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Positive Mood and Executive Function: Evidence From Stroop and Fluency Tasks

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Contrasting predictions have been made about the effects of positive mood states on the performance of frontal lobe tests that tap executive functions such as inhibition, switching, and strategy use. It has been argued that positive mood is likely to improve some cognitive processes, particularly those dependent on the frontal cortex and anterior cingulate of the brain. However, there is some evidence that happy mood may impair executive functioning. The current experiments investigated the effects of positive mood on Stroop and fluency tests, which are frequently used to assess executive function. Positive mood impaired performance on a switching condition of the Stroop test, but improved performance on a creative uses test of fluency. The effect of positive mood on an executive task may therefore depend on whether a task is inherently motivating or is impaired by diffuse semantic activation.

Ashby, Isen, and Turken (1999, p. 529) argued that "with few exceptions, cognitive psychologists have ignored positive affect in their own theories of human cognition." There is evidence that being in a positive mood state can improve performance on some types of cognitive tasks. For example, positive mood can improve creativity (e.g., Hirt, Melton, McDonald, & Harackiewucz, 1996; Isen, 1999; Isen, Daubman, & Nowicki, 1987) and enhance recall of happy memories (Teasdale & Fogarty, 1979). It has been argued that being in a positive mood state increases the flexibility with which material can be reinterpreted and enhances the ability to switch between different cognitive sets (Isen, 1999; Isen & Daubman, 1984). Isen argued that in the vast majority of situations, positive affect facilitates efficient and thorough thought processes. However, positive mood states have been found to impair some aspects of cognition, causing poor performance on tasks assessing memory, deductive reasoning, and planning (Oaksford, Morris, Grainger, & Williams, 1996; Seibert & Ellis, 1991; Spies, Hesse, & Hummitzsch, 1996). Positive mood may increase the load on working memory because being happy tends to increase the incidence of mood-related thoughts that interrupt processing on a given cognitive task (Seibert & Ellis, 1991). In relation to social cognition, it has been found that positive mood increases the likelihood of using stereotypes to judge people (Bodenhausen, Kramer, & Süsser, 1994). Forgas and Fiedler (1996) argued that positive mood results in more superficial, heuristic categorization judgments that can result in intergroup discrimination.

Ashby et al. (1999) proposed a neuropsychological theory of the influence of positive affect on cognition. They argued that positive mood results in increased dopamine levels in the brain, particularly in the prefrontal cortex and anterior cingulate, which then results in better cognitive performance on some tasks. Happy mood states are known to increase frontal lobe activity, particularly in the left hemisphere (Davidson, Ekman, Saron, Senukis, & Friesen, 1990). Baker, Frith, and Dolan (1997) showed that induced elated mood results in increasing cerebral blood flow in a number of regions within the frontal lobes. There is considerable evidence that prefrontal cortex and anterior cingulate are involved in executive functions such as inhibition, switching, and strategy use (e.g., Cabeza & Nyberg, 2000; Cuenod et al., 1995; Peterson et al., 1999).

Supervisory control processes or executive processes are important in the control of our thoughts and actions, for example, in planning, problem solving

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(Phillips, Wynn, Gilhooly, Della Sala, & Logie, 1999; Ward & Allport, 1997), and trouble shooting (e.g., Norman & Shallice, 1986), and when performing novel tasks (e.g., Shiffrin & Schneider, 1977). There is still considerable debate about the exact taxonomy of executive processes, but some important executive functions include the suppression of unwanted responses (Monsell, 1996), switching from one task to another (Allport, Styles, & Hseih, 1994), and generating effective retrieval strategies (Crowe, 1992). Everyone experiences occasional lapses in executive control (Reason, 1984), whereas focal frontal lobe damage may cause more general deterioration in executive functions (e.g., Shallice, 1988).

Two contrasting predictions can be made about the effects of happy mood states on executive function tests. Some authors argue that positive mood is likely to improve performance on many cognitive tasks (Ashby et al., 1999; Isen, 1999). Ashby et al. predicted that because of increased dopamine release in the anterior cingulate and prefrontal cortex, moderate levels of positive affect may improve working memory and cognitive set selection. This suggests that positive mood might improve performance on at least some executive function tests.

In contrast, other authors argue that positive mood particularly impairs performance on executive function tests (Oaksford et al., 1996; Spies et al., 1996). Oaksford et al. investigated the effects of positive affect on the Tower of London task, which they described as a classic test of executive functioning, and found that positive mood impaired performance on the task. Oaksford et al. argued that impairment of executive control processes underlies the deleterious effects of positive mood on deontic reasoning. Spies et al. argued that positive mood reduces the capacity available to carry out executive processes and present supporting evidence that induced positive mood impaired performance on a working-memory span task thought to depend on executive capacity. Also, there is neuropsychological evidence suggesting that separable areas within the anterior cingulate are involved in emotional and cognitive control processes and that the relationship between these two areas may be inhibitory (Bush, Luu, & Posner, 2000). This implies that manipulations that increase demands for emotional control may reduce capacity for control of cognitive processes.

Some authors have therefore predicted that happy mood states will enhance cognitive control processes, whereas others have predicted impairment. The current article directly investigates the role of happy mood in a number of different executive functions. There is some consensus that executive function does not consist of a single cognitive controller but instead a number of putatively differentiable functions such as inhibition of irrelevant stimuli or responses, strategy generation, monitoring, and attentional switching (Burgess & Shallice, 1996; Miyake et al., 2000; Ward, Roberts, & Phillips, 2001). The current experiments investigate the effects of happy mood on tasks proposed to assess inhibition, strategic retrieval, and switching.

Variants of two tasks are used—verbal fluency and Stroop color ink naming. A large number of tasks are frequently used to assess executive function, but these tasks were chosen for three reasons: (a) Considerable neuroimaging and cognitive neuropsychological research has confirmed the role of executive processes and the prefrontal regions of the brain in these tasks, and both Stroop and fluency tasks are widely used in clinical and experimental studies as methods to assess executive functioning; (b) both tasks are quick to administer, which is important given the transient nature of experimentally induced mood effects; and (c) fluency and Stroop are not as potentially frustrating to participants as some widely used frontal lobe tests such as the Wisconsin Card Sorting Test, which sometimes distresses those attempting it and is therefore likely to rather quickly reverse the effects of induced positive mood. Experiment 1 examines the effect of positive mood states on the Stroop task, and Experiment 2 examines the effects of positive mood on a range of different verbal fluency tasks.

Experiment 1: Stroop Tasks

The Stroop task is proposed to assess ability to inhibit a prepotent response. In a control condition, the participant is asked to name the color of blocks as quickly as possible. In the experimental Stroop condition, color names are printed in an incompatible color of ink and the participant is asked to name the color of the ink rather than read the color word. Longer color-ink-naming times on the Stroop condition indicate problems in inhibiting the habitual tendency to read the color name. This Stroop cost is relatively large and robust.

The Stroop test is sometimes cited as a *frontal lobe test* despite comparatively few studies of the task in patients with focal brain lesions (although, see Perret, 1974). In the last decade, a substantial number of neuroimaging studies have examined localized activation during the Stroop task. Cabeza and Nyberg

(2000) reviewed the positron emission tomography (PET) studies of Stroop task performance up to the end of 1998. They found that comparing conditions of Stroop color ink naming with baseline naming conditions tended to show significant activation within the prefrontal cortex and anterior cingulate, and also considerable parietal lobe activity. Peterson et al. (1999) carried out a functional magnetic resonance imaging (fMRI) study of Stroop performance and found substantial activation in many brain areas. Peterson et al. summarized their own along with a number of other Stroop activation studies and concluded that the most consistent brain area activated is the anterior cingulate, with additional activation in dorsolateral prefrontal areas. MacDonald, Cohen, Stenger, and Carter (2000) offered evidence that the anterior cingulate and prefrontal cortex are involved in different cognitive components of the Stroop test.

In the current study, we examined the effects of positive mood on the following four Stroop naming conditions: (a) the control condition, naming the color of ink in which characters are printed; (b) color word reading, reading aloud color words printed in different color inks; (c) the classic Stroop condition, naming the color of ink in which incompatible color words are printed; and (d) switching between naming color of ink and reading color words. The switching condition is included because there is evidence that switching involves different executive functions to those of Stroop inhibition tasks (Ward et al., 2001). It therefore gives an opportunity to assess the effects of happy mood on a task condition involving both switching and inhibition.

Method

Participants

In all, 36 participants, mostly undergraduate students, completed the experiment. Age ranged from 16 to 40 years ($M = 21.56$ years, $SD = 5.87$). There were 5 men and 13 women in each mood condition.

Materials

Stroop testing was carried out with a laptop, which allowed response times to be recorded for each individual trial. All responses were made with one of four labeled keys (blue, black, red, or green), which retained the same mapping throughout the experiment. Each stimulus consisted of a display of 20-point characters, displayed in one of four colors (blue, black, red, or green). For each of the five Stroop task conditions outlined below, participants were given 8 practice trials, then 24 main trials. Any errors made during the practice phase of each task were pointed out to the participant, but no feedback was given to the 24 trials in the main phase. Analyses were conducted only on the 24 main phase trials for each task.

Mood measurement inventories were used to record mood at various stages of the experiment. Two different inventories were used—the first mood inventory (MI1) used the adjectives happy–sad, active–exhausted, peaceful–anxious, carefree–serious, and energetic–sombre. The positive mood indicators (three hedonic, one physical arousal, and one worry measure) were presented at the left-hand side of a page, with the negative words on the right, and a scale from 1–9 written in numerals in between each word pair. Participants were asked to rate their current mood state with the numerical scales. Scores were totaled across the five word pairs. The second mood inventory (MI2) used the same format but a different set of five adjectives: positive–negative, lively–tired, calm–uptight, bright–dispirited, and cheerful–low. This is similar to the mood measurement used by Oaksford et al. (1996). Mood scores were reversed so that higher values indicated more positive mood.

Procedure

The participant first completed a baseline condition on the computer Stroop task to familiarize themselves with the key-response mappings. This task consisted of seeing color words (blue, black, green, red) displayed in black, and the participant was instructed simply to press the corresponding key for each color word. After completing the baseline task, the participant rated their current mood on MI1.

Next, the mood induction was carried out with a mood-memory procedure (see e.g., Bodenhausen et al., 1994), with half the participants in the neutral condition and the other half in the happy mood condition. In total, the mood induction procedure took around 5 min. Pilot work indicated that the mood-memory procedure was an effective method of inducing both happy and neutral mood. Those in the happy mood condition were asked to identify an occasion on which they experienced a high level of happiness, to think about the occasion, concentrating on how it made them feel, and then to describe the event to the experimenter. The experimenter asked questions to elicit further details of the nature of the happy experience. Those in the neutral condition were asked to think about the usual events of an average Monday (ignoring unusual or infrequent occurrences), and then to tell the experimenter about these. The experimenter asked questions to elicit further details of the average events of a Monday. Participants then rated their mood on MI2.

Next, the following four computerized Stroop tasks were administered: color x naming (xxxx), reading color words (colwd), naming display color—the classic Stroop condition (stroop), and alternating between naming display color and reading color word (alt). These tasks were carried out in one of three orders to ensure that any mood effects on individual tasks were not due to the transient nature of mood induction interacting with task order (Order 1: xxxx, colwd, stroop, alt; Order 2: stroop, alt, xxxx, colwd; and Order 3: alt, xxxx, colwd, stroop). In the xxxx task, all stimuli were four xs that were displayed in either black, blue, red, or green, and participants were asked to name the color of the display for each trial. For the other three conditions (colwd, stroop, alt), each trial consisted of a color word displayed in a different color (e.g., RED). In the colwd condition, participants were instructed to read the color word (so the correct answer to the example would be *red*). In the Stroop condition, participants were instructed to name the color of the display (so the correct answer to the above example would be *black*). In the alt condition, participants were told to alternate from one trial to the next between naming the color of the display and reading the color word. For each trial in the alt condition, a brief cue was given stating whether to name the display color or read the color word before the color word stimulus appeared.

Error rates on the Stroop tasks were low. Out of the 24 trials in each condition, the number of error trials for the conditions were as follows: xxxx (M = 0.39, SD = 0.73); colwd (M = 0.44, SD = 0.69); stroop (M = 0.53, SD = 0.85); and alt (M = 1.57, SD = 1.26). These error rates were too low to conduct further analyses. In all of the results reported below, correct reaction times to stimuli were analyzed; error trials were excluded. Stroop cost was calculated by subtracting correct reaction times on the xxxx color-naming condition from the Stroop color-display naming condition. Alternation cost was calculated by subtracting the mean of the two constituent tasks (color word reading and color display naming) from the alternating condition time (i.e., alternation cost = alt − 0.5 × [colwd + stroop]). Analysis revealed that there was no effect of task order on performance of the Stroop tasks, $F(2, 30) = 1.24$, nor a significant interaction between task order and mood group in predicting correct reaction times on the Stroop tasks, $F(2, 30) = 1.78$, so that in all of the reported analyses, data were collapsed across task order conditions.

Results

Mood Measurement

Self-rated mood scores are reported in Table 1. The effect of mood group (happy vs. neutral) on self-rated mood at three different stages of the experiment (premood induction, postmood induction, and the end of the experiment) was examined by a univariate analysis of variance (ANOVA). There was no overall main effect of mood group, $F(1, 34) = 0.60$. There was a significant effect of the stage of the experiment at which the rating was taken, $F(2, 68) = 23.20, p < .01$, and a significant interaction between mood group and stage of measurement, $F(2, 68) = 13.61$, $p < .01$. Tukey's honestly significant difference (HSD) test with $p < .05$ was used to examine differences between the means. As would be expected, there was no difference in rated mood between the happy and neutral groups before the mood induction, but a highly significant difference after the mood induction. By the end of the experiment, there was no significant difference in mood ratings between the neutral and happy mood group. The neutral group showed no difference in rated mood across the three times of measurement, whereas the positive group retained a significantly higher mood rating at the end of the experiment compared with before the mood induction.

Cognitive Performance

An analysis of the effect of mood group on reaction times on the baseline computer task (color words displayed in black), which was carried out before the mood induction, revealed no group difference, $t(34) = .58$. Next, the effect of mood group on correct reaction times on the four postmood induction Stroop tasks was examined with a mixed design ANOVA. Performance on the tasks is shown in Figure 1. There

Table 1
Mood Ratings Before and After the Mood Induction Procedure and After the Stroop Tests

Mood condition	Before induction		After induction		After Stroop	
	M	*SD*	*M*	*SD*	*M*	*SD*
Neutral	5.37	0.88	5.53	0.90	5.64	0.92
Positive	5.11	1.28	6.39	0.97	5.79	1.16

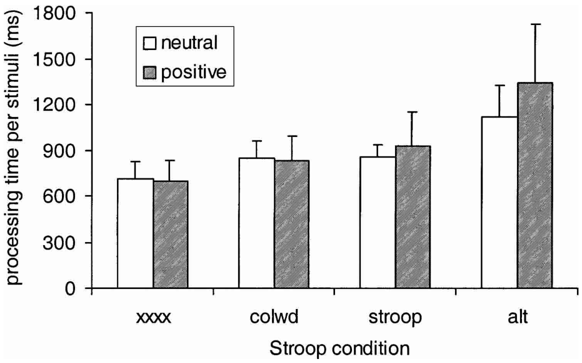

Figure 1. The performance of positive and neutral mood groups on Stroop tasks. Bars represent 1 *SD.* xxxx = naming the color of xs; colwd = reading color words; stroop = naming display color of color words; alt = alternating between reading color words and naming display color.

was no overall effect of mood group on reaction time, $F(1, 34) = 1.79$. The tasks differed from each other, $F(3, 102) = 86.25$, $p < .01$, with the xxxx task performed faster than both the colwd and Stroop tasks, and all of these tasks performed faster than the alt task. There was a significant interaction between mood group and task type, $F(3, 102) = 5.64$, $p = .01$. Tukey's HSD test with $p < .05$ revealed that there was no significant difference in performance between happy and neutral groups on the xxxx, colwd, and Stroop tasks, but the happy group was considerably slower at performing the alt task.

The effect of mood group on Stroop cost and alternation cost was examined by using *t* tests. The effect of mood group on Stroop cost approached significance, $t(34) = 1.94$, $p = .06$, and the effect of mood group on alternation cost was significant, $t(34) = 2.54$, $p < .05$. In both cases, costs were higher for those in the happy mood group.

Discussion

These results provide some support for the argument that positive mood states impair executive functions (Oaksford et al., 1996). Being in a happy mood resulted in slower performance on the alternating condition of the Stroop task. It appears that this effect is not simply due to those in happy mood being generally slower at all processes, because there was no mood effect on color xxxx naming or color word reading. Post hoc testing showed no significant mood effect on reaction time on the Stroop inhibition condition; however, when a Stroop cost was calculated by subtracting color naming time from Stroop time, the mood effect approached significance ($p = .06$), with the happy mood group showing a trend to higher Stroop costs.

The strongest mood effect occurred on the alternating condition of the task. There are a number of possible explanations for this. The alternating condition in the current study can be considered the most complex condition, because it required both Stroop inhibition and switching of attention. This compound executive load might have resulted in a stronger effect of happy mood states. This suggests that the higher the executive load in a task, the more that being in a positive mood will impair performance. However, happy mood might cause particular impairment on attentional switching, perhaps because attention is more likely to be distracted by thoughts that maintain the happy mood.

At the end of the experiment, there was no longer a difference in rated mood between the two experimental groups, which indicates that the induced positive mood had faded by this point. There was no effect of task order on the mood effects found, which suggests that positive mood must have been maintained well enough for a period of time to influence performance on the alternating condition whether it was presented first or last among the four tasks.

These results suggest that positive mood causes poorer performance on the executive function of switching, and possibly inhibition. Experiment 2 examines the effect of happy mood on fluency tasks, which have been used to assess executive functions such as retrieval strategy generation, but have also been used to examine creativity and divergent thinking. Previous results suggest that creativity is improved by happy mood (e.g., Isen & Daubman, 1984), but executive tasks are impaired by happy mood (Stroop results above, and Oaksford et al., 1996). In which direction will happy mood influence fluency performance when fluency has been used to assess both executive function and creativity? This question is examined in Experiment 2, by investigating the effects of happy mood on a variety of fluency tasks.

Experiment 2: Fluency Tasks

Fluency tasks require the generation of words that meet specific criteria in a short time period. Common types of fluency are semantic (retrieving words by semantic category such as types of animal) and phonemic (retrieving words beginning with a specific letter). Repeatedly retrieving words with a phonemic criterion is a relatively novel way of searching, so it has been argued that participants need to be able to generate and use effective retrieval strategies and suppress the usual tendency to search for words by meaning (e.g., Crowe, 1992; Perret, 1974; Phillips, 1997, 1999). There is substantial evidence from neuroimaging studies to support the involvement of (left) prefrontal areas and the anterior cingulate in letter fluency performance (e.g., Baker et al., 1997; Cantor-Graae, Warkentin, Franzen, & Risberg, 1993; Cuenod et al., 1995; Frith, Friston, Liddle, & Frackowiak, 1991; Gourovitch et al., 2000; Phelps, Hyder, Blamire, & Shulman, 1997).

Ashby et al. (1999) specifically argued that positive affect is likely to improve word fluency because of enhanced flexibility in seeing novel ways to categorize and think about words. This suggests that positive mood should improve performance on fluency tasks that demand novel ways of retrieving words. Fluency tasks such as uses for objects, which require the generation of innovative uses of items such as a shoe or pencil, have often been used to assess creativity. There is ample evidence that happy mood improves creative problem solving, which suggests that performance on fluency tasks such as uses for objects should improve in positive mood states. The uses for an object test has been used in individual differences and neuropsychological literature to assess divergent thinking (e.g., Butler et al., 1993). In a neuroimaging study, Carlsson, Wendt, and Risberg (2000) reported evidence that performing the uses fluency test results in substantial frontal lobe activation.

Other variants of fluency tasks have been used to heavily load executive function by requiring the alternation of retrieval between two different categories (e.g., letter and semantic). For example, Downes, Sharp, Costall, Sagar, and Howe (1993) argued that a fluency task requiring switching between semantic and initial letter retrieval taps attentional control and the ability to inhibit previous response patterns. The results from Experiment 1 support the Oaksford et al. (1996) hypothesis that happy mood impairs executive functions such as inhibition and switching. This would suggest that performance on alternating fluency should be poorer during induced positive mood.

And what of the effects of positive mood on letter fluency? Bartolic, Basso, Schefft, Glauser, and Titanic-Schlefft (1999) examined the influence of induced positive and negative mood states on letter and figural fluency performance. They reported that those in a positive mood state showed better letter fluency compared with figural fluency, with the reverse pattern for negative mood. They did not report a neutral mood condition nor the scores from a premood induction test of fluency, so it is not clear whether positive mood improved or impaired letter fluency compared with neutral mood states. Baker et al. (1997) reported that induced elated mood altered the pattern of brain activation during a letter fluency paradigm, such that elation reduced blood flow in the prefrontal cortex during fluency performance.

In Experiment 2, we examine the effect of induced positive mood on three types of fluency task: letter fluency, uses for objects, and alternating retrieval of words by letter and semantic category. All three of these tasks have been used to assess executive function (Crowe, 1992; Downes et al., 1993; Lezak, 1995), and two are known to result in activation of prefrontal cortex (Baker et al., 1997; Carlsson et al., 2000). All three tasks have some similar requirements (same time limit, strategic search, and oral production of a list of words). Yet, previous literature suggests that the creative aspect of the uses task may result in improved performance under happy mood, whereas the executive loading of the alternating task may result in impairment under happy mood.

Method

Participants

In all, 60 people took part, 34 women and 26 men, aged between 16- and 52-years-old ($M = 29.1$, $SD = 6.4$). Most were undergraduate students.

Materials

A stopwatch was used to record time intervals, and a tape recorder was used to record and play back responses for scoring. Mood induction passages were used to induce positive and neutral mood. Each passage consisted of around 400 words. The happy passage contained several short stories taken from magazines and newspapers rated as funny in a pilot study. The neutral mood passage was a detailed description of a property.

The same mood measurement inventories as in Experiment 1 were used to record mood at various stages of the experiment.

Procedure

Mood rating 1. Participants were asked to rate their current mood state at the beginning of the session on the MI1 rate scale.

Mood induction. Each individual was allocated into either the happy or neutral mood condition and given the appropriate passage to read.

Mood rating 2. Participants then completed the MI2 rating scale, with the instruction to rate how they felt at the current moment.

Fluency tasks. Each participant completed three verbal fluency tasks. The order of presentation of these tasks was varied so that equal numbers of participants in each mood induction condition received each order of presentation of the fluency tasks. Each of the fluency tasks had a time limit of 1 min. The three fluency tasks were (a) initial letter fluency, saying as many words beginning with the letter A as possible within 1 min. Participants were asked to exclude proper names, numbers, and extensions of the same word; (b) uses, naming as many different uncommon uses as possible for a cup; and (c) alternation, alternating semantic category and phonemic criteria, in this case producing one word beginning with M, then naming a type of vegetable, then a word beginning with M, then a type of vegetable, and so on.

Fluency performance was scored in terms of the number of words produced in 1 min—very few errors were made, and these were not further analyzed.

Mood rating 3. Participants were asked to rate their current mood state at the end of the session on the MI1 rating scale.

Results

Mood Measurement

Table 2 shows the mood inventory scores for the positive and neutral groups at the three times of measurement. There was no overall effect of mood group on rated mood, $F(1. 58) = 6.40$, $p < .05$, and an effect of time of measurement, $F(2, 116) = 17.54$, $p < .01$. The interaction between mood group and time was also significant, $F(2, 116) = 11.17$, $p < .01$. Tukey's HSD test revealed that the mood groups did not differ before the mood induction, but the happy group showed more positive mood ratings both immediately after the mood induction and at the end of the experiment.

Table 2
Mood Ratings Before and After the Mood Induction Procedure and After the Fluency Tests

Mood condition	Before induction		After induction		After fluency	
	M	*SD*	*M*	*SD*	*M*	*SD*
Neutral	4.69	1.01	4.80	1.09	4.57	1.08
Positive	4.76	1.06	5.96	0.90	5.17	1.24

Fluency Performance

The effect of the mood manipulation on performance on the three fluency tasks is shown in Figure 2. An ANOVA revealed that there was an effect of fluency task, $F(2, 116) = 59.85$, $p < .01$, with Tukey's LSD test at $p < .05$ showing that fewest words were produced on the uses fluency task, significantly more on the letter fluency task, and significantly more again on the alternating fluency task. There was no overall effect of mood group on performance, $F(1, 58) = 0.13$. There was a significant interaction between mood group and type of fluency task, $F(2, 116) = 3.87$, $p < .05$, which was investigated by using Tukey's HSD test with $p < .05$. There was not a significant difference between positive and neutral groups in performance on the letter fluency task. The positive mood group produced significantly more words than the neutral group in the uses fluency task. The neutral mood group tended to produce more words than the positive group in the alternating fluency task, but this difference was not significant. For the neutral group, there were significant differences in production across all three fluency tasks, with uses < letter < alternating fluency. For the positive mood group, fewer words were produced in the uses compared with both letter and alternating fluency, but these did not differ from each other. Overall, these results suggest improved performance on uses fluency with positive mood and a trend toward impaired performance on alternating fluency.

Correlations were calculated between the mood measures taken before and after the fluency tests and performance on the fluency tasks in terms of number of words produced. There were significant correlations between mood rating taken after the tasks and both letter (.30) and uses (.30) fluency. The more

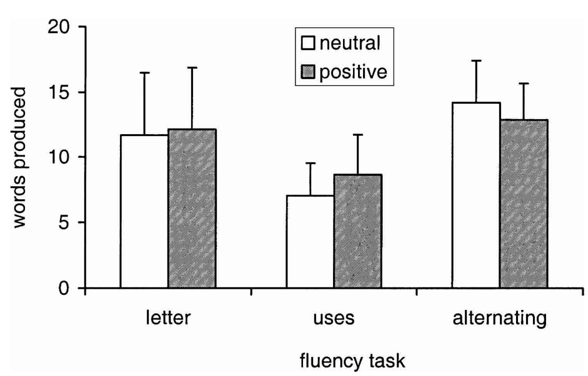

Figure 2. The performance of positive and neutral mood groups on the three fluency tasks. Bars represent 1 *SD*.

positively an individual rated their mood, the more words they produced in the time limit.

Discussion

In line with other results on creative problem-solving tasks, induced positive mood improved performance, in this case the production of a greater number of novel uses for a cup. There was no effect of positive mood on letter fluency performance, although a significant correlation indicated that the more positively an individual rated their mood by the end of the experiment, the more words were produced in the letter fluency task. In line with the findings from Experiment 1, positive mood caused poorer performance on alternating fluency, although this effect only approached significance.

These results show opposite direction of effects of happy mood on two different fluency tasks. It appears that the extent to which a task requires creativity versus controlled switching may be important when predicting the influence of mood on performance. This also raises questions about the extent to which creativity depends on executive functioning.

General Discussion

Induced positive mood states caused impaired performance on the alternation condition of the Stroop test and improved performance on a creative fluency test. The current results indicate that very subtle influences on an individual's mood—an article read in a newspaper before an experiment, reminiscence about happy events before a testing session—might have a significant impact on widely used tests of neuropsychological function.

These results highlight the potential usefulness of positive mood as a tool for examining emotion and cognition. Many manipulations of cognitive variables, or studies of individual differences, suggest common directions of effects; for example, cognitive variables tend to show correlations such that good performance on one variable very often predicts good performance on others. The results from the current studies, along with a review of previous literature, indicate that positive mood significantly improves performance on some cognitive tests, whereas impairing performance on others. In both current experiments, positive mood had the most detrimental effect on conditions demanding alternation—switching between one category of response and another. In contrast, the production of novel strategies for retrieval in the uses and letter fluency tasks seemed to be enhanced by positive mood. There is currently much debate about the number and nature of executive control processes and how they interrelate (see e.g., Miyake et al., 2000; Rabbitt, 1997). There is evidence that there may be separable components controlling task switching, inhibition, and monitoring (Miyake et al., 2000; Ward et al., 2001). Mood manipulations might prove to be one tool to examine this issue experimentally.

The finding that happy mood improves some aspects of cognition but impairs others does not support the idea that happy mood generally results in fewer cognitive resources being devoted to complex tasks (e.g., Mackie & Worth, 1989). The fluency results indicate that it is not the most subjectively difficult or effortful tasks that are necessarily most impaired by happy mood. Uses fluency is generally reported to require considerable concentration and yet was improved by induced positive mood. The fluency task on which the highest number of words produced (alternating fluency) was impaired by positive mood yet uses fluency, on which overall performance was considerably poorer, was enhanced by positive mood.

The current results suggest that the ability to switch from one task set (mapping of a set of stimuli to a particular set of responses) to another may be impaired in a happy mood. In both experiments, the switching conditions showed the greatest decrements under positive mood. This appears to be contrary to the prediction (Isen, 1999) that positive mood might facilitate some components of cognitive flexibility. However, it is important to distinguish between the process of spontaneously switching task perspectives (i.e., flexibility) and forced switching between task sets. Spontaneously switching between different retrieval strategies is likely to be beneficial to performance on tasks such as letter and uses fluency, where short periods of focus away from the task at hand might actually benefit creativity. In contrast, the alternating Stroop and fluency tasks investigated here demand repeated effortful suppression of an active task set as well as activation of a previously suppressed task set (Monsell, 1996). Any drift in immediate focus on such a rigidly structured task is likely to impair performance. Reformulating stimulus–response mappings in response to externally driven criteria appears to be one aspect of executive function that is particularly susceptible to interference from positive mood.

Seibert and Ellis (1991) argued that positive mood, like negative mood, causes more mood-salient, but task-irrelevant, thoughts to be activated. Also, it has been argued that positive mood results in a wider range of associations to be made to words (Isen, 1999; Isen, Johnson, Mertz, & Robinson, 1985), which can result in greater ability to reinterpret situations. Happy mood may therefore result in more diffuse semantic activation. This could explain the current results, because diffuse thoughts might improve creativity and reinterpretation on a task such as uses of a cup, whereas impairing performance on tasks that require careful and constant attention to response demands such as the alternating Stroop task. If this explanation is correct, uses fluency and letter fluency may be enhanced by diffuse semantic activation, whereas alternating fluency and Stroop switching are impaired under such conditions. In essence, task-irrelevant semantic activation might improve creativity while impairing switching.

Another possible interpretation of happy mood effects in the current study is the effort conservation hypothesis described by Bodenhausen et al. (1994). They proposed that happy people are not motivated to engage in cognitively effortful processing, unless underinvestment in the task at hand might have direct bearing on well-being, or the task itself is perceived as being intrinsically enjoyable (and, indeed, Bodenhausen et al. cited creativity as an example of an enjoyable task). Bodenhausen et al. applied this principle to the cognitive processes involved in stereotyping, but it may also apply to other cognitive functions such as the executive processes investigated here. Motivation might be a key factor in determining the extent to which people in a happy frame of mind devote effort to cognitive tasks. Ashby et al. (1999) argued that positive mood will only improve performance on tasks that people are motivated to attend to, and Isen (1999) argued that positive mood is likely to impair performance on tasks that are dull or unpleasant. Happy mood might therefore increase the effort devoted to a task such as uses fluency, which is generally perceived as fun to do. However, relatively demanding and dull tasks such as alternating Stroop might not inspire effort from those in a happy mood. Most executive or frontal-lobe tasks that are used in neuropsychological testing (e.g., Wisconsin Card Sorting Test, Tower tests, trail-making test, assessments of working-memory span) would be better described as dull rather than fun, so if the effort conservation hypothesis is correct, happy mood is likely to impair performance on most such measures. Isen also suggested that positive mood is likely to impair task performance where instructions do not highlight task importance. However, this does not explain the current pattern of results, because clear instructions to maximize performance were given in fluency and Stroop conditions, yet performance on some conditions was improved by happy mood, whereas on others, performance was impaired.

Caution must be exercised in extrapolating the current results to real-life cognitive control processes. There is a lot of current interest in real-life problem-solving and planning tasks, and such tasks may be much more motivating for participants to devote effort to, resulting in positive effects of happy mood states. For example, recent studies have investigated executive function in relation to planning holidays or parties (Miotto & Morris, 1998; Pentland, Todd, & Anderson, 1998), and such situations might be considerably more motivating than abstract planning tasks such as the Tower of London, which happy mood impairs (Oaksford et al., 1996).

Ashby et al. (1999) offered a neuropsychological explanation for the effects of happy mood on cognition—specifically, that increased dopamine levels in areas such as the anterior cingulate and prefrontal regions facilitate processing in tasks dependent on those brain areas. Can such a neuropsychological theory explain how some tasks that are known to involve these brain areas are impaired by happy mood (e.g., switching), whereas others are enhanced by happy mood (e.g., creative fluency)? Both the exact distribution of dopaminergic transmission and the exact involvement of different brain areas in the range of Stroop and fluency tasks described here remain uncertain. However, the current results raise some interesting possibilities. For example, perhaps motivational factors might mediate the effects of increasing neurotransmitter flow. Alternatively, the effects of dopaminergic changes on other brain areas than the frontal lobes and anterior cingulate may be important. There is substantial neuroimaging evidence that many brain areas are involved in executive tasks such as the Stroop (e.g., Cabeza & Nyberg, 2000). For example, Ashby et al. suggested that the basal ganglia may also play a major role in switching. They also argued that an inhibitory relationship between dopamine levels in the frontal cortex and basal ganglia might predict impaired cognitive switching in happy mood states.

Conclusions

The current results do not support the idea that happy mood generally improves performance on tasks that involve prefrontal cortical and anterior cingulate function. Nor do they suggest that happy mood generally lowers the cognitive resources available for executive functioning. Some executive functions, such as task–set switching are impaired by induced happy mood, whereas others such as generating creative output are enhanced by happy mood. This may be due to the interaction between mood state and the intrinsic motivation provided by different cognitive tasks. Another explanation might be the differential effects of diffusely activated semantic networks on tasks demanding creativity versus close concentration. Small everyday events that influence mood may substantially impair or enhance performance on commonly used tests of executive function.

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