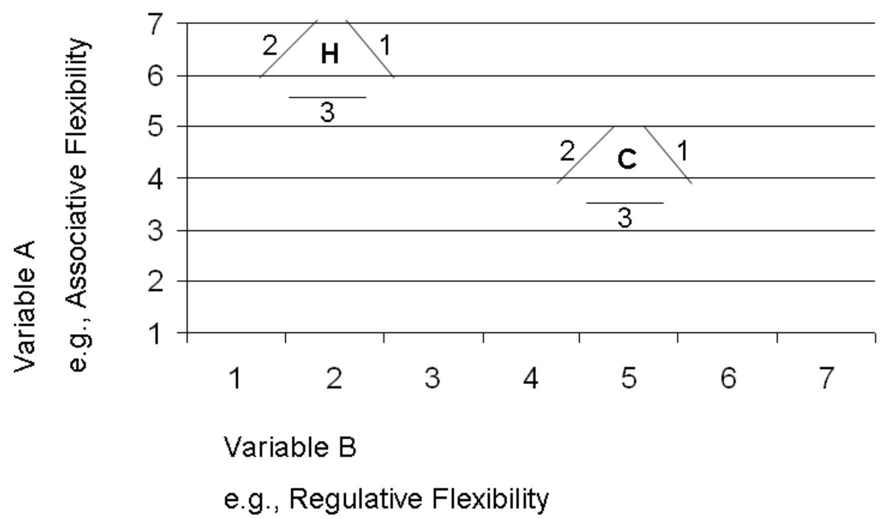

Figure 4.1. The relation of variables at the group and individual level of analysis.

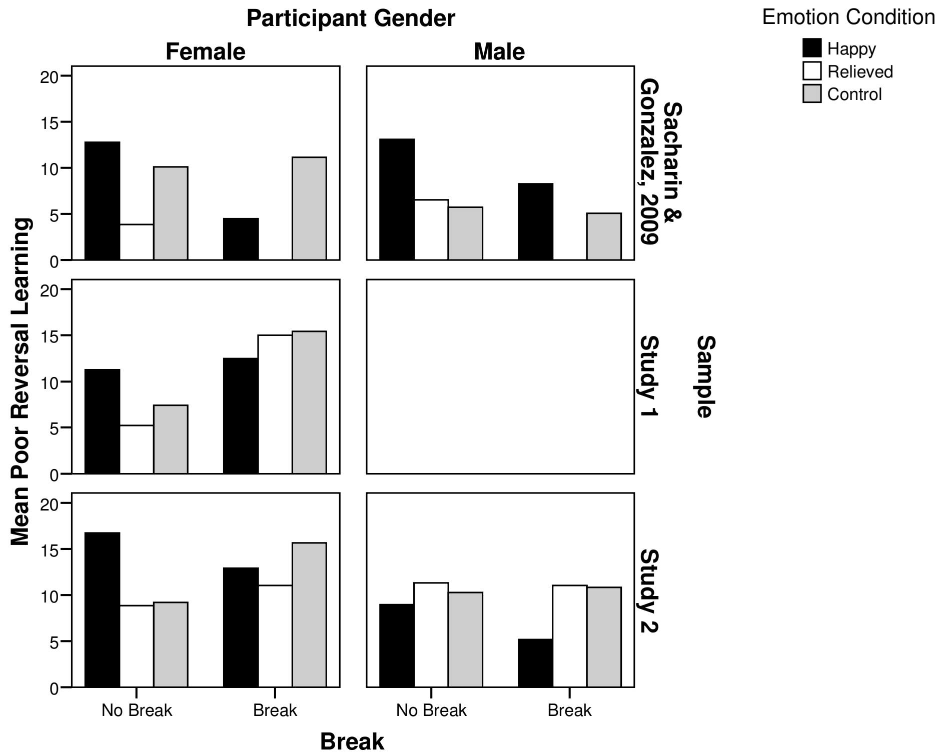

Figure 4.2. Mean reversal learning scores in different samples by gender and time of data collection.

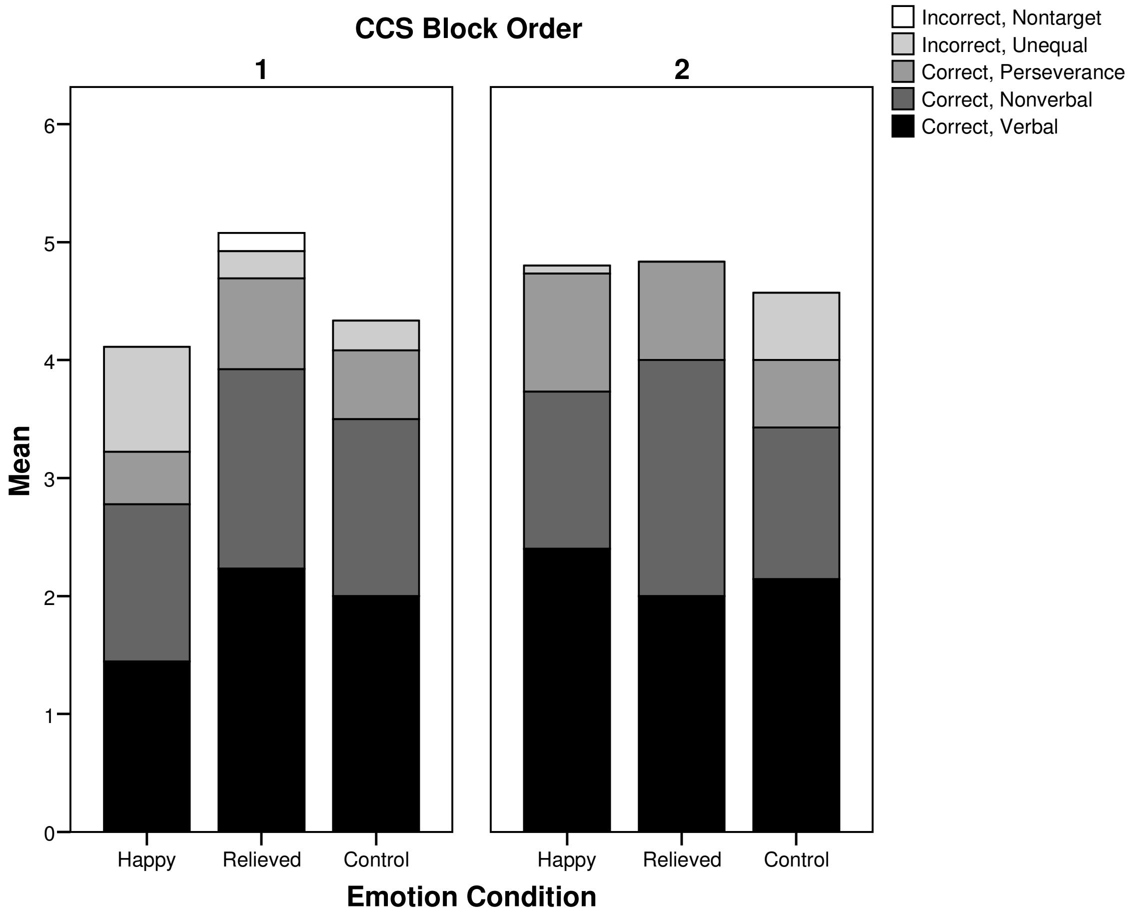

Figure 4.3. Mean number of sorts in the Free Sorting sub-task of the CCST for different blocks of experiment and emotion conditions.

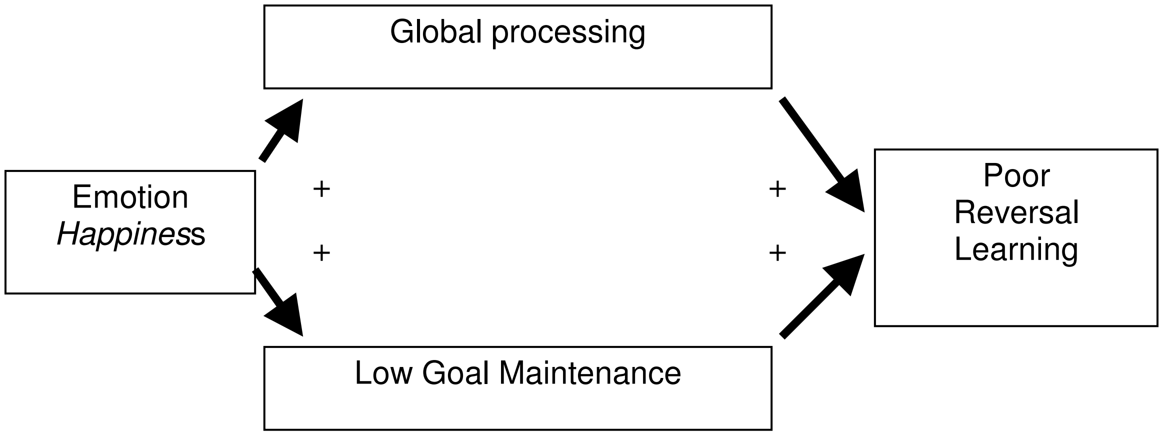

Figure 4.4. Model for the mediation of the influence of happiness on reversal learning by global processing and low goal maintenance.

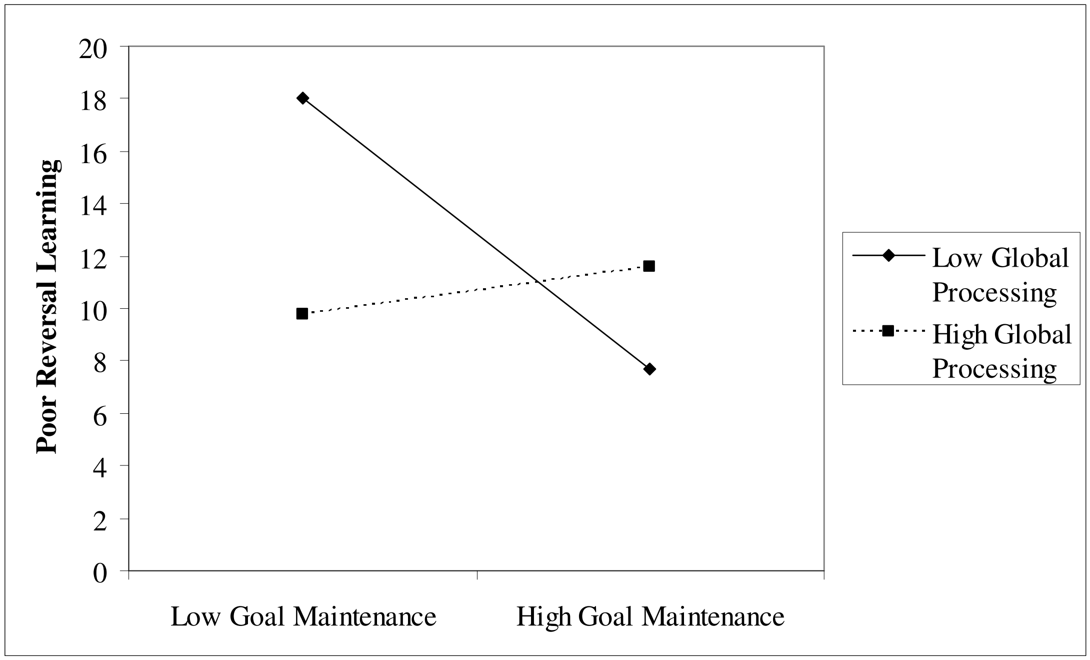

Figure 4.5. Regression of poor reversal learning on goal maintenance and global processing for women.

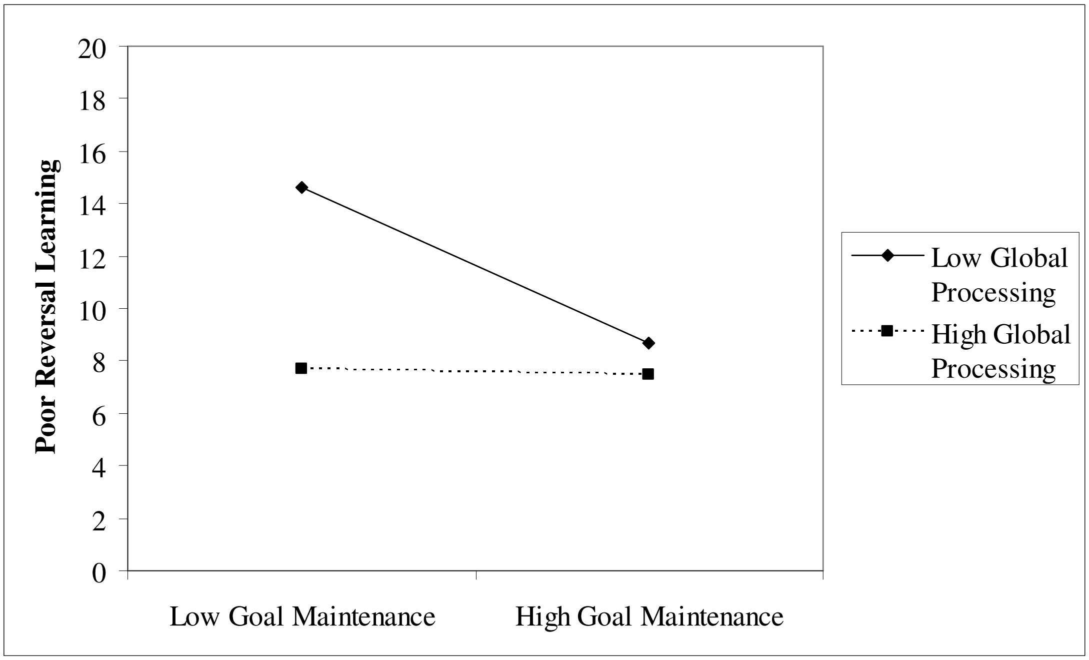

Figure 4.6. Regression of poor reversal learning on goal maintenance and global processing for men.

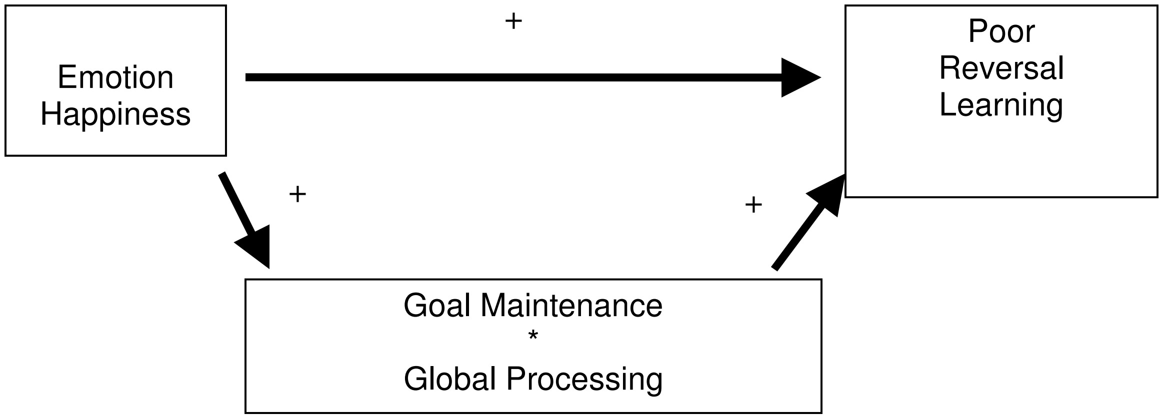

Figure 4.7. The resulting model of the influence of happiness and the interaction of goal maintenance and global processing on reversal learning.

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Chapter 5

Summary and Conclusions

A large body of research in social psychology shows that positive emotions increase cognitive flexibility (e.g., Isen and colleagues). However, recent studies illustrate that different positive and negative emotions influence flexibility on creative tasks differently (e.g., De Dreu, Baas, & Nijstad, 2008). Also, according to research in both cognitive psychology and psychiatry, flexibility is not a unitary concept. In light of these findings, it seems necessary to specify more clearly which emotions influence which types of cognitive flexibility.

In this dissertation, I differentiated between three types of flexibility. Associative flexibility is the ability to generate unusual associations, regulative flexibility is the ability to adapt to changing reward situations, and attentional flexibility is the ability to shift attention. In chapter 4, the different types were introduced in detail and a taxonomy of tasks for their assessment was proposed. The goals of the dissertation were to (a) review the influence of positive and negative emotions on associative flexibility, (b) examine how different positive emotions influence regulative and attentional flexibility, and (c) identify mediator variables. The predictions for the influence of emotions on flexibility of several models will be evaluated after a review of the major findings.

Summary of Major Findings

A common belief is that positive affect improves cognitive flexibility in the creativity domain. The influence of emotions on associative flexibility was examined in chapter 2 with a meta-analysis, and in chapter 4 with an experiment. Overall, chapters 2 and 4 showed that positive affect increased associative flexibility. In chapter 2, I reviewed existing experimental studies on idea generation and categorization. Meta-analytical comparisons of positive and neutral emotions' influence on idea generation and categorization showed that positive affect increased the number of ideas generated and the unusualness of ideas and category members. In chapter 4, associative flexibility was measured with an idea generation task and a remote associate task. In line with previous research, I found that happiness improved idea generation.

Happiness enhances associative flexibility, but not all positive emotions do. In chapter 4, relief did not improve performance in idea generation. Happiness and relief differ in several ways. For example, happiness is associated with a belief that the world is good and fair. This belief might be particularly helpful for associative flexibility, because feeling safe and optimistic may allow for exploratory, playful, and creative behavior (Fredrickson, 1998; Schwarz & Clore, 2007). However, relief is not characterized by the belief in a good world (Tong, 2008), and may not facilitate associative flexibility. When predicting the influence of positive affect on flexibility, it is not possible to generalize from happiness to other positive emotions.

It has been suggested that while happiness improves cognitive breadth and creativity, negative emotions have the opposite effect (e.g., Fredrickson & Branigan, 2005). Contrary to the idea that negative emotions reduce flexibility, a meta-analytic comparison of positive and negative emotions showed that negative emotions could increase associative flexibility. However, the effects were more varied than with positive affect. This supports the idea that positive and negative emotions are different processes with outcomes that do not lie on opposite ends of the same continuum.

The influence of emotions on associative flexibility was not robust and strongly influenced by situational variables. In chapter 4, task order influenced the effects of emotions on idea generation, as well as performance in the remote associate task. In the meta-analysis of chapter 2, performance goals were identified as moderators, in line with previous research (Baas, De Dreu, & Nijstad, 2008; Davis, 2009). Another moderator of the emotions-cognition relationship was task difficulty. With easy tasks, the difference between positive and negative emotions could be larger than with difficult tasks. Thus, the influence of emotions was sensitive to a variety of moderators. Furthermore, a large amount of heterogeneity in the meta-analysis suggested that not all relevant moderators could be identified.

The influence of emotions on cognitive flexibility depends not only on the specific emotion, but also on the type of flexibility. I found that although happiness improved associative flexibility, it impaired regulative flexibility. The influence of emotions on regulative flexibility was examined in chapters 3 and 4. Based on the facilitating effect of happiness on associative flexibility, the major question was whether happiness would also improve regulative flexibility. In chapter 3, the influence of different positive and negative emotions on regulative flexibility was tested experimentally with a reversal learning task. I found that happiness impaired reversal learning, but relief, worry, and sadness did not impair reversal learning. In chapter 4, I replicated the result that happiness impairs flexibility in reversal learning, but relief does not. In study 2 of chapter 4, an unexpected gender difference emerged, and men's reversal learning was not influenced by emotions. Understanding the reason for this gender difference requires future research.

The appraisals underlying happiness may explain why happiness improves associative flexibility and impairs regulative flexibility. For example, a belief in a good and fair world may reduce and individual's motivation to learn and understand reward-contingencies, because there is no need to understand what is rewarding and what is not when everything is already at its best. The same belief may also improve associative flexibility, because the safety signal from this belief could increase exploratory and creative behavior (Fredrickson, 1998; Schwarz & Clore, 2007). Happiness, relief, sadness, and worry also differ regarding associated activation levels and approach/avoidance tendencies (Baas et al., 2008), but these differences could not explain the pattern of results.

The influence of emotions on attentional flexibility was also assessed in chapter 4. Attentional flexibility was assessed with a California Card Sorting Test (Delis, Squire, Bihrle, & Massman, 1992). I found that happiness, but not relief, impaired performance for initiating sorts from the verbal domain. There were no effects for nonverbal sorts or descriptions. Thus, while there was some indication that attentional flexibility is impaired under happiness, the evidence was somewhat weak, and more research is required before conclusions can be drawn with certainty.

One concern was that the results in the experimental studies are not specific to reversal learning, but due to confounding factors resulting in a general decrease in performance after happiness. In study 2 of chapter 4, I therefore assessed associative, regulative, and attentional flexibility simultaneously in one study. The results confirmed that the influence of happiness is specific to regulative flexibility, and does not reflect a general impairment.

Given the multitude of types of flexibilities identified in chapter 4 and resulting complexity in explanations for the influence of emotions on flexibility, one goal of this dissertation was to identify mediator variables. Mediation could provide information useful in developing a parsimonious theory for the influence of emotions on cognitive tendencies. Mediation requires that differences on the group level are reflected in individual differences. Chapter 4 described why group differences are not necessarily reflected in individual differences.

In chapter 4, I proposed various mediator variables and examined the potential of global processing and goal maintenance as potential mediators in the relation between emotions and regulative flexibility. Although it has been argued that flexibility in creative performance might be due to global and unfocused processing (Fredrickson, 1998; Isen, Johnson, Mertz, & Robinson, 1985; Schwarz & Clore, 2007), I did not find that these processes mediated the influence of emotions on regulative flexibility. Past research showed that happiness increases global processing and decreases goal maintenance and reversal learning. Therefore, I expected that reversal learning would be negatively associated with global processing and positively associated with goal maintenance. Contrary to expectations, global processing was positively associated with reversal learning, a result that could be due to the specific stimuli used to assess reversal learning. In line with the prediction based on group differences, reversal learning was improved with goal maintenance. Although emotions influenced the combination of global processing and goal maintenance, a mediation analysis showed that happiness impaired reversal learning independent of goal maintenance and global processing. It is possible that despite the non-mediation for regulative flexibility, global processing and goal maintenance might still play a role for mediating associative flexibility, if the processes underlying associative and regulative flexibility differ.

Chapter 4 suggests that no one variable explains the effects of emotions on both associative and regulative flexibility. Although happiness influenced regulative and associative flexibility in opposite ways, chapter 4 showed that there was no negative association of the performance in these tasks on an individual level. This finding indicates that the identification of a mediator variable that could explain the effects on both associative and regulative flexibility might be complicated by other variables. For example, smart individuals may have high regulative and associative flexibility. When grouping individuals by intelligence, associative and regulative flexibility would be positively associated. However, when grouping individuals by emotion, associative and regulative flexibility would be negatively associated. With smart individuals in either emotion group, individual differences would not correspond to either group difference. More research is required before conclusions regarding the reliability of the independence of associative and regulative flexibility can be drawn with certainty, particularly given the limitations of the current research.

Limitations

An implicit goal of the dissertation, which was only achieved with limitations, was to examine the influence of *emotions* on cognition. Throughout chapters 3 and 4, manipulation checks indicated that feeling measures were either insensitive to manipulated emotions or that the manipulation of emotions was of limited success. Clearly, using different induction techniques to arouse emotions could have shed some light on this issue. A meta-analytical review suggests that using this type of emotion induction is generally successful (Westermann, Spies, Stahl, & Hesse, 1996). However, the authors also reported that for positive emotions the effectiveness of the induction showed a significant amount of heterogeneity, suggesting that the success varies. It is possible that instead of 'hot' emotions, 'cold' emotional mind-sets were evoked. Using the memory of an emotional event to induce emotions is a top-down experience of emotions where conceptual knowledge can result in experiencing an emotion (Barrett, 2006). However, the conceptual knowledge associated with an emotion may also guide behavior regardless of the experience of a feeling state (Friedman & Förster, 2005). For example, appraisals of a situation associated with an emotion may be carried into a new situation and affect decision making (Lerner & Keltner, 2000). However, it is not clear if only the appraisals or additional feeling states are carried over. In a study conducted to examine whether semantic knowledge of emotions influences emotion congruent judgments similarly to emotions, activating semantic concepts of emotions with a sentence unscrambling task showed no effect on a subsequent measure, but inducing emotions with films and music did (Innes-Ker & Niedenthal, 2002). Future research is necessary to differentiate between emotions and emotional conceptualizations, and to examine the influence on cognitive tendencies.

Another limitation is that the results in study 1 of chapter 4 were heavily influenced by order effects. As indicated in the discussion of that chapter, future research is necessary to examine if the effects occur at random or according to a systematic and meaningful pattern. For example, task order effects for associative flexibility tasks may be due to beliefs in a good and fair world associated with happiness (Tong, 2008) that initially result in maintenance of the pleasant status quo (compare Schwarz & Clore, 2007) and only later lead to creative and explorative behavior (compare Fredrickson, 1998). The results indicate that the influence of emotions / emotional mind-sets on flexibility may depend on the timing of a task.

Across the experiments reported in chapters 2-4, several subjects were excluded from the analysis because they were suspicious, did not seem to understand the task, or because they were run during break. The first two problems could be ameliorated in future research by using better cover stories and improved task instructions. However, understanding and dealing with the ‘break effect’ seems more complicated. A systematic analysis of changes in participants’ motivation, cognitive abilities, and general mood during break could shed some light on this issue. Regardless of the underlying reasons, the fact that emotions do not influence regulative flexibility during break time indicates that the effects, though replicable across three studies, are not robust. Future research is required to better understand which variables change the relation of emotion and cognitive flexibility, and why.

A further limitation is that in the three experimental studies conducted in chapters 3 and 4, and in most of the studies reviewed in chapter 2, participants consisted of college students. Past research indicates that attention and memory for emotional events changes over the course of the life span (e.g., Mather & Carstensen, 2003). It is not clear whether the emotion-cognition link is similarly affected by aging. Thus, it is not possible to know whether the findings presented in this dissertation extend to other populations.

Evaluation of Findings Regarding Existing Theory

Models predicting that positive affect increases cognitive flexibility were confirmed only for the contrast between positive and neutral emotions, and only for associative flexibility. According to the Broaden and Build Model (Fredrickson, 1998), positive emotions increase flexibility, because play, exploration, and networking are evolutionary advantageous. The Broaden and Build Theory is based on the notion that in contrast to positive emotions, negative emotions narrow thinking. In line with this model, I found that positive affect increased associative flexibility (chapter 2). However, the Broaden and Build Model cannot explain why negative emotions could improve associative flexibility (chapter 2), and why happiness impaired regulative flexibility (chapters 3 and 4).

According to the Mood as Information Model (Schwarz & Clore, 1983; 2007), positive mood increases broad thinking when the mood signals that there is no problem requiring analytic, bottom-up thinking. Also, the Affect as Information Model assumes that negative and positive moods have opposite effects. When aggregating across various positive and negative emotions in the meta-analysis, the model was supported for associative flexibility with positive emotions, but not for negative emotions (chapter 2). However, the affect as information logic also assumes that specific emotions have differential effects on thinking. Appraisals associated with an emotion may signal which behavior is most required (Schwarz & Clore, 2007). This idea proved to be valuable for suggesting explanations for why various emotions may influence cognitive flexibility differently. Happiness differs from the other three emotion conditions on several appraisals. I suggested that differences in beliefs of a good and fair world with happiness compared to other emotions and neutral states might explain why happiness influenced associative and regulative flexibility differently. Further research is required to test this idea.

The models that incorporate an affect as information logic, the Mood as Input Model (Martin, Ward, Achee, & Wyer, 1993) and the Mood Behavior Model (Gendolla, 2000), found support regarding moderators in the emotion-flexibility link (chapter 2). The influence of positive and negative emotions on associative flexibility was moderated by task goals, in line with the Mood as Input Model (Martin et al., 1993). Building on the affect as information logic, the mood as input model suggests that the information provided by moods is used differently depending on the situation. Also, task difficulty was a moderator, in line with the Mood Behavior Model (Gendolla, 2000). This model suggests that mood is but one piece of information, and that information provided by the task itself can outweigh the informational value of emotions.

Capacity theories (e.g., Mackie & Worth, 1989) predict that emotions cause a cognitive load that reduces performance in executive functions. However, the results from chapters 3 and 4 did not support this idea, since neither relief, sadness, nor worry impaired performance in the executive function task used to assess regulative flexibility.

The Dopaminergic Model (Ashby, Isen, & Turken, 1999) predicts that positive affect increases flexibility mediated by dopamine, and makes no predictions for negative emotions. This was confirmed for associative flexibility, but not for regulative flexibility. However, the underlying rationale of the model that increased levels of dopamine mediate the emotion-cognition link is nonetheless promising. In fact, the findings of this dissertation are well in line with the underlying logic proposed by Ashby et al.'s (1999) dopaminergic model. Given the relation of dopamine levels and reversal learning found in Parkinson's patients, it seems that the model needs to be specified to take instances into account where increased dopamine impairs flexibility.

Future Research

A differentiation of the Dopaminergic Model was suggested in this dissertation. Specifically, I proposed the differentiation between different types of flexibility that are differently influenced by positive affect. I showed that happiness facilitates associative flexibility and impairs regulative flexibility. Although there was some evidence that happiness impairs attentional flexibility, these results should be replicated before conclusions can be drawn.

Also, more research is required to confirm the taxonomy of tasks to measure different types of flexibility suggested in this dissertation. In the current research, only a limited number of the tasks were studied. Thus, further research is necessary to test the merit of the suggested taxonomy.

Another differentiation of the Dopaminergic Model concerns the need to distinguish between different positive emotions. The research in this dissertation shows that happiness and relief do not affect flexibility in the same way. Future research is necessary to understand why these emotions had different outcomes, and how other emotions would influence cognitive tendencies. Also, examining the implications of emotions versus emotional mindsets is a fruitful avenue for future research.

Future research should also examine how trait differences in emotionality interact with state emotions. For example, trait differences in threat sensitivity increase relief reactions (Carver, 2009). Future research could examine how the combination of situational factors and trait differences in emotionality influence cognitive tendencies. Differences in the sensitivity to threats and rewards (Carver & White, 1994; Gray, 1990) could increase or reduce cognitive tendencies following emotional events.

Eventually, a psychological explanation for why different emotions differently influence flexibility needs to be established. Current models are either not able to explain research evidence (e.g., capacity theories), or require further specification (e.g., which are the relevant appraisals). Integrating across sub-fields of psychological research (e.g., social and cognitive psychology) is a fruitful avenue for building a theory that can explain why different emotions influence different types of flexibility differently.

The current research was inspired by the notion that positive affect improves cognitive flexibility across a broad range of settings. I found that happiness improves flexibility in creating novel associations, but impairs flexibility in dealing with changes in reward situations. However, relief does not improve or impair performance. Thus, neither positive emotion nor flexibility is a unitary concept. The distinction between flexibility types is important for predicting the influence of specific emotions. In the current dissertation, I differentiated associative, regulative, and attentional flexibility and proposed a related taxonomy of tasks. More research integrating knowledge on cognitive tendencies, affective states, and underlying mechanisms is required to develop a psychological explanation for the influence of emotions on cognitive flexibility.

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