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Control beliefs moderate emotion influences on complex problem solving

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The assumption that positive affect leads to a better performance in various cognitive tasks has become well established. We investigated whether positive and negative feedback-induced emotions influence performance and strategies of 74 university students in a computer-simulated complex problem-solving scenario. We further analysed whether control beliefs moderate the relation between emotions and complex problem solving. While overall scenario performance was not affected by emotions, strategy was: Participants with negative emotions were more information-oriented in their problem-solving behaviour. Control beliefs significantly interacted with induced emotions: Students with internal control beliefs benefited most from positive emotions, whereas students with external control beliefs performed best when no emotions were induced. We suggest that the moderating effect may be due to a motivating side effect of the emotion elicitation and outline different approaches to test emotion influences in complex problem solving.

INTRODUCTION

While mathematician Andrew Wiles was brooding over Fermat's last theorem – a complex problem that had exasperated dozens of illustrious mathematicians before – he was in a state of emotional agitation. In 1993, after living in seclusion for seven years, his first thorough attempt of proof was heavily criticised. It was within this episode of distress and depression that he brought about a cast-iron proof of Fermat's last theorem (Singh, 1997). This excerpt from the stirring history of Fermat's last theorem shows that feelings can influence our thinking in an either beneficial or harmful way. However, anecdotes of that kind confront us with numerous questions: What emotions are beneficial to our problem-solving abilities and what emotions impair our performance? In what tasks do emotions generally exert an influence and why?

The present study addressed the effects of emotions on problem solving in complex and dynamic situations. In recent years, there has been growing research interest in the role of affect in cognitive processes (e.g., Fiedler, 2001; Schwarz, 2000). Yet, most empirical studies in this field have focussed solely on unspecific positive or negative mood states and have employed simple cognitive tasks rather than more complex problem-solving situations. With the current investigation we pursued three goals. Firstly, we explored whether it is possible to induce emotions in individuals who solve complex problems. Secondly, we tested whether the findings from studies on the influence of affect on simple cognitive tasks apply to complex problems. Since we expected that control beliefs play a distinct intervening role in emotion regulation, we thirdly examined whether control beliefs moderate the influence of emotions on complex problem solving. In accordance with these objectives, we clarify the three main issues of this investigation in the following paragraphs and summarise our ideas in a schematic model.

THEORETICAL RATIONALE AND RESEARCH OVERVIEW

Complex problem solving: When you do not know what to do

As there is no unified definition of complex problem solving (CPS), the concept is often circumscribed by contrasting it with simple cognitive tasks in terms of the following five characteristic criteria: (a) complexity of the situation, (b) connectivity of variables, (c) dynamic development, (d) intransparency or opaqueness, and (e) polytely (pursue of multiple goals; see Frensch & Funke, 1995, for a detailed consideration).

Simple problem-solving tasks, e.g., Duncker's (1945) candle task, Maier's (1930) nine-dot problem, or the famous Tower of Hanoi (e.g., Simon, 1975), require creative ingenuity and restructuring of the given information. However, these tasks do not directly reflect the demands of problems in complex and dynamic situations that people are confronted with in their daily professional and private lives. In response to this criticism a new approach was initiated by Broadbent (e.g., Broadbent, 1977) and Dörner (e.g., Dörner, 1980). Following this pioneering work, research on CPS has made considerable headway in the last 30 years and has been studied extensively by means of computer-simulated scenarios, like Lohhausen, Tailorshop, or Biology Lab (see Funke, 2001, for an overview). These complex and semantically-rich computerised tasks are constructed to mirror characteristics of real-life problems (e.g., Berry & Broadbent, 1995; Brehmer, 1995; Dörner & Wearing, 1995). In the arguably best-known scenario Lohhausen (Dörner, Kreuzig, Reither, & Stäudel, 1983), participants act as mayor of a small town and have to direct the economic climate and people's well-being to govern the town successfully. These complex problem-solving tasks demand the gain and integration of information, the elaboration and attainment of goals, the planning of action, decision-making, and self-management (Dörner, 1986).

Up to now, most research on CPS centred around one of the three areas (a) the influence of personal factors (e.g., intelligence, previous knowledge, or personality traits) on CPS, (b) the influence of situational determinants (e.g., group problem solving, conceptual formulation, or feedback) on CPS, and (c) system characteristics (e.g., formal aspects such as the semantic embedding of the system). Despite considerable progress made in this research domain, the question of whether affect (distinct emotions or moods) influences CPS has rarely been addressed.

Emotions: When you know where your feelings come from

Looking at affective influences on cognition, it appears important to distinguish between emotions and moods (e.g., Siemer, 2001). Emotions are commonly understood as short-lived, intense phenomena that usually have a clear cognitive content and a salient cause that is highly accessible to the person experiencing the emotion (e.g., Clore, Schwarz, & Conway, 1994). Moods can be differentiated from emotions by their core properties (a) globality, (b) diffuseness, (c) lack of intentionality, (d) longer duration, and (e) lower intensity (e.g., Clore et al., 1994; Ekman, 1994; Frijda, 1994; Oatley & Johnson-Laird, 1987, 1996; Schwarz, 1990). As described earlier, most studies to date have, by and large, focussed on the influence of moods on cognitive processes or have only dealt with simple cognitive tasks. We summarise the results of these studies and outline those investigations dealing with the influence of person variables on complex problem-solving tasks. It should be noted that the terms affect, emotion, and mood have been used interchangeably in most previous studies. Henceforth, we will employ these terms in accord with the cited author.

Emotions and complex problem solving

A number of studies looked at the role of constructs such as perceived emotional intelligence, emotional resilience, emotional reactivity, uncertainty, and anxiety as a trait in complex problem-solving scenarios (Dörner, 1998; Stäudel, 1987). Likewise, other authors have dealt with the influence of stress, coping abilities, and achievement motivation on complex problem solving (Hesse, Spies, & Lüer, 1983). The results of these studies are inconsistent: Whereas some authors have found emotional variables to impair complex problem solving, most studies detected no effect at all. However, all studies have focussed almost solely on the outcome of complex problem-solving tasks and disregarded the conceivable influence of emotional variables on processing strategies. Moreover, emotional variables have not been induced experimentally.

As previous research demonstrates, moods and emotions can profoundly influence both strategic approaches and solution quality of cognitive tasks in general. Some of the uncertainty surrounding the question of whether this influence is disruptive or facilitative seems now resolved: The results of most studies, employing a wide range of induction methods and cognitive tasks, indicate that positive affect enhances simple and creative problem solving (see Isen, Daubman, & Nowicki, 1987). Positive affect also facilitates efficient decision making in complex environments (e.g., in making a medical diagnosis; Isen, 2001). There is further evidence for the contention that elated moods lead to flexible, creative, efficient, and thorough thinking and that people prefer wider cognitive categories when induced with positive affect (Bohner, Marz, Bless, Schwarz, & Strack, 1992; Fiedler, 2001; Forgas & Fiedler, 1996; Isen, 2001). In addition to that, affective states are assumed to influence the selection of strategies for information processing in simple cognitive tasks. A large body of experimental research documents that individuals in a positive affective state are more likely to use a heuristic processing strategy (characterised by top-down processing and the productive use of generic knowledge structures). Negative affect, on the other hand, facilitates careful bottom-up processing and a more systematic gathering of information. Individuals in a bad mood pay more attention to the details at hand (Fiedler, 2001; Hertel, Neuhof, Theuer, & Kerr, 2000; Schwarz, 2000).

Theoretical explanations. Different descriptive models have been offered for these findings, as for instance the affect-infusion model (Forgas, 1994), the mood-and-general-knowledge approach (Bless & Fiedler, 1995), or the affect-as-information hypothesis (Schwarz, 1990). Fiedler's affect-cognition theory (2001) plausibly describes the underlying cognitive processes and postulates that positive and negative mood states are affective cues to appetitive and aversive settings: "While negative mood supports the conservative function of sticking to the stimulus facts and avoiding mistakes, positive mood supports the creative function of active generation, or enriching the stimulus input with inferences based on prior knowledge" (Fiedler, 2001, p. 3). Fiedler uses the Piagetian terms *accommodation* (tuning the cognitive system to fit the stimulus environment) and *assimilation* (transforming external environment to fit internal knowledge structures), to label these two processes, respectively. Negative mood thus facilitates accommodation, and positive mood supports assimilative functions.

Control beliefs: When you either believe in yourself or trust in chance or others

CPS is not only thought to be influenced by emotional states but also by personality factors, especially control beliefs. Generalised control beliefs constitute relatively stable personality characteristics, reflecting an individual's belief that he or she can cope with difficult demands. This construct has been operationalised under a variety of different labels, namely self-efficacy, optimistic self-belief, locus of control of reinforcement, and hope. According to Krampen's (1991) expectancy-value approach, control beliefs are theoretically derived from the expectancy of contingency in action and represent the subjective expectancy that feasible actions will be successful in any given situation. Similar to the notion of internal versus external locus of control (LOC), Krampen conceives internal control beliefs as pointing to a person's opinion that he or she is in a position to influence events in any given situation by his or her own action. External control beliefs indicate that an individual perceives upcoming events as controlled by chance or other people's influence. According to Krampen, people with internal LOC are characterised by high activity, self-assuredness, inventiveness, quick decision-making, and high responsibility. These individuals trust in their own abilities and feel relatively independent of other persons or situations. People with external LOC, on the other hand, are more insecure and passive when facing new situations. They can be distinguished by their low self-assuredness and they feel dependent on other people or trust in chance and fate.

Control beliefs and complex problem solving

Previous studies on the relationship between personality factors and CPS have merely concentrated on cognitive styles, e.g., impulsivity vs. reflexivity, strategic flexibility, or heuristic competence, and on dispositional personality traits, such as extraversion, neuroticism, and rigidity (Dörner et al., 1983; see Schaub, 2001, for an overview). The studies yielded a variety of singular findings that cannot be fitted into a coherent pattern. Stäudel (1987) has found positive correlations between problem-solving ability and *self-assuredness*. According to Krampen (1991), self-assuredness is a component of internality in control beliefs and a relation between control beliefs and CPS is therefore feasible. There are two ways in which control beliefs may influence CPS: In addition to a direct effect, control beliefs could moderate the relationship between emotions and CPS, as Dörner (1998) suggests that control beliefs affect CPS by influencing the regulation of emotions (see also Bartl & Dörner, 1998). Individuals with internality and externality in control beliefs should deal differently with emotions: We expected that individuals with an internal LOC benefit more from positive emotions than do individuals with an external LOC. Individuals with an external LOC should, however, be better able to regulate negative emotions.

Figure 1. Schematic depiction of the interplay between emotions, control beliefs, complex problem-solving performance, and complex problem-solving behaviour. Arrows with labels H_1 to H_4 stand for those hypotheses that were tested here.

The theoretical assumptions described so far are summarised in Figure 1. We provide this as a heuristic framework to illustrate the theoretical context into which the current study is incorporated. The framework depicts the origins and functions of emotions in a feedback loop. Concerning the origin of emotions, a sensed value (evaluation) is compared to a reference value (goal) that is set in accordance with control beliefs. If there is a positive discrepancy, positive emotions arise; if the discrepancy is in fact negative, negative emotions are triggered (Carver & Scheier, 1999). Those connections referring to the origin of emotions were not tested here. The illustration shows the pertinent relations between control beliefs (as a trait), emotions, complex problem-solving behaviour (action), and performance (outcome).

OVERVIEW OF THE PRESENT STUDY

We report and discuss the findings of an experimental study on the influence of feedback-induced emotions and control beliefs as a trait on CPS. A computer-simulated scenario was used to test complex problem-solving performance and problem-solving behaviour. Four hypotheses were tested. Firstly, it is predicted that positive emotions, in contrast to negative emotions, lead to a better performance in the complex problem-solving scenario employed, as this task requires assimilative functions (Hypothesis 1). Secondly, positive and negative emotions are predicted to lead to different problem-solving behaviours: Positive emotions cause an intuitive, hypothesis-oriented approach, whereas negative emotions are associated with more detail-oriented, information-based action (Hypothesis 2). Thirdly, control beliefs are hypothesised to directly influence CPS. Individuals with internal LOC are predicted to show a significantly higher problem-solving performance as compared to participants with external LOC (Hypothesis 3). Finally, it is expected that control beliefs moderate the influence of emotions on CPS. Individuals, who have an internal LOC, benefit from positive emotions more than individuals with an external LOC. Likewise, individuals, who are external in their control beliefs, perform better than individuals with internality in their control beliefs when experiencing negative emotions (Hypothesis 4). Gender differences (effects of biological sex) were also taken into account as an additional factor for each of the hypotheses under study.

METHODS

Measures

Emotion induction. A wide variety of induction techniques have been employed in emotion research amongst which music and films have been most successful (e.g., Niedenthal, Halberstadt, & Setterlund, 1997; Westermann, Spies, Stahl, & Hesse, 1996). In selecting an adequate treatment method for this study, two constraints had to be taken into account. Firstly, the treatment had to be administered between the introductory period and the testing period of the computer-simulated scenario and was hence restricted to a very short time frame. Secondly, the emotion induction method had to be relevant to the problem-solving task to appear authentic, which made music and films not useful as induction material. Positive and negative emotions were instead elicited experimentally two times throughout the experiment by giving false (either positive or negative) feedback on performance. The first feedback was administered by telling students a false score after they had completed the spatial-reasoning test, a subtest of the intelligence structure test 2000 (Intelligenz-Struktur-Test, I-S-T 2000; Amthauer, Brocke, Liepmann, & Beauducel, 1999). The second feedback was provided after half time of the computer-simulated scenario and was displayed automatically in a pop-up window, which informed participants about their position in a fictitious ranking (positive: "You are in position 12 out of 250 and are thus better than 95,2% of all participants", negative: "You are in position 208 out of 250. That means that 83,2% of all participants have performed better than you").

Emotion measures. Emotions were measured seven times using a 14-item questionnaire. Participants were asked to mark a 10-cm line between the two poles <u>null</u> and <u>all pervasive</u> for each of 14 emotion adjectives (content, sad, excited, tense, confused, angry, anxious, surprised, enthusiastic, interested, calm, happy, ashamed, proud). Emotion labels were put in different random order on each of the questionnaires to prevent sequence effects. This selection of adjectives was based on a questionnaire by Schmidt-Atzert and Hüppe (1996) and on a German version of Watson et al.'s PANAS scales (Krohne, Egloff, Kohlmann, & Tausch, 1996). The questionnaire was a paper and pencil test and was announced by a pop-up window inside the computer-simulated scenario.

Control beliefs. Krampen's (1991) competence and control beliefs questionnaire (Fragebogen zu Kompetenz- und Kontrollüberzeugungen, FKK) has been used frequently in a variety of contexts since its first version was published in German (Krampen, 1981). The questionnaire measures three aspects of LOC and one aspect of competence orientation, namely *internality*, *powerful others externality*, *chance control externality*, *and self-concept* on four distinguishable scales. These four scales can be aggregated to two secondary scales and a tertiary scale (internality vs. externality in control beliefs) that will be used for purposes of data analysis in this study. Krampen (1991) has argued that control beliefs can be domain-specific. We therefore rephrased some of the items of the FKK, thus yielding a questionnaire measuring control beliefs in problem solving, the FKK-PS. Table 1 shows four items and adjunctive scales with indication of their reliability.

Table 1

Overview of FKK-PS scales and text examples with reliability indexes

Scale (with number of items)	Item (with item-number)	Cronbach's alpha
Primary scales		
Internality in control beliefs (8)	„Whether I am able to solve a problem or not totally depends on my own effort and endurance." (5)	.60
Social externality in control beliefs (8)	„Whether I am able to solve a problem or not depends on the support of other people." (26)	.74
Chance control (8)	„Whether I am able to solve a problem or not is entirely a matter of luck." (15)	.72
Self-concept of own abilities (8)	„I sometimes do not have a clue what to do under the circumstances." (24)[a]	.78
Secondary scales		
Self-efficacy (16)		.80
Externality in control beliefs (16)		.78
Tertiary scale		
Internality versus externality in control beliefs (32)		.63

[a] Item is reverse coded.

Complex problem solving. The computer-simulated scenario FSYS 2.0 (Wagener, 2001) was used in the current study[1]. In this dynamic and complex system, problem solvers have to manage a forest enterprise over a period of 50 fictitious months (simulation cycles) at a profit. In order to achieve that goal, they have to plant, raise, and fell trees in five structurally equivalent partitions of the forest and have to maintain the wood's quality (e.g., fertilise grounds, do pest control). FSYS is based on Dörner's (1986) model of demands on problem solvers. The scenario is accordingly designed to indicate strategies in different aspects of problem-solving behaviour additionally to the overall success in controlling the system. FSYS delivers 14 scales that are depicted in Table 2. The scales are organised in four groups, representing scenario performance (SP), quality of measures (QM), acquisition of information (AI) and self-management (SM). For the 90-minute duration of the test session, the program protocols and calculates the individual's performance data with regard to the overall profit yielded and behavioural components on the scales mentioned before.

Table 2

Overview of selected FSYS scales

Dimension and scale name	Description of scale
Scenario performance (SP)	
Earned capital (SKAPKOR)	Account balance (income minus expenses for wood maintenance) plus value of forest after 50 cycles
Quality of measures (QM)	
Prevention of errors (MNOFEHL)	Correct dosage of e.g., fertiliser and pesticide
Assigning of priorities (MPRIORI)	Adequateness of decisions in goal conflicts
Efficiency of actions (MEFFIZI)	Total vs. partial achievement of subgoals
Early comprehension (MVERSTA)	Time in scenario when all possible measures have been ordered once
Acquisition of information (AI)	
Early orientation (IORIENT)	Number of text elements accessed in first five cycles
Information before acting (IVORHAND)	Knowledge acquisition about effects of measures before acting
Reading statistics (IFEEDS)	Gaining overview of business process by reading graphs and/or tables
Surveying of forest areas (IKONTI)	Continuity of inspection of forest areas
Self-management (SM)	
Decidedness in action taking (ESICHER)	Number of decisions that have been cancelled within the same cycle

Additional measures. Personal data (e.g., age, gender, subject of studies) were collected at the end of the experiment on a short standardised questionnaire that also asked for feedback on the experiment and any inconveniences that might have disrupted a smooth procedure. No such influences were reported.

Participants and procedure

Participants were 74 students and graduates of different fields of study; $\underline{n} = 32$ were female and $\underline{n} = 42$ were male; the mean age was $\underline{M} = 24{,}6$ ($\underline{SD} = 2{,}89$). Students were contacted in academic courses during March 2001 and took part on a voluntary basis. They were either returned partial credit for a course requirement or got a book-gift. The experiment took place at the Department of Psychology of the University of Heidelberg.

Participants were sent the modified version of the FKK-PS via email one week before the experimental session and were asked to return the questionnaire before the session. According to their result in the FKK-PS (either internality or externality in control beliefs) respondents were assigned to three conditions (either positive or negative treatment or a control group without any treatment) in a randomised manner thus resulting in a 2x3 design. Individuals were distributed equally across the cells with $\underline{n} = 12$ subjects in the four treatment groups and $\underline{n} = 13$ subjects in the two control groups. The students were then tested individually. They first had to complete the spatial-reasoning test from the I-S-T 2000 (Amthauer et al., 1999) and were then given the written instructions for the computer-simulated scenario. The space-test result was employed to induce emotions by giving false feedback on the score. Emotions were measured directly before the space-test and after the feedback. People then had 90 minutes to work on the scenario FSYS. Every tenth cycle, a pop-up window instructed participants to complete another emotion questionnaire. After the 25th cycle, the second feedback was given automatically in a pop-up window. Emotions were measured immediately afterwards. Due to high standardisation of instructions and procedure, there was no interaction between participants and experimenter except during the first feedback-cycle.

RESULTS

The significance level for all statistical hypotheses tests was set at $p = .05$; significance levels for treatment-check purposes could be set at $p = .01$ since higher effect sizes were expected here. All significance tests were one-tailed. In addition to levels of significance, effect sizes $\underline{d}$, $\underline{f}$, or $\underline{f}^2$ are reported, following the conventions of Cohen (1987). An a priori power analysis with G-Power (Erdfelder, Faul, & Buchner, 1996) revealed that, in consideration of a sample size of $\underline{N} = 74$, an expected large effect ($f = 0.40$) can be detected with a power of 0.85 for Hypotheses 1 and 2 and a medium effect ($f^2 = 0.15$) can be verified with a power of 0.91 for Hypothesis 3 and with a power of 0.84 for Hypothesis 4. When analyses of variance (ANOVAs) are reported, different degrees of freedom within the same data analysis reflect the fact that outliers were omitted.

Manipulation check: How good was the emotion elicitation?

To test whether the induction method was successful, emotion scores were compared between the three groups for each of the two points of measurement before and after the feedback was given. Emotion scores were derived from a differential R-technique factor analysis (Barton, Cattell, & Curran, 1973) that yielded three factors. Equally weighted emotions were aggregated to obtain three single emotion scores that represent the factors by summing participants' ratings of arousal, positive, and negative emotions. Subsequent one-way ANOVAs were then carried out on these emotion scores with feedback as an independent variable. We also conducted a multivariate analysis of variance (MANOVA) on emotion score, but because the outcomes were comparable, we report the results of the ANOVA here. All treatment-group means differed significantly from those of the control group in the expected direction.

Generally, positive feedback elicited substantially higher positive emotions whereas negative feedback reduced positive emotions; $F(2, 70) = 5.05$, $p < .01$, $f = 0.38$ for the first emotion induction, $F(2, 71) = 10.03$, $p < .01$, $f = 0.53$ for the second induction. Negative emotions increased after negative feedback and decreased after the positive feedback, respectively, but this effect was only significant for the second induction; $F(2, 70) < 1$, n.s., $f = 0.12$, $F(2, 68) = 9.74$, $p < .01$, $f = 0.54$. Treatment effects were not significant at any other point of measurement after the first and second emotion induction. Concerning arousal, only the second negative feedback as compared to the other conditions led to a stronger arousal, $F(2, 71) = 5.166$, $p < .01$, $f = 0.38$.

To address the issue of which emotions were primarily elicited, effect sizes were compared. The first and second positive induction chiefly elicited medium sized effects on pride, while the two negative inductions increased anger and shame and led to reduced contentment. Note that the effect sizes for shame ($d = 0.57$ and 0.80) and contentment ($d = -1.00$ and -1.54) indicate medium to large effects for both, the first and the second induction, respectively.

Finally, the manipulation check was conducted separately for women and men. Men reacted significantly stronger to the second induction; $F(2, 38) = 6.024$, $p < .01$ for positive emotions, $F(2, 38) = 8.138$, $p < .01$ for negative emotions. For women the effects of the second induction were not significant; $F(2, 27) = 2.510$, n.s. for positive emotions, $F(2, 27) = 2.552$, n.s. for negative emotions. As no gender differences were found for the first induction, this result might be due to the fact that women were less involved in the scenario. A comparison of means on the emotion scale interest yielded no significant differences, but there was a tendency for reported means for women to gradually decrease whereas men's interest remained stable.

To summarise, treatment effects were clearly demonstrated for the second emotion induction. The effectiveness of the first induction with regard to negative emotions was less clear than its effects on positive emotions. The effect sizes clearly show that there was a notable effect on participants' shame and contentment in both treatment groups.

Do emotions influence the outcome of complex problem solving?

To test the assumption that positive emotions facilitate and negative emotions impair CPS (Hypothesis 1) under consideration of possible gender effects, a two-way ANOVA was carried out on scenario performance with feedback and gender. The analysis showed that there were no effects of emotions on the SP-scale (scenario performance), $F(2, 68) < 1$, n.s., $f = 0.05$. However, a significant main effect of gender on scenario performance was detected, $F(1, 68) = 4.763$, $p < .05$. Male students performed better ($M = 67.68$, $SD = 3.42$) than did females ($M = 56.23$, $SD = 3.98$), $d = 1.42$.

Creative vs. careful processing: Do positive and negative emotions direct our strategies?

We tested whether positive and negative emotions lead to different information-processing modes, as specified in Hypothesis 2. A MANOVA was computed on QM-scales (quality of measures) and AI-scales (acquisition of information) with feedback as a factor. Emotions indeed had an influence on the AI-scales that was significant for continuity in information; $F(2, 71) = 3.596$, $p < .05$, $f = 0.31$. There was also a substantial effect for early orientation in the scenario; $F(2, 71) = 2.993$, $p = .05$, $f = 0.29$. Participants with induced negative emotions were more thorough in searching and using information as opposed to both the control group and the positive treatment group. There were differences on the QM-scales pointing to a better action handling in the group of positively induced participants but not significantly so. The F-statistic for the multivariate test (Wilk's lambda) was significant; $F(14, 130) = 2.108$, $p < .05$.

Control beliefs: Does trust in one's own abilities lead to better performance?

In order to test the Hypothesis 3 that an internal LOC leads to a better performance in CPS than an external LOC, a general linear model (GLM) on scenario performance with the tertiary scale of the FKK-PS as an independent variable was carried out. Control beliefs had a small effect ($f^2 = 0.03$) on CPS. This effect was not significant, $F(1, 72) = 2.024$ – a finding which might, in fact, be due to sample size and power (a post-hoc analysis revealed a power of 1 - □ = 0.31).

Do control beliefs moderate the influence of emotions on complex problem solving?

Next, the moderator hypothesis (Hypothesis 4) was addressed. A GLM with treatment (positive, negative, no treatment), control beliefs (as measured by the tertiary scale of the FKK-PS), and the interaction between feedback and control beliefs revealed a significant interaction between emotion and control beliefs; $F(2, 68) = 3.390$, $p < .05$. The effect can be considered as medium sized with $f^2 = 0.15$.

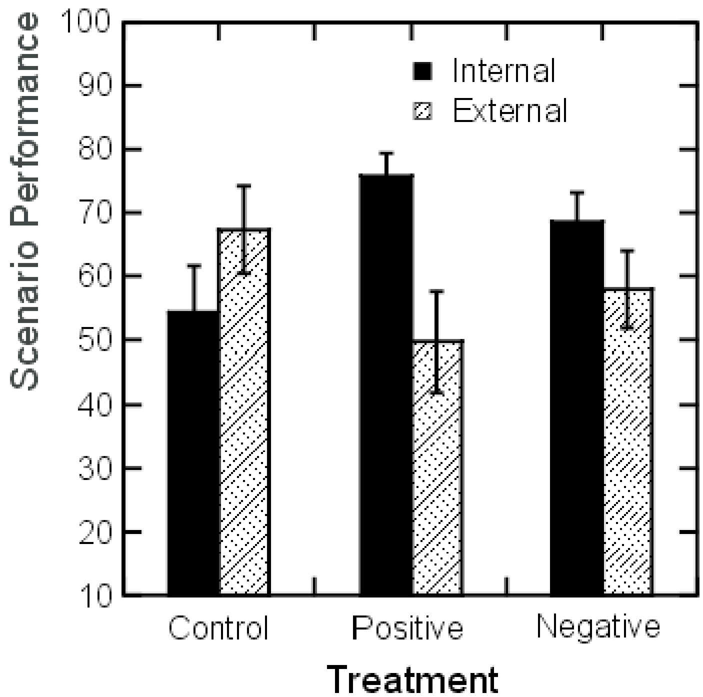

Figure 2. Interaction between treatment (positive, negative, or control group) and control beliefs (internal or external), showing that control beliefs moderate the influence of emotions on scenario performance.

A median split was done on the tertiary scale for illustration purposes to demonstrate the interaction between feedback and control beliefs. The results of this analysis are depicted in Figure 2. It can be seen that participants with an internal LOC performed best after receiving an achievement feedback, especially if this was a positive feedback. They were also better able to regulate negative emotions. However, participants with an external LOC performed best when no emotion was induced. These results suggest that the feedback might have had a motivating side effect.

To take possible gender differences into consideration, separate GLMs by gender were computed. Surprisingly, the interaction between feedback and control beliefs existed for men, $F(2, 36) = 5.750$, $p < .01$, but not for women, $F(2, 26) < 1$, n.s.. To summarise, control beliefs can indeed be seen as a moderator variable that contributes to the relation between emotions and CPS. The role of gender and the feedback's motivating effect, which might, in fact, be responsible for the significance of the interaction, will be discussed below.

DISCUSSION

How did Andrew Wiles so successfully prove Fermat's last theorem apart from being a mathematical genius? The answer to that question is not clear based upon the results presented here, since his task was different from the scenario undertaken by our subjects. However, our results clearly demonstrate that emotions influence complex problem-solving behaviour, although they do not exert an influence on overall scenario success unless control beliefs are considered as a moderator variable.

Emotions do not influence complex problem solving

Concerning the influence of positive and negative emotions on scenario performance (Hypothesis 1), there were no significant differences between participants that were induced with positive emotions and those students that received a negative treatment. This result is inconsistent with most previous studies on simple problem solving (e.g., Isen, 2001). To account for the finding, we will concentrate on two possible causes: (a) the conceivable inefficiency of the treatment, and (b) the nature and demands of the complex problem-solving situation.

Firstly, the result could originate from an inefficient treatment, but the manipulation check demonstrated that both treatments elicited emotions, and that there were medium to large effects on the emotion dimensions. Three other issues are related to the question of treatment efficiency: (a) the intensity and duration of evoked emotions, (b) the influence of labelling state emotions, and (c) the attention that individuals pay to affective cues and the perceived relevance of emotions. Considering the first point, differences in emotions were only significant directly after the treatment was given. Apparently, induced emotions have been intense but short and did not last long enough to cause substantial differences in scenario performance. As to the second point, there is some evidence that labelling state emotions can reduce their impact on cognitive processes (Keltner, Locke, & Audrain, 1993). Emotions have been measured seven times throughout the experiment in order to gain information about the duration of the treatment effects and the stability of emotions. Based on the findings of Keltner et al. (1993), we do assume that the number of emotion questionnaires applied in this study could have caused an unwanted reduction of emotion influence on measurable cognitive processes. Concerning attention to emotions, Gasper and Clore (2000) found that the perception of the relevance of affective cues influences the use of emotions as a basis for judgement. According to the affect-as-information hypothesis (Schwarz, 1990), affect influences cognitive processes only when it is experienced as a source of relevant information. We presume here that participants valued emotional states as relevant, because emotions were induced by performance feedback directly relevant to the task at hand. Yet, we did not control whether and how often individuals actually attended to their emotions and can thus only suspect that some students might have rarely noticed their feelings, let alone considered their feelings as a useful source of information.

Three conclusions can be drawn from these considerations. First, other emotion elicitation methods (i.e., inducement by music, pictures, or odours) might well prove to be more efficient. The music method, however, is only feasible when it does not interfere with the requirements of the task, as would have been the case here. Alternatively, performance feedback could have been applied after each cycle. Problematic as this might be, a sustained treatment could also prohibit effects of scenario-inherent feedback (such as graphical process information) on students' performance. Second, the efficiency and duration of the treatment should be tested beforehand and questionnaires should be omitted in the main experiment to prevent a possible reduction of effects. Third, a variety of measures have been developed to assess individual differences in emotional attention and monitoring (for an overview see Gasper & Clore, 2000; Otto, Döring-Seipel, Grebe & Lantermann, 2001). We think it advisable to measure emotional attention and clarity as well as emotional stability as traits, especially in a demanding complex problem-solving situation.

This leads us to a second possible explanation for the findings to Hypothesis 1 that relates to the nature of the task employed here. The computer-simulated scenario FSYS constitutes a highly complex, challenging and intriguing situation for the problem solver.

Students might have felt required to regulate their emotions or have been focussing more on the cognitive task than on their feelings.

Individuals with negative emotions are well-informed problem solvers

Concerning Hypothesis 2, it was shown that positive and negative emotions elicited distinguishable problem-solving strategies: As predicted by Fiedler's (2001) affect-cognition model, negative emotions led to a more detailed information search and to a more systematic approach to the scenario. The differences on the scale for early orientation in the first five months can be assumed to be a direct cause of the first treatment. As far as the effect of treatment on complex problem-solving behaviour is concerned, it can be concluded that Fiedler's model applies well to emotions in CPS.

The results of Hypothesis 2 also show that the treatment has been successful. It can be inferred that emotions do, in fact, influence CPS on the levels of action handling and information acquisition. One possible conclusion is that different emotion-induced strategies for CPS lead to the same result in the scenario FSYS. On the one hand, the problem solver has to be well informed and can thus benefit from negative emotions. On the other hand, quick and flexible decision-making is required – an approach that is basically elicited by positive emotion. It is, in fact, probably the switching between different strategies (elicited by both, positive and negative emotions) that accounts for success in complex problem solving. From this assumption we draw the conclusion that the dichotomy between positive and negative emotions does not necessarily lead to a classification of successful and unsuccessful problem solvers in a complex, dynamic scenario.

Control beliefs do only play a marginal role in complex problem solving

Concerning the role of control beliefs (Hypothesis 3), our aim was twofold: It was hypothesised that individuals with an internal LOC should be better problem solvers than those participants with an external LOC. Astonishingly, there were no such differences between problem solvers with internality versus externality in control beliefs, at least not significantly so. However, a small effect was found. This finding is consistent with the results yielded from previous work (e.g., Stäudel, 1987), stating that control beliefs play a marginal role in CPS.

Yet, control beliefs appear to moderate the effect of emotions on CPS, as the results to Hypothesis 4 indicate: Participants with internal control beliefs benefited most from positive emotions. Individuals with external control beliefs, however, did not perform best when negative emotions were elicited, but when no emotions were induced. In contrast to our expectations, we did not find significant differences between the two treatment groups and the control group, but between those students who received a feedback and the control group. Considering the theoretical background of the construct of control beliefs (e.g., Krampen, 1991), we claim that the feedback had a motivating effect on those students with an internal LOC and that the interaction between treatment and control beliefs is thus due to the motivational effects of the feedback. Being more active and achievement oriented, individuals with internal control beliefs can be assumed to seek other people's feedback on certain tasks that are relevant to them. In contrast what is suggested by previous work, we conclude that individuals with an internal orientation in control beliefs depend on external acknowledgement of their performance to be successful. Participants with an external LOC, on the other hand, might have mistrusted the positive performance feedback since they hold luck or other people responsible for their own success or failure.

The role of gender: Men and women perform significantly differently

Although there is evidence in the literature for gender differences in cognitive tasks, we did not expect to find any differences here since FSYS was formerly believed to be a gender-neutral scenario (Wagener, 2001). In addition to the main effect of gender on scenario performance, the moderator effect of control beliefs only holds for men: For women, there was no significant interaction between control beliefs and emotions. The wide difference between both groups with regard to self-reported positive and negative emotions was also astonishing, especially since the literature does, succinctly, not indicate any consistent gender differences in emotionality (Brody & Hall, 2000). The results of the manipulation check show men to be more reactive to the emotion induction, especially to the second treatment. Furthermore, men seemed to be more involved in the scenario, as the comparison of means on the subscale interest indicates. Women, on the other hand, were less reactive to the feedback. How can we account for these gender differences? The differences in reactivity to the feedback might simply be due to the fact that women were more emotionally stable or less in need for a feedback. However, it is more likely that women were less involved in the scenario and consequently less interested in their personal success and therefore less exerted.

OUTLOOK

The findings of the present study have interesting implications on both empirical and theoretical levels. Many aspects of the results demonstrate that studying emotions within the research domain of CPS requires a different approach from analysing the effects of induced emotions on simple cognitive processes. Future research should therefore concentrate on (a) the formation and effect of different problem-solving strategies on behaviour in complex tasks rather than on emotion-influences on overall success, (b) the moderating influence of traits, e.g., control beliefs or emotional intelligence, on complex problem solving. Considering the attention to, clarity, and repair of emotions as moderating trait aspects (Otto et al., 2001) might enhance the understanding of emotion influences on cognitive processes in complex and dynamic situations. Moreover, as the affect-cognition link is not unidirectional, we can assume that perceived success or failure in FSYS might have triggered emotions at any time throughout the scenario. Either, emotions have to be induced each cycle or post-cognitive emotions have to be controlled by means of process-tracing methods (thus testing the assumed relations in Figure 1). Several attempts have already been made to compare precise emotions of the same valence (e.g., Lerner & Keltner, 2000) and further endeavour should be made to induce emotions purposefully (such as shame and pride by using performance feedback).

It also seems worth to consider extending other theoretical approaches from cognitive and social psychology to CPS. Mellers has offered a decision-affect theory of anticipated emotions that takes the emotional responses to the outcome of choice into account (e.g., Mellers, Schwartz, & Ritov, 1999). Decision-affect theory provides a descriptive account of actual emotions and would thus allow us to examine connections between anticipated emotions, strategy selection in CPS, and actual emotional responses. It might also be possible to differentiate between distinct emotions in order to answer the normative question whether people should actually employ emotions as a relevant parameter to guide their behaviour in complex situations.

REFERENCES

Amthauer, R., Brocke, B., Liepman, D., & Beauducel, A. (1999). Intelligenz-Struktur-Test 2000 [Intelligence Structure Test 2000]. Göttingen, Germany: Hogrefe.

Bartl, C. & Dörner, D. (1998). PSI: A theory of the integration of cognition, emotion, and motivation. In F.E. Ritter & R.M. Young (Eds.), Proceedings of the Second European Conference on Cognitive Modeling (pp. 66-73). Nottingham, England: Nottingham University Press.

Barton, K., Cattell, R.B., & Curran, J.P. (1973). Psychological states: Their definition through P-technique and Differential R (dR) technique factor analysis. Journal of Behavioral Science, 1, 273-278.

Berry, D.C. & Broadbent, D.E. (1995). Implicit learning in the control of complex systems. In P.A. Frensch & J. Funke (Eds.), Complex problem solving: The European perspective (pp. 131-150). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bless, H. & Fiedler, K. (1995). Affective states and the influence of activated general knowledge. Personality and Social Psychology Bulletin, 21, 766-778.

Bohner, G., Marz, P., Bless, H., Schwarz, N., & Strack, F. (1992). Zum Einfluß von Stimmungen auf Attributionsprozesse [On the influence of mood on attribution processes]. Zeitschrift für Sozialpsychologie, 23, 194-205.

Brehmer, B. (1995). Feedback delays in complex dynamic decision tasks. In P.A. Frensch & J. Funke (Eds.), Complex problem solving: The European perspective (pp. 103-130). Hillsdale, NJ: Lawrence Erlbaum Associates.

Broadbent, D.E. (1977). Levels, hierarchies, and the locus of control. Quarterly Journal of Experimental Psychology, 29, 181-201.

Brody, L.R. & Hall, J.A. (2000). Gender, emotion, and expression. In M. Lewis & J. Haviland-Jones (Eds.), Handbook of emotions (pp. 338-349). New York: Guilford.

Carver, C.S., & Scheier, M.F. (1999). Origins and functions of positive and negative affect: A control-process view. Psychological Review, 97, 19-35.

Clore, G.L., Schwarz, N., & Conway, M. (1994). Affective causes and consequences of social information processing. In R.S. Wyer & T.K. Srull (Eds.), Handbook of social cognition (pp. 323-417). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, J. (1987). Statistical power analysis for the behavioral sciences (Rev. ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Dörner, D. (1980). On the difficulties people have in dealing with complexity. Simulation & Games, 11, 87-106.

Dörner, D. (1986). Diagnostik der operativen Intelligenz [Diagnosis of operative intelligence]. Diagnostica, 32, 290-308.

Dörner, D. (1998). Emotionen, kognitive Prozesse und der Gebrauch von Wissen [Emotions, cognitive processes, and use of knowledge]. In F. Klix & H. Spada (Eds.), Enzyklopädie der Psychologie, Kognition, Bd. 6: Wissen (pp. 301-335). Göttingen, Germany: Hogrefe.

Dörner, D., Kreuzig, H.W., Reither, F., & Stäudel, T. (1983). Lohhausen: Vom Umgang mit Unbestimmheit und Komplexität [Lohhausen: On handling indefiniteness and complexity]. Bern, Switzerland: Huber.

Dörner, D. & Wearing, A.J. (1995). Complex problem solving: Toward a (computersimulated) theory. In P.A. Frensch & J. Funke (Eds.), Complex problem solving: The European perspective (pp. 65-99). Hillsdale, NJ: Lawrence Erlbaum Associates.

Duncker, K. (1945). On problem solving. Psychological Monographs, 58 (270).

Ekman, P. (1994). Moods, emotions, and traits. In P. Ekman & R.J. Davidson (Eds.), The nature of emotion. Fundamental questions (pp. 411-430). New York: Oxford University Press.

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. Behavior Research Methods, Instruments, & Computers, 28, 1-11.

Fiedler, K. (2001). Affective states trigger processes of assimilation and accomodation. In L.L. Martin & G.L. Clore (Eds.), Theories of mood and cognition: A user's guidebook (pp. 85-98). Mahwah, NJ: Lawrence Erlbaum Associates.

Forgas, J.P. (1994). The role of emotion in social judgements: An introductory review and an affect infusion model (AIM). European Journal of Social Psychology, 24, 1-14.

Forgas, J.P. & Fiedler, K. (1996). Mood effects on intergroup discrimination: The role of affect in reward allocation decisions. Journal of Personality and Social Psychology, 70, 28-40.

Frensch, P.A. & Funke, J. (1995). Definitions, traditions, and a general framework for understanding complex problem solving. In P.A. Frensch & J. Funke (Eds.), Complex problem solving: The European perspective (pp. 3-25). Hillsdale, NJ: Lawrence Erlbaum Associates.

Frijda, N.H. (1994). Emotions require cognitions, even if simple ones. In P. Ekman & J. Davidson (Eds.), The nature of emotion: Fundamental questions (pp. 197-212). New York: Oxford University Press.

Funke, J. (2001). Dynamic systems as tools for analysing human judgment. Thinking and Reasoning, 7, 69-89.

Gasper, K. & Clore, G.L. (2000). Do you have to pay attention to your feelings to be influenced by them? Personality and Social Psychology Bulletin, 26, 698-711.

Hertel, G., Neuhof, J., Theuer, T., & Kerr, N.L. (2000). Mood effects on cooperation in small groups: Does positive mood simply lead to more cooperation? Cognition and Emotion, 14, 441-472.

Hesse, F.W., Spies, K., Lüer, G. (1983). Einfluß motivationaler Faktoren auf das Problemlöseverhalten im Umgang mit komplexen Problemen [Influence of motivational factors on performance in complex problem solving]. Zeitschrift für Experimentelle und Angewandte Psychologie, 30, 400-424.

Isen, A.M. (2001). An influence of positive affect on decision making in complex situations: Theoretical issues with practical implications. Journal of Consumer Psychology, 11, 75-85.

Isen, A.M., Daubman, K.A., & Nowicki, G.P. (1987). Positive affect facilitates creative problem solving. Journal of Personality and Social Psychology, 52, 1122-1131.

Keltner, D., Locke, K.D., & Audrain, P.C. (1993). The influence of attributions on the relevance of negative feelings to personal satisfaction. Personality & Social Psychology Bulletin, 19, 21-29.

Krampen, G. (1981). IPC-Fragebogen zu Kontrollüberzeugungen [IPC questionnaire on control beliefs]. Göttingen, Germany: Hogrefe.

Krampen, G. (1991). Fragebogen zu Kompetenz- und Kontrollüberzeugungen (FKK) [Questionnaire on competence beliefs and control beliefs (FKK)]. Göttingen, Germany: Hogrefe.

Krohne, H.W., Egloff, B., Kohlmann, C.-W., & Tausch, A. (1996). Untersuchungen mit einer deutschen Version der "Positive and Negative Affect Schedule" (PANAS) [Investigations

with a German version of the Positive and Negative Affect Schedule (PANAS)]. Diagnostica, 42, 139-156.
Lerner, J.S. & Keltner, D. (2000). Beyond valence. Toward a model of emotion-specific influences on judgement and choice. Cognition and Emotion, 14, 473-493.
Maier, N.R.F. (1930). Reasoning in humans: I. On direction. Journal of Comparative Psychology, 10, 115-143.
Mellers, B., Schwartz, A., & Ritov, I. (1999). Emotion-based choice. Journal of Experimental Psychology: General, 128, 332-345.
Niedenthal, P.M., Halberstadt, J.B., & Setterlund, M.B. (1997). Being happy and seeing "happy": Emotional state mediates visual word recognition. Cognition and Emotion, 11, 403-432.
Oatley, K. & Johnson-Laird, P.L. (1987). Towards a cognitive theory of emotion. Cognition and Emotion, 1, 29-50.
Oatley, K. & Johnson-Laird, P.L. (1996). The communicative theory of emotions: Empirical tests, mental models, and implications for social interaction. In L.L. Martin & A. Tesser (Eds.), Striving and feeling: Interactions among goals, affect, and self-regulation (pp. 363-380). Mahwah, NJ: Lawrence Erlbaum Associates.
Otto, J.H., Döring-Seipel, E., Grebe, M., & Lantermann, E.-D. (2001). Entwicklung eines Fragebogens zur Erfassung der wahrgenommenen emotionalen Intelligenz: Aufmerksamkeit auf, Klarheit und Beeinflussbarkeit von Emotionen [Development of a questionnaire for measuring perceived emotional intelligence: Attention to, clarity, and repair of emotions]. Diagnostica, 47, 178-187.
Schaub, H. (2001). Persönlichkeit und Problemlösen: Persönlichkeitsfaktoren als Parameter eines informationsverarbeitenden Systems [Personality and problem solving: Personality factors as parameters of an information processing system]. Weinheim, Germany: Psychologie Verlags Union.
Schmidt-Atzert, L. & Hüppe, M. (1996). Emotionsskalen EMO 16. Ein Fragebogen zur Selbstbeschreibung des aktuellen emotionalen Gefühlszustandes [Emotion scales EMO 16. An inventory for the self-rating of current emotional states]. Diagnostica, 42, 242-267.
Schwarz, N. (1990). Feelings as information: Informational and motivational functions of affective states. In E.T. Higgins & R.M. Sorrentino (Eds.), Handbook of motivation and cognition (pp. 527-561). New York: Guilford Press.
Schwarz, N. (2000). Emotion, cognition, and decision making. Cognition and Emotion, 14, 433-440.
Siemer, M. (2001). Mood-specific effects on appraisal and emotion judgements. Cognition and Emotion, 15, 453-485.
Simon, H.A. (1975). The functional equivalence of problem solving skills. Cognitive Psychology, 7, 268-288.
Singh, S. (1997). Fermat's last theorem. The story of a riddle that confounded the world's greatest minds for 358 years. London: Fourth Estate.
Städel, T. (1987). Problemlösen, Emotionen und Kompetenz: Die Überprüfung eines integrativen Konstrukts [Problem solving, emotions, and competence: Examination of an integrative construct]. Regensburg, Germany: Roderer.
Wagener, D. (2001). Psychologische Diagnostik mit komplexen Szenarios [Psychological diagnosis with complex scenarios]. Lengerich, Germany: Pabst Science Publishers.

Westermann, R., Spies, K., Stahl, G., Hesse, F.W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. European Journal of Social Psychology, 26, 557-580.

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