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The joint impact of mood state and task difficulty on cardiovascular and electrodermal reactivity in active coping

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Abstract

An experiment with $N = 56$ university students investigated the joint effects of manipulated mood state and task difficulty on cardiovascular and electrodermal reactivity during mood inductions and performance on a letter cancellation task. We tested our theory-based prediction that moods per se do not involve autonomic adjustments whereas mood and task difficulty interact during task performance to determine autonomic reactivity with respect to active coping. Specifically, we anticipated for an easy task weaker reactivity in a positive mood (due to low subjective demand) than in a negative mood (due to high subjective demand). Conversely, we expected, for a difficult task, stronger reactivity in a positive mood (high, but not yet too high, subjective demand) than in a negative mood (too high subjective demand). Adjustments of systolic blood pressure, diastolic blood pressure, and tonic skin conductance level described exactly the predicted pattern. Furthermore, task performance was associated with autonomic reactivity in the difficult conditions.

Descriptors: Mood, Active coping, Emotions and autonomic adjustment, Task-engagement, Cardiovascular

It is a well-replicated finding that the elicitation of specific emotions involves adjustments in the activity of the autonomic nervous system (e.g., Ax, 1953; Levenson, Ekman, & Friesen, 1990; Schachter, 1957; Schwartz, Weinberger, & Singer, 1981; Shapiro, Jamner, & Goldstein, 1997; Sinha, Lovallo, & Parsons, 1992; Stemmler, 1989), reflecting the mobilization of bodily resources for emotion-specific actions (e.g., Frijda, 1986; LeDoux, 1996; Levenson, 1988). The impact of mood states on motivation and related autonomic adjustments is less clear.

Moods are relatively long-lasting affective phenomena (Ekman, 1984), which are, in contrast to emotions, experienced without concurrent awareness of their origins (Frijda, 1993; Gendolla, 2000; Keltner & Gross, 1999; Schwarz & Clore, 1996; Wilson, Laser, & Stone, 1982). That is, relatively short-lived emotions (e.g., "being angry about XY") are object-related and involve an end state (e.g., "destruction of XY"; Plutchik, 1980), while moods (e.g., "feeling irritated") do not. Consequently, it is unlikely that mood states involve specific action tendencies (Arnold, 1960; Frijda, 1986) and related autonomic adjustments. However, we assume that moods can have a strong impact on autonomic nervous system activity when they are experienced in a specific context: When people are faced with demands that call for the mobilization of effort and thus stimulate sympathetic arousal—that is, in active coping (Obrist, 1981).[1]

Active Coping and Autonomic Response

There is compelling evidence that cardiovascular activity—especially systolic blood pressure (SBP)—is proportionally adjusted to the extent of task demand when people have control over a performance outcome (e.g., Bongard, 1995; Gendolla, 1998, 1999; Gerin, Litt, Deich, & Pickering, 1995; Light, 1981; Light & Obrist, 1983; Lovallo et al., 1985; Manuck, Harvey, Lechneiter, & Neal, 1978; Obrist, 1976, 1981; Smith, Baldwin, & Christensen, 1989; Wright & Dill, 1993; Wright & Dismukes, 1995). Evidence for effects on diastolic blood pressure (DBP; e.g., Storey, Wright, & Williams, 1996) and heart rate (HR; e.g., Elliott, 1969; Fowles, 1988; Gellatly & Meyer, 1992; Gendolla, 1998; 1999; Obrist, 1981) is available, but less consistent (Wright, 1996). Thus, adjustments of SBP, DBP, and HR may occur simultaneously in active coping (e.g., Al'Absi et al., 1997; Gendolla, 1999; Smith, Allred, Morrison, & Carlson, 1989). But SBP with its strong link to β-adrenergic sympathetic discharge on the heart (Obrist, 1981; see also Krantz et al., 1987) seems to be the most reliably affected among these indices.

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[1]It is important to note that we highlight the role of mood states in acute, effort-related autonomic adjustments *in* an active-coping situation (Obrist, 1981), rather than the long-term effects of aggregated moods on chronic autonomic activity (e.g., Shapiro, Jamner, & Goldstein, 1997; Schwartz, Warren, & Pickering, 1994).

Wright and colleagues (see Wright, 1996, 1998, for reviews) have demonstrated that cardiovascular adjustments in active coping follow the theoretical predictions outlined in the effort mobilization model by Brehm and colleagues (e.g., Brehm & Self, 1989; Wright & Brehm, 1989). Accordingly, cardiovascular activity increases proportionally to the extent of subjective demand until (a) the demand level exceeds a person's abilities (i.e., active coping is too difficult and thus impossible) and/or (b) the amount of necessary effort for active coping is not justified by the outcome's importance defined as "potential motivation" (see also Gendolla, 1998, 1999).

It has also been posited that electrodermal activity (EDA) refers to effort mobilization (e.g., Dawson, Schell, & Filion, 1990; Pecchinenda & Smith, 1996; Stennett, 1957). But the role of EDA in active coping is by no means clear. EDA responses, which are predominantly linked to sympathetic activity, are usually only poorly correlated with cardiovascular responses. This could be due to individual autonomic response patterns (Lacey, 1967) or to the fact that cardiovascular and EDA responses are linked to different behavioral systems (cf. Gray, 1987). According to Fowles (1983, 1988), cardiac activity is linked to a behavioral approach system, whereas EDA is linked to a behavioral inhibition system. This suggests that cardiovascular activity should proportionally respond to the extent of task demand while EDA should not.

Mood and Active Coping

According to a recent theory of mood impacts on motivation and behavior, the *m*ood–*b*ehavior *m*odel (MBM; Gendolla, 2000), moods are not motivational states because they are not object related. Consequently, moods per se are not expected to involve autonomic adjustments that refer to effort mobilization. Nevertheless, in active coping situations, mood states can have an impact on autonomic activity by means of two processes.[2] The process that is highly relevant for the present research is the *informational mood impact* on judgments of subjective demand. It refers to the answers people find when asking themselves implicit questions in face of an actual demand. Examples are "Can I cope with this demand?" and "Do I have to invest high effort?" The MBM posits that moods can influence these appraisals in terms of mood congruency effects (e.g., Abele & Gendolla, 1999; Abele & Petzold, 1994; Forgas & Bower, 1987; Mayer, Gaschke, Braverman, & Evans, 1992; Schwarz & Clore, 1983) in that people are more optimistic in a positive than in a negative mood. That is, in active coping, subjective demand will be higher in a negative mood than in a positive mood (e.g., Gendolla, Abele, & Krüsken, in press; Gendolla & Krüsken, 1999). We posit that this results in effort-related autonomic adjustments because they are—within specified limits (Brehm & Self, 1989; Wright & Brehm, 1989)—proportionally related to the extent of subjective demand (Wright, 1996, 1998).

Applying our reasoning on the informational mood impact on behavior to Brehm's model of effort mobilization (Brehm & Self, 1989; Wright, 1996; Wright & Brehm, 1989) facilitates specific predictions on mood effects on autonomic adjustments in active coping. Accordingly, mood has a congruency effect on the extent of subjective demand and thus impacts autonomic adjustments that refer to active coping (e.g., Gendolla et al., in press). However, when a given demand has a fixed difficulty level, mood is not the only factor that determines effort-related autonomic adjustments. Rather, mood interacts with objective task difficulty, as depicted in Figure 1.

Panel A of Figure 1 shows the general relationship between task difficulty and effort mobilization. Effort increases proportionally to task difficulty until the level of potential motivation is reached. If this point is accomplished, no more effort will be mobilized. The same happens on task difficulty levels that are so high that active coping is impossible. Panel B of Figure 1 shows the informational impact of mood on this process. The predictions for objectively easy and difficult tasks are as follows: (a) Individuals in a negative mood will mobilize more effort than individuals in a positive mood when objective task difficulty is low, because in a negative mood, subjective task demand is higher than in a positive mood. (b) If a task is objectively difficult, persons in a negative mood will mobilize little effort, because they perceive task demand as too high for them, which results in disengagement. Persons in a positive mood will, by contrast, be highly engaged because they perceive task demand as high, but not yet too high.

We tested these predictions in an experiment in which participants were induced into positive versus negative moods by exposure to music and later performed a letter cancellation task that was manipulated in terms of objective task difficulty (easy versus difficult). Cardiovascular (SBP, DBP, HR) and electrodermal (tonic skin conductance level [SCL], number of unspecific skin conductance responses [SCRs]) activity was monitored during a habituation period, the mood inductions, and task performance. In accordance with the evidence from active coping research discussed above, we expected that SBP reactivity in particular would describe the pattern described in Figure 1 during task performance. We also anticipated that no cardiovascular effects would occur during the mood inductions, because exposure to music did not call for active coping and mood per se was not considered as motivational state. Given the equivocal assumptions about the role of EDA in active coping, we analyzed reactivity of SCL and SCRs exploratively.

Method

Participants and Design

Fifty-six university students (47 women, 9 men, average age 24 years) with various majors participated voluntarily and received 10 Deutsche Marks (about US $5.00) or, if they preferred, a certification of course credit for showing up in the study. Respondents were randomly assigned to the conditions of a 2 (mood: negative versus positive) $\times$ 2 (task difficulty: easy versus difficult) between-subjects design. Distributions of women and men were balanced in the conditions (11:3 in the positive-mood-difficult cell and 12:2 in the remaining cells). In the analyses of autonomic responses, the experimental design was enlarged with a within-subjects factor (Time of measure: mood inductions versus task performance).

[2]The MBM makes, of course, more comprehensive predictions on how mood states can impact behavior, but space limitations allow only a brief discussion of the processes that are directly relevant for the present research. However, the MBM can be summarized in five basic postulates: (1) Moods have—in contrast to emotions—no stable or specific motivational implications or functions. (2) Moods influence behavior by their *informational* and *directive* impacts. (3) The informational and directive mood impacts can influence behavior independently. (4) The strength of the informational mood impact is a function of the effective informational weight of mood and the extent of mood-primed associations. (5) The strength of the directive mood impact is jointly determined by the strength of the hedonic motive and the magnitude of behaviors' instrumentality for motive satisfaction. The strength of the hedonic motive is in turn determined by mood intensity, mood salience, and situational context. The magnitude of behaviors' instrumentality for motive satisfaction is determined by the hedonic tone of behavior itself, the hedonic tone of behavioral outcomes, and mood valence.

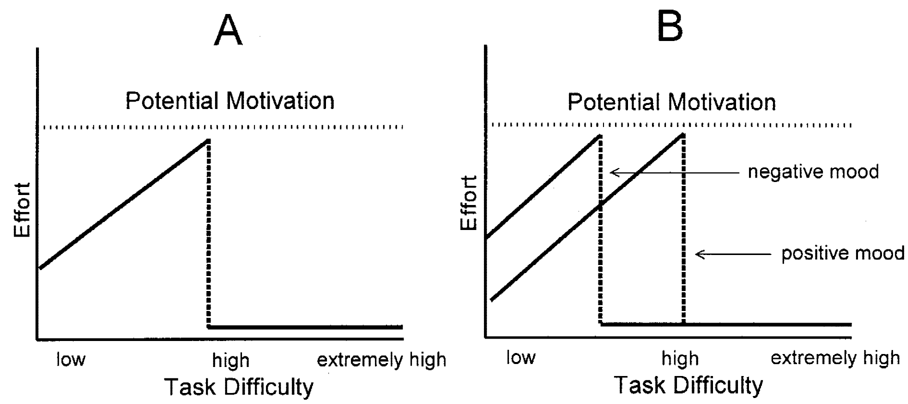

Figure 1. Predictions on the joint impact of mood and task difficulty on the mobilization of effort. Panel A shows the general relationship between task difficulty and effort mobilization. Panel B shows the informational impact of mood. Potential motivation is the amount of maximally justified effort. The figure is adapted from Wright (1998), who investigated the joint impact of ability beliefs and task difficulty on cardiovascular adjustments.

Apparatus and Material

We measured autonomic activity with a computer-aided multichannel monitor (Par Electronics Physioport III). SBP, DBP (both in millimeters of mercury), and HR (in beats per minute) were determined oscillometrically. A blood pressure cuff (Boso) that was placed over the brachial arteria above the elbows of participants' nondominant arms was inflated automatically in intervals of 2 min during the critical measurement periods. Each determination took about 30 s. The obtained values were stored on computer disk. The EDA measures were taken with two 10-mm recording surface area Ag-AgCl electrodes (Hellige), which were attached with adhesive collars on the thenar and hypothenar eminences of the palms of participants' nondominant hand. Participants washed their hands with water and nonabrasive soap and dried them before the electrodes were attached. A commercially available 0.05 molar NaCl electrolyte solution gel was used for the recordings and a constant potential of 0.7 V was applied to the electrodes. Values of tonic SCL (in microSiemens) were stored in intervals of 2 min during the critical measurement periods. The spontaneous SCRs exceeding $\pm 0.05\ \mu S$ were counted continuously and stored as number per minute scores. The experimenter and participants were ignorant of any physiological values during the experimental session.

Mood measures. Subjective mood was assessed with the *positive hedonic tone* (happy, joyful, contended, cheerful) and *negative hedonic tone* (sad, frustrated, depressed, dissatisfied) scales of the UWIST mood adjective checklist (Matthews, Jones, & Chamberlain, 1990). Participants rated the extent to which each of the eight adjectives reflected their momentary feeling state ("Right now, I'm feeling . . ."). The scales ranged from *not at all* (0) to *very much* (6).

Performance task. Participants performed a letter cancellation task that was adapted from the d2 Mental Concentration Test (Brickenkamp, 1981). Task material consisted of rows with random sequence of the letters *d* and *p* (47 letters per row). Placed above and/or below each letter were one, two, or no apostrophes. Participants received instructions to mark all *d*s that carried two apostrophes (e.g., d", d,,). The task consisted of 10 rows in the easy conditions and of 15 rows in the difficult conditions. The total performance time was 5 min for all participants.

Procedure

The study was described as an investigation in physiological responses during relaxation and demand. Upon arriving at the laboratory participants were greeted by the experimenter (who was blind to the hypotheses) and informed, again, that cardiovascular and EDA measures would be taken. After hand washing and application of the blood pressure cuff and the electrodes, we assessed biographical data (age, sex, course of studies) and the subjective mood baselines with a short questionnaire. Participants (who sat alone behind a screen) read "Before we start we need to assess your momentary feeling state, because every individual enters the laboratory in a different state. This is not a test and there are no right or wrong answers. Just rate honestly and spontaneously how you feel right now." Having read these instructions, participants completed the UWIST mood adjective check list.

Then the experimenter explained that the session would start with the assessment of physiological responses during the presentation with music that would facilitate relaxation. Participants received a pair of headphones and were instructed to listen attentively. Furthermore participants learned that they would later receive a short questionnaire with questions about the music. The music presentation started for all participants with a 7-min-long hedonically neutral meditation music piece performed by Cherif Khabil ("untitled"). The relaxation music was followed by the music we presented for the mood manipulation. In the positive mood conditions, participants listened to two "easy listening" pieces ("Hero" performed by Kai Winding featuring Kenny Burrell, and "Thunderball" performed by Ingfried Hoffmann) and a few minutes of Vivaldi's "Le quattro stagioni, Op. 1 Allegro". In the negative mood conditions participants listened to a sad cello piece ("The coup" composed by Hans Zimmer) from the soundtrack of the movie *The House of Spirits*. Each music presentation took about 8 min. Each 2 min SBP, DBP, and HR were measured and values of tonic SCL and the number of SCRs per minute were stored. Measures taken during presentation with the relaxation music were later used for the determination of physiological baseline values and the measures assessed during the happy or sad music presentations served later for the determination of autonomic reactivity during the mood inductions.

After the music presentations all participants received a questionnaire that was entitled "Questions about the pieces of music."

The questionnaire consisted of several filler items, included for the sake of distraction, such as "Did you know the music?" and "Should more music of this type be played on the radio?" Embedded into these questions participants rated the UWIST mood adjective check list a second time. This measure served as manipulation check of the mood inductions.

Having filled out the questionnaire, participants received written instructions for the d2-task—the demand. The instructions were entitled "Task 2: Pattern recognition d2." Participants read that the task would deal with pattern recognition in order to test their ability to concentrate. They were instructed to work as fast and correctly as possible. The experimenter assessed the performance time with a stop watch, but gave all participants the same feedback—that they needed 25 s (which was about the actual time participants took). This (bogus) feedback was followed by our manipulation of objective task difficulty. According to pretests, it was very difficult to complete one row of the d2 task within 20 s, but it was relatively easy to do so within 30 s, although this required continuous performance without sitting idle before starting with the next line. The task difficulty manipulation was adapted to this. In the easy conditions, the experimenter said, "You needed 25 seconds for the test line. In the following performance period you will get 30 seconds to complete one line." In the difficult conditions the experimenter said, "You needed 25 seconds for the test line. In the following performance period you should work a bit faster. You will get 20 seconds to complete each line." Participants learned furthermore that they would perform for 5 min.

Then we assessed task-related subjective ratings. To check the effectiveness of the task difficulty manipulation, participants were asked "How likely is it that you will perform the task successfully?" and answered on a seven-point rating scale ranging from *very unlikely* (1) to *very likely* (7). To assess whether the manipulations affected the importance of success (which was not intended), participants answered the question "How important is it for you to achieve a good outcome on the forthcoming task?" on a scale ranging from *extremely unimportant* (1) to *extremely important* (7). Then participants received the task material. They were instructed to perform row by row and to switch to the next row as soon as the experimenter would say so. In the easy conditions participants switched in intervals of 30 s, and in the difficult conditions they did so in intervals of 20 s until the 5 min were over. Each 2 min (starting 30 s after task onset) SBP, DBP, HR were measured and values of tonic SCL and the number of SCRs per minute were stored. After task performance, participants were probed for suspicion in the manipulations, were debriefed, and received their payment or a certification for course credit, respectively.

Results

Subjective Measures

Mood. We created mood scores for each participant by summing the positive hedonic tone scale values with the reverse-coded negative hedonic tone scale values (mood baselines Cronbach's $\alpha = .85$, mood manipulation check Cronbach's $\alpha = .79$). Given that people often use a wider scale range for reports about positive affect than about negative affect (e.g., Sommers, 1984), we had standardized the positive and negative mood scores beforehand to prevent psychometric judgment biases. A 2 (mood) × 2 (task difficulty) between-subjects analysis of variance (ANOVA) of the standardized mood baselines revealed no differences between the conditions (all ps $> .30$, $MSE = 1.04$, $M = 0.00$).[3] To evaluate the effectiveness of the mood manipulations, we calculated mood difference scores by subtracting the standardized mood baseline scores from the standardized mood manipulation check scores. As anticipated, a 2 × 2 ANOVA revealed only a highly significant main effect of the mood manipulation, $F(1,52) = 9.21$, $p < .004$, $MSE = 0.49$, indicating its success. Mood difference scores were lower in the negative mood condition ($M = -0.28$, $SE = 0.12$) and higher in the positive mood condition ($M = 0.28$, $SE = 0.14$).

Expectancy and importance of success. A 2 × 2 between-subjects ANOVA of the expectancy of success ratings revealed only a significant main effect of task difficulty, $F(1,52) = 4.60$, $p < .04$, $MSE = 1.71$, reflecting a successful difficulty manipulation: In the easy conditions, the probability ratings were higher (Ms $= 4.79$, $SE = 0.23$) than in the difficult conditions ($M = 4.04$, $SE = 0.14$). As expected, the manipulations had no significant impact on rated importance of success (all ps $> .10$, $MSE = 2.56$).

Physiological Baselines

The averages of the last three measures of SBP, DBP, HR, SCL, and SCRs during the habituation period constituted the baseline values of these indices. According to 2 × 2 between-subjects ANOVAs, there were no baseline differences between conditions for any measure (all ps $> .15$). Overall cell means and standard errors were as follows: SBP ($M = 117.25$, $SE = 1.27$), DBP ($M = 76.51$, $SE = 1.19$), HR ($M = 80.35$, $SE = 1.46$), SCL ($M = 3.98$, $SE = 0.28$), SCRs ($M = 1.55$, $SE = 0.21$).

Cardiovascular Reactivity

Change (delta) scores (Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991) were computed for each participant by subtracting the baseline values from the values obtained during the mood induction and task performance periods. The averages of the respective change scores computed for the mood induction and task performance periods constituted the reactivity scores of SBP, DBP, and HR, respectively. We submitted the change scores to 2 × 2 × 2 mixed-model ANOVAs with mood and task difficulty as between-subjects factors and time (mood induction versus task performance) as a within-subjects factor.

SBP Reactivity. Cell means and standard errors are depicted in Figure 2 (left panel). The mixed-model ANOVA revealed a significant main effect of time, $F(1,52) = 154.29$, $p < .001$, reflecting stronger reactivity during task performance than during the mood inductions (Ms $= 8.42$ versus -2.02) and a reliable overall mood by task difficulty interaction, $F(1,52) = 9.64$, $p < .003$. Most relevant, this two-way interaction was moderated by the anticipated significant three-way interaction between mood, task difficulty, and time, $F(1,52) = 8.08$, $p < .006$. We further explored this effect with separate 2 (mood) × 2 (task difficulty) between-subjects ANOVAs of the SBP responses during both periods of measure.

The between-subjects ANOVA of systolic reactivity during the mood inductions yielded no significant effects (all ps $> .13$, $MSE = 17.96$). But the 2 × 2 ANOVA of the performance-related SBP responses revealed, as the only reliable effect, the expected significant two-way interaction, $F(1,52) = 11.62$, $p < .001$, $MSE = 50.90$. As depicted in Figure 2, the pattern of cell means described

[3]Unless indicted otherwise, all probability values in this paper are two tailed.

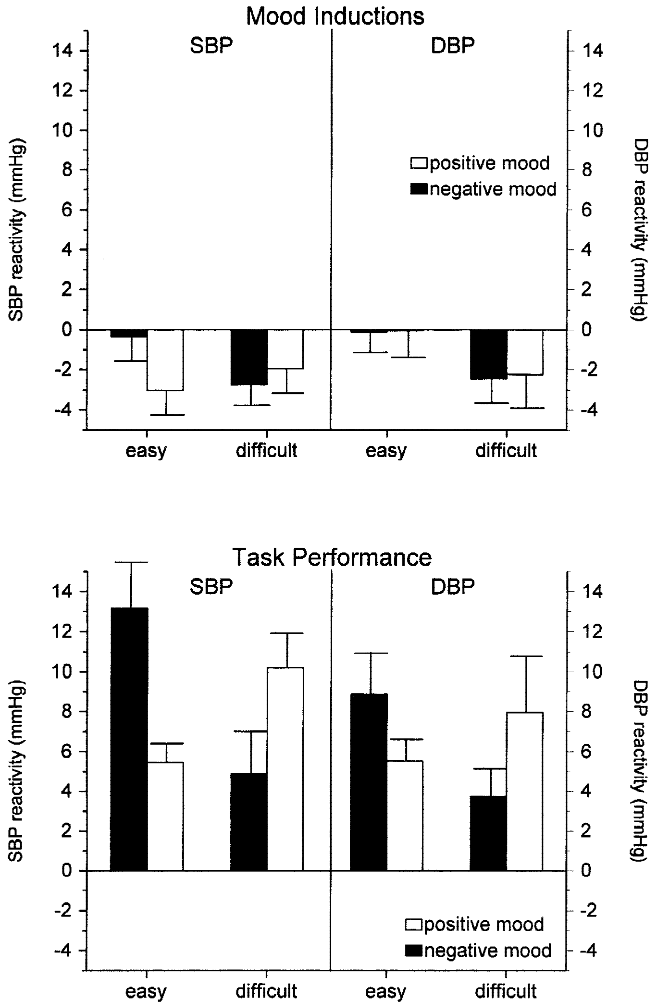

Figure 2. Cell means of SBP and DBP reactivity during the mood inductions (top panel) and task performance (bottom panel). Error bars give *SE*s of cell means.

the predicted crossover interaction that we further explored with cell contrasts based on the *MSE* of the ANOVA. Given the focused nature of these comparisons due to our predictions, we used one-tailed tests. In full support of our predictions, these cell comparisons revealed that SBP reactivity was stronger in a negative mood ($M = 13.15$, $SE = 2.45$) than in a positive mood ($M = 5.45$, $SE = 0.96$), $t(52) = 2.86$, $p < .003$, when the task was easy. Conversely, SBP reactivity was stronger in a positive mood ($M = 10.19$, $SE = 1.65$) than in a negative mood ($M = 4.89$, $SE = 2.21$), $t(52) = 1.97$, $p < .03$, when the task was difficult.

DBP reactivity. Cell means and standard errors are depicted in Figure 2 (right panel). The mixed-model ANOVA yielded a significant main effect of time, $F(1,52) = 78.32$, $p < .001$, indicating stronger reactivity during task performance than during the mood inductions (*M*s = 6.51 versus −1.21), and a significant three-way interaction between mood, task difficulty, and time, $F(1,52) = 4.50$, $p < .04$. As for the systolic responses, we further highlighted this effect with separate 2×2 between-subjects ANOVAs of the DBP responses during both periods of measure. The 2×2 ANOVA of diastolic reactivity during the mood inductions revealed no significant effects.[4] However, the 2×2 ANOVA of DBP reactivity during task performance yielded, as the only reliable effect, a mood by task difficulty interaction, $F(1,52) = 5.76$, $p < .02$, $MSE = 34.53$, which was further explored with cell contrasts. Given that we had no strict predictions on diastolic reactivity, we used two-tailed tests. As depicted in Figure 2, the pattern of cell means paralleled that of systolic reactivity and described a crossover interaction. On the difficult level, DBP reactivity was stronger in a positive mood ($M = 7.95$, $SE = 1.22$) than in a negative mood ($M = 3.74$, $SE = 1.66$), $t(52) = 1.90$, $p < .06$. On the easy level, there was stronger DBP reactivity in a negative mood ($M = 8.85$, $SE = 2.07$) than in a positive mood ($M = 5.52$, $SE = 1.16$), but this difference was not significant, $t(52) = 1.50$, $p < .14$.

HR reactivity. Cell means and standard errors are presented in Table 1. According to the mixed-model ANOVA, only the main effect of time was significant, $F(1,52) = 58.47$, $p < .001$, and reflected stronger reactivity during task performance than during the mood inductions (*M*s = 10.47 versus −0.63). However, inspection of Table 1 suggests that HR reactivity during task performance at least roughly described the expected effort-related pattern.

Electrodermal Reactivity

We determined and analyzed electrodermal reactivity in parallel fashion to the cardiovascular responses. Cell means and standard errors are presented in Table 1.

SCL reactivity. The $2 \times 2 \times 2$ mixed-model ANOVA revealed a significant main effect of time, $F(1,51) = 112.29$, $p < .001$, reflecting stronger reactivity during task performance than during the mood inductions (*M*s = 3.35 versus 0.33), and a significant three-way interaction between mood, task difficulty, and time. We further explored this effect with separate 2×2 between-subjects ANOVAs for both time periods. The ANOVA of the SCL responses during the mood inductions yielded no significant effects (all *p*s > .13, $MSE = 1.30$). But the ANOVA of SCL reactivity during task performance revealed a marginally significant interaction between mood and task difficulty, $F(1,51) = 3.39$, $p < .07$, $MSE = 4.43$. As presented in Table 1, the pattern of cell means paralleled those of SBP and DBP and described a crossover interaction. Cell contrasts revealed that SCL responses in a negative mood were stronger than in a positive mood when the task was easy, $t(51) = 2.04$, $p < .03$. But the difference between the stronger SCL response in a positive than in a negative mood when the task was difficult did not attain significance ($p > .28$).

SCRs reactivity. According to the mixed-model ANOVA, the only significant effect was a main effect of time, $F(1,51) = 68.66$, $p < .001$, indicating a higher increase in the number of spontaneous SCRs during task performance than during the mood inductions (*M*s = 1.58 versus −0.14). However, though statistically not significant, inspection of Table 1 shows that the reactivity of SCRs during task performance described the same crossover-interaction pattern as did the responses of SBP, DBP, and SCL.

Task Performance

We analyzed task performance in terms of three measures: the total number of marked symbols (indicating performance speed), the

[4] The only effect that tended toward significance was a main effect of task difficulty, $F(1,52) = 3.30$, $p < .07$, $MSE = 23.86$, (*M*s = −0.08 easy versus −2.34 difficult), which is hardly interpretable, because this factor was not yet manipulated during the mood inductions.

Table 1. *Cell Means and Standard Errors (in Parentheses) of HR, SCL, and SCRs During Mood Inductions and Task Performance*

	Easy		Difficult	
	Negative mood	Positive mood	Negative mood	Positive mood
Mood inductions				
HR	0.48	−2.04	0.36	−1.31
	(1.06)	(1.36)	(1.06)	(1.25)
SCL	0.02	0.64	0.18	0.48
	(0.44)	(0.23)	(0.21)	(0.29)
SCRs	−0.71	0.14	−0.31	0.32
	(0.37)	(0.21)	(0.22)	(0.29)
Task performance				
HR	13.15	8.11	10.00	10.61
	(2.37)	(2.83)	(2.46)	(2.37)
SCL	4.36	2.74	2.91	3.38
	(0.84)	(0.47)	(0.49)	(0.34)
SCRs	1.80	1.67	1.33	1.50
	(0.47)	(0.51)	(0.39)	(0.41)

*Notes: MSE*s for HR are 49.28 (between effects) and 58.95 (within effects). *MSE*s for SCL are 3.50 (between effects) and 2.23 (within effects). *MSE*s for SCRs are 2.69 (between effects) and 1.18 (within effects). $n = 14$ in each cell.

total number of errors (of both commission and omission), and the net performance index (i.e., marked symbols minus errors). Cell means and standard errors appear in Table 2.

A 2 × 2 between-subjects ANOVA of the total number of marked symbols revealed a significant main effect of task difficulty, $F(1,52) = 24.83$, $p < .001$, reflecting that more symbols were marked in the difficult conditions than in the easy conditions (*M*s = 535.68 versus 464.82) and a marginally significant main effect of mood, $F(1,52) = 3.64$, $p = .06$, indicating more marked symbols in a positive than in a negative mood (*M*s = 513.82 versus 486.68). The two-way interaction was also marginally significant, $F(1,52) = 3.62$, $p = .06$. Cell contrasts, based on the mean square error, revealed that mood had no impact in the easy conditions ($p > .50$). But in the difficult conditions, participants in a positive mood marked more symbols than those in a negative mood, $t(52) = 2.69$, $p < .01$. An ANOVA of the number of committed errors revealed a significant main effect of task difficulty, $F(1,52) = 15.31$, $p < .001$, reflecting more errors in the difficult than in the easy conditions (*M*s = 25.61 versus 9.57), and a reliable main effect of mood, $F(1,52) = 4.71$, $p < .04$, indicating more errors in a positive than in a negative mood (*M*s = 22.04 versus 13.14). The interaction only approached significance, $F(1,52) = 2.49$, $p = .12$. However, focused contrasts found again no impact of mood in the easy conditions ($p > .50$), but more errors in a positive than in a negative mood when the task was difficult, $t(52) = 2.65$, $p < .01$. Finally, the ANOVA of the net performance index revealed a significant main effect of task difficulty, $F(1,52) = 16.14$, $p < .001$, reflecting more correctly identified symbols in the difficult than in the easy conditions (*M*s = 510.07 versus 455.25). The main effect of mood, $F(1,52) = 1.79$, $p < .19$, and the interaction, $F(1,52) = 2.28$, $p < .14$, were both not reliable. However, cell contrasts found that mood had no impact in the easy conditions ($p > .50$), but that more symbols were correctly identified in a positive than in a negative mood when the task was difficult, $t(52) = 2.01$, $p < .05$. Thus, in summary, the analysis of the performance measures revealed faster and more accurate performance in a positive than in a negative mood when task difficulty was high. This effect parallels the reactivity patterns of SBP, DBP, and SCL (see above).

Table 2. *Cell Means and Standard Errors (in Parentheses) of the Task Performance Measures*

	Easy		Difficult	
	Negative mood	Positive mood	Negative mood	Positive mood
Marked symbols				
	464.79	464.86	508.57	562.79
	(2.94)	(2.16)	(21.97)	(17.69)
Committed errors				
	8.36	10.79	17.93	33.29
	(1.52)	(2.45)	(4.55)	(6.18)
Net performance				
	456.43	454.07	490.64	529.50
	(3.96)	(3.52)	(19.46)	(18.14)

Notes: MSEs for marked symbols, errors, and the net performance index are 2831.04, 235.18, and 2607.60. $n = 14$ in each cell.

Discussion

According to a recent theory of mood and motivation, the MBM (Gendolla, 2000), we predicted that moods per se do not involve autonomic adjustments referring to effort mobilization, because moods are, in contrast to specific emotions, not considered as motivational states. Nevertheless, we anticipated that moods will impact autonomic activity in active coping (Obrist, 1981), that is, when individuals are faced with demands that call for the mobilization of effort (Wright, 1996). Under this condition we expected mood with its informational impact to interact with objective task difficulty to produce a pattern of effort-related autonomic adjustments, depicted in Figure 1.

Effects on Autonomic Adjustments

Results for SBP reactivity, our primary measure of effort due to its strong link to β-adrenergic impact on the heart (Obrist, 1981; Krantz et al., 1987; Wright, 1996), fully supported our predictions. During the mood inductions, which were highly effective according to the manipulation check, SBP generally decreased relative to baseline values. But systolic adjustments during task performance exactly described the reactivity pattern we had predicted for active coping: When the task was easy, SBP reactivity was strong in a negative mood, but relatively weak in a positive mood. Conversely, systolic responses were relatively strong in a positive mood, but weak in a negative mood, when the task was difficult. That is, though the effectively induced moods per se did not involve systolic adjustments, they interacted, as predicted, with objective task difficulty in active coping. Furthermore, DBP adjustments paralleled those of SBP, though the SBP pattern was clearer, according to the comparisons of single conditions. The DBP effects were less anticipated because decreases in vascular tone, which are usually observed in active coping, should minimize the impact of cardiac activity on DBP (Sherwood, Dolan, & Light, 1990). Nevertheless, there is also other evidence for DBP adjustments in active coping (e.g., Al'Absi et al., 1997; Gendolla, 1999; Lovallo et al., 1985; Smith, Allred et al., 1989, Smith, Baldwin et al., 1989; Storey et al., 1996; Wright & Dill, 1993), which suggests either that effort mobilization is sometimes associated with greater vasoconstriction than vasodilation or that myocardial contractility can be so high that it also elevates blood pressure between pulse beats. However, in the present study, the DBP effects are also attributable to task characteristics. The d2 task involves a strong motoric speed component. Therefore it is possible that muscle tension in participants' arms affected vasoconstriction, which in turn resulted in parallel reactivity patterns of SBP and DBP. Though this post hoc explanation calls for further research, it is also applicable to the weak effects on HR that did not attain statistical significance. Nevertheless, HR reactivity at least roughly described the predicted effort-related pattern. The absence of a correspondence between SBP and HR adjustments suggests that the parasympathetic impact on the heart masked the sympathetic impact (Berntson, Cacioppo, & Quigley, 1993), which is likely to happen during performance on tasks that involve a motoric component (Obrist, 1981). Thus, we attribute the relatively weak HR effects again to the characteristics of the d2 task with its strong motoric speed component.

The observed effects on EDA are also of interest. Reactivity of tonic SCL described the same pattern as that of SBP and DBP. This may reflect an adaptive bodily response in that sweating of the palms facilitates better grip to the pencil participants needed to hold to complete the letter cancellation task (cf. Edelberg, 1973). The effects on the number of unspecific SCRs—which are controversial because this measure has been posited to reflect both inhibition (Fowles, 1988) and task engagement (Pecchinenda & Smith, 1996)—were weaker and did not attain statistical significance, though also the reactivity pattern of SCRs corresponds to our effort-related predictions. However, given the equivocal findings in the psychophysiological literature, further research is needed to specify under exactly which conditions EDA refers to active coping.

In summary, we interpret the pattern of observed autonomic responses as follows: In accordance with the broad literature on active coping, discussed above, we observed strong effects on SBP adjustments that exactly described the shape we had predicted according to our theoretical assumptions. Thus, we conclude that mood interacts with objective task difficulty to determine effort mobilization. The pattern of SBP adjustments was paralleled by significant reactivity effects on DBP and SCL and weaker, nonsignificant, effects on HR and SCRs. We attribute these findings to the characteristics of the d2 task with its strong motoric speed component and suggest that DBP and SCL adjustments may parallel myocardial effects in active coping settings that involve a similar type of task.

Effects on Task Performance and Subjective Measures

The observed effects on performance are also of interest. Cell comparisons revealed no differences in any performance indices when the task was objectively easy, but faster and better net performance in a positive mood than in a negative mood when task difficulty was objectively high. This latter finding corresponds to the observed pattern of autonomic responses and further indicates that we elicited active coping. Accordingly, mobilized effort played no significant role when task difficulty was low—which is not surprising, because the task difficulty manipulation was supposed to create a performance standard that was easily attainable. But autonomic reactivity was associated with achievement when task difficulty was high and effort was necessary to meet the standard. However, the explicable lack of performance effects in the easy conditions also indicates that the relationship between effort mobilization and performance is loose and complex rather than strictly linear (see Eysenck, 1982; Gendolla, 1999).

A potential shortcoming of the present study is that it does not provide direct evidence for our assumption that the predicted and observed effort-related pattern of autonomic adjustments occurred due to mood congruency effects on the extent of subjective demand. Participants' probability of success ratings, which have been demonstrated to be vulnerable to mood congruency effects (e.g., Cunningham, 1988; Wright & Mischel, 1982), indicate only a highly successful task difficulty manipulation, but show no mood effects. However, it is important to note that participants rated task demand *before* task performance. Though other studies in our laboratory revealed significant mood congruency effects on demand appraisals at this point of measure (Gendolla et al., in press; Gendolla & Krüsken, 1999), it is most important how demanding a person "feels" a task *during* performance. But it is hardly possible to measure this, because it necessitates interruptions of the active coping process that are likely to result in disengagement. However, most relevant is that the physiological findings obtained *during* active coping are in full support of our predictions. Therefore we conclude that the present study supports our reasoning on the joint effects of mood and objective task difficulty on autonomic adjustments in active coping. Accordingly, moods per se do not involve effort-related autonomic adjustments, but they can impact effort-related autonomic reactivity in active coping.

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