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Mood impact on cardiovascular reactivity when task difficulty is unclear

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Abstract Research in the context of the mood-behavior-model (Gendolla in Rev Gen Psychol 4:348–408, 2000) has shown that moods can have an impact on effort mobilization due to congruency effects on demand appraisals. However, the mood research literature suggests that mood may also influence effort mobilization by its impact on appraisals of the instrumentality of success. In a single factor (mood valence: negative vs. neutral vs. positive) between-persons design, participants performed a memory task under conditions of unclear task difficulty. By successfully performing the task, participants could earn the chance to win a monetary reward. As predicted for tasks with unclear difficulty, effort mobilization—assessed as cardiovascular reactivity—increased from negative to positive mood. This effect was mediated by the subjective probability of winning the monetary reward for successful performance. These results demonstrate for the first time that mood can influence effort mobilization via the estimated instrumentality of success.

Keywords Mood · Instrumentality · Reward · Cardiovascular reactivity · Unclear task difficulty

The motivational and behavioral implications of moods have been a central topic of research for several decades. Earlier approaches, such as Isen's perspective on mood regulation (Clark and Isen 1982; Isen 1984) and Schwarz's cognitive tuning hypothesis (Schwarz 1990) posited stable mood effects on motivation and behavior. Isen postulated that negative mood initiates mood repair whereas positive mood leads to mood maintenance. According to the cognitive tuning hypothesis, a negative mood signals a problematic person–situation relationship; positive mood indicates that everything is fine. Consequently, negative mood should lead to an analytic processing style that requires a high amount of resources, whereas positive mood should results in a less demanding heuristic processing style (see also Morris 1999). However, the assumption that moods have stable effects on motivation has been seriously challenged by studies that demonstrated the context dependency of mood effects on persistence (e.g., Martin et al. 1993) and affect regulation (e.g., Erber and Erber 2000; Erber et al. 1996).

Mood impact on effort mobilization

Research in the context of the mood-behavior-model (MBM) (Gendolla 2000) has focused on mood effects on effort intensity (i.e. resource mobilization for instrumental behavior at one given moment). The MBM posits that mood can exert its impact on effort by serving as information for behavior-related judgments. To arrive at specific predictions, the MBM draws on motivational intensity theory (Brehm and Self 1989) and its integration with Obrist's active coping approach (Obrist 1981) by Wright (1996). Motivational intensity theory's predictions are developed from the basic assumption that human behavior is guided by a resource conservation principle. Individuals try to avoid wasting resources and, therefore, do not invest more effort than necessary for goal attainment. It follows that effort mobilization should depend on two variables: task difficulty and success importance. *Task difficulty* determines effort as long as success is possible and

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justified: the higher task difficulty, the higher effort mobilization. *Success importance*—which is influenced by needs, incentive value, and instrumentality of success—only determines the maximally justified amount of effort. If the necessary resources outweigh the benefits, individuals should disengage and effort mobilization should be low.[1] However, these predictions only apply when performers have a clear idea about the difficulty of the upcoming task. If this is not the case—that is, if performers have no information about task difficulty (*unclear difficulty)*—motivational intensity theory predicts that success importance should directly determine effort mobilization: the higher success importance, the higher effort mobilization. In situations of unclear task difficulty, individuals have no task difficulty information available to guide their effort investment. Consequently, they should rely on success importance to avoid investing more effort than justified. It follows from the above predictions that—depending on the availability of task difficulty information—different judgments should be salient and guide effort mobilization. Given that mood should exert its impact on behavior by providing information for the salient behavior-related judgment—as predicted by the mood-as-input model (e.g., Martin 2001; Martin et al. 1993)—mood should influence the perception of task demand under conditions of clear task difficulty, whereas mood should have an impact on success importance under conditions of unclear task difficulty.

In the last years, Gendolla and colleagues provided ample support for the first prediction. They have shown that mood is used as information for the evaluation of task difficulty, which leads to a mood congruency effect on task difficulty: the more negative the mood, the higher the subjective task difficulty. Furthermore, they demonstrated that this mood effect is integrated together with objective task difficulty to form a task difficulty appraisal that determines effort mobilization (Gendolla et al. 2007; Richter et al. 2006, for reviews). Specifically, they showed that negative mood results in higher effort mobilization than positive mood at low levels of task difficulty, whereas positive mood leads to higher effort than negative mood at higher difficulty levels. At very high difficulty levels, effort mobilization was low and independent of mood valence. According to Gendolla and colleagues, this happens because resources are mobilized proportionally to subjective task demand as long as success is regarded as possible and worthwhile—as posited by motivational intensity theory (Brehm and Self 1989; Wright and Kirby 2001). Moreover, subjective task difficulty mediated this mood impact on effort mobilization (Gendolla and Krüsken 2002a) and mood effects on both demand appraisals and effort mobilization disappeared when mood's informative value is taken into question (Gendolla and Krüsken 2002b).

However, Gendolla and colleagues did only investigate mood impact on effort mobilization when information about task difficulty was available. Thus, they provided support for the prediction that mood effects on effort mobilization are mediated by mood effects on task difficulty when task difficulty is salient. So far, there are no empirical studies that have examined mood effects on effort mobilization when no task difficulty information is available (i.e. when task difficulty is unclear). The general prediction of motivational intensity theory that effort mobilization is proportional to success importance under conditions of unclear difficulty has been supported by recent studies (Richter and Gendolla 2006, 2007, 2009) but the impact of mood in this context has not been investigated. According to motivational intensity theory, success importance should be salient and guide effort mobilization under this condition. Consequently, mood effects on effort mobilization should be mediated by success importance and its determinants need, incentive value, and instrumentality of success when task difficulty is unclear.

Interestingly, Nygren et al. (1996) have shown mood congruency effects on the estimated probability of winning a reward: the more positive the mood, the higher the estimated probability of receiving a reward. Likewise, there is evidence that mood has congruency effects on the expectancy of positive outcomes (e.g., Cunningham 1988). The probability of winning a reward that can be attained by succeeding on a task refers to the instrumentality of success—a variable that determines success importance (e.g., Wright and Gregorich 1991; Wright et al. 1992): The more likely it appears that success will indeed lead to a desired reward, the more important it is to succeed and the more effort is justified for success. According to the logic of motivational intensity theory, mood effects on the subjective instrumentality of success should therefore influence effort mobilization under conditions of unclear task difficulty.

Effort mobilization and cardiovascular reactivity

Research on the mood-behavior-model and motivational intensity theory has relied on cardiovascular activity—especially blood pressure and heart rate—to assess effort mobilization. This approach draws on Obrist's demonstration that task engagement under conditions of active

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[1] Please note that motivational intensity theory's predictions about effort mobilization refer to resource (or energy) mobilization and not to perceived effort. This implies that the theory makes no predictions about the relationship of perceived effort and perceived task difficulty. Motivational intensity theory postulates that effort—the amount of energy that individuals invest in behavior—is an outcome of both perceived task difficulty and success importance. Please also note that objective task difficulty should only be a distant determinant of effort mobilization by exerting an impact on subjective task difficulty.

coping—i.e. when individuals can control performance outcomes—is reflected by increases in myocardial beta-adrenergic activity (Obrist 1981). Beta-adrenergic activity determines heart rate and the force of myocardial contraction and has by this means an impact on various cardiovascular indices. However, according to Wright (1996), among heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP), SBP should be the most sensitive to variations in effort because it is more systematically related to the force of myocardial contraction than DBP or HR. Furthermore, the empirical research on motivational intensity theory has consistently found effects on SBP. Effects on DBP or HR have been less coherent (Gendolla et al. 2007; Wright and Kirby 2001).

The present experiment

After being induced into a positive, neutral, or negative mood participants performed a memory task under conditions of unclear task difficulty. By successfully performing the task, participants could earn the chance to win a monetary reward. As outlined above, we hypothesized for this type of task that mood should have a congruency effect on participants' estimates of the probability of receiving the reward. To extend preceding research and to test our predictions more precisely, we included a "neutral" mood control condition. Congruent with preceding studies that have tested the predictions of motivational intensity theory and the mood-behavior-model, effort mobilization was operationalized as cardiovascular reactivity—i.e. the change of cardiovascular activity from rest to task performance. Due to the anticipated mood congruency effect on participants' instrumentality appraisals we expected a rise in cardiovascular reactivity (especially SBP) from the negative to the positive mood condition.

Methods

Participants and design

Thirty-first-year psychology students participated in the experiment for course credit and were randomly assigned to a single factor (mood valence: negative vs. neutral vs. positive) between-persons design. The distribution of women and men was balanced between the conditions.[2] Participation in the experiment was voluntary and anonymous.

Apparatus and physiological measurement

A Vasotrac APM205A monitor (Medwave, Arden Hills, MN) assessed SBP (in millimeters of mercury [mmHg]), DBP (in millimeters of mercury [mmHg]), and HR (in beats per minute [bpm]) during three measurement periods: habituation, mood induction, and task performance. The Vasotrac's cuff was placed around the wrist of the participant's non-dominant arm and collected one measure every 12–15 heart beats. All obtained measures were automatically stored on a computer. Experiment generation software (INQUISIT by Millisecond Software, Seattle, WA) controlled the presentation of all stimuli and collected participants' responses. The participants and the experimenter, who was hired and ignorant of the hypotheses, were ignorant of all data collected during the experimental session.

Procedure

The experiment was run in individual sessions. After having applied the blood pressure cuff, the experimenter started the INQUISIT program and left the room. Participants then answered some biographical questions and rated their actual mood using eight adjectives of the UWIST scale (Matthews et al. 1990) with positive (*happy*, *joyful*, *contended*, *cheerful*) and negative (*sad*, *frustrated*, *depressed*, *dissatisfied*) hedonic tone. They indicated for each adjective in how far it corresponded to their actual mood state using a scale ranging from *not at all* (1) to *very much* (9). During the following 10 min of habituation, participants could leaf through some old magazines while cardiovascular measures were assessed.

Mood inductions

After habituation period, participants were instructed to write down a personal event. Participants in the *negative mood* condition were instructed to describe an event that made them sad, participants in the *positive mood* condition described an event that made them happy. Participants in the *neutral mood* condition learned that they should describe the way from their apartment to the university. This method of autobiographical recollection has been shown to be effective for the induction of moods (Westermann et al. 1996). Furthermore, this procedures has been successfully employed in our own research (e.g., Gendolla et al. 2001; Gendolla and Krüsken 2002a). Participants worked on this task for 5 min. Cardiovascular measures were assessed in intervals of 12–15 heart beats during this time. After the mood induction participants received the instructions for the memory task.

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[2] There were 8 women and 2 men in both the negative mood cell and the neutral mood cell and 9 women and 1 man in the positive mood cell.

Task performance

The task consisted of a list of eight senseless letter series, each consisting of four letters. The letter series were presented successively in intervals of 37.5 s. That is, only the first letter series was presented at the beginning. After 37.5 s, the first two letter series were visible on the screen. After the next 37.5 s, the third letter series was added. This procedure was repeated until, 37.5 s before the task end all eight letter series had appeared on the screen. Total performance time was 5 min. To create a task with unclear difficulty, participants received information about the general task procedure but were not informed about the total number of letter series, performance time, and the time interval between the presentations of the different letter series (e.g., Richter and Gendolla 2007, 2008). Furthermore, participants were informed that they could win 15 Swiss Francs (about USD 15) if they would correctly recall all of the presented letter series at the end of task performance. Participants further learned that they would have the opportunity to draw one ball out of a bag including several white and some black balls if they succeeded on the task. If they would draw a black one, they would receive the 15 Swiss Francs. There was no further specific information concerning the probability of drawing a black ball.

After the task instructions participants rated again the eight UWIST adjectives. Furthermore, participants rated the probability of drawing a black ball ("How likely is it that you will draw a black ball?") on a scale ranging from *very unlikely* (1) to *very likely* (9). Then, they performed the task for 5 min. Cardiovascular measures were obtained in intervals of 12–15 heart beats during this time.

At the end of the task participants noted all letter series they could recall on a separate sheet of paper and rated task difficulty ("How difficult did the task appear to you?") on a scale ranging from *very easy* (1) to *very difficult* (9). Then, participants, who had correctly recalled the eight letter series, drew one ball out of the bag. If they drew a black ball, they received the promised reward of 15 Swiss Francs. Finally, all participants were carefully debriefed, probed for suspicion, and given their course credit.

Data analysis

Cardiovascular reactivity measures were analyzed in two steps. First, we used mixed-model ANOVAs with mood valence (negative vs. neutral vs. positive) as between-persons factor and measurement period (mood induction vs. task performance) as within-persons factor. Since we predicted that cardiovascular reactivity during task performance should rise from negative to positive mood, whereas cardiovascular reactivity during the mood induction should not be affected by the mood manipulation, we also tested the linear trend × measurement period interaction. Second, we analyzed cardiovascular reactivity separately for each period using single factor (mood valence: negative vs. neutral vs. positive) between-persons ANOVAs. Following these ANOVAs we compared the cell means using *t*-tests for independent samples. If cardiovascular reactivity scores were significantly correlated with their baseline measures or the number of letters written during the mood induction, we included these measures as covariates in all analyses.

All other measures were analyzed using one-factorial (mood valence: negative vs. neutral vs. positive) between-persons ANOVAs. Cell means were compared either using *t*-tests or Tukey's HSD tests. *t*-tests were used to test our a priori predictions concerning the impact of mood on the pre-task rating and on mood change scores. All other post-hoc comparisons were Tukey's HSD tests. Since our predictions concerning mood impact on cardiovascular reactivity, pre-task rating, and mood change scores were directional, we used one-tailed *t*-tests.

Results

Preliminary analyses

Three (mood valence) × 2 (gender) between-persons ANOVAs found no gender main effects on any of the cardiovascular baseline and reactivity measures ($ps > .12$). Unexpectedly, there was a significant gender × mood interaction on HR task reactivity, $F(2, 24) = 7.87, p = .002$, $\mathrm{MSE} = 26.23$, $\eta_{\mathrm{p}}^2 = .40$.[3] All other interactions were not significant ($ps > .09$). However, the analyses of gender effects were based on a very low number of men. Consequently, we did not include gender as a covariate in the analyses of HR reactivity but we repeated all HR analyses including only female participants. Since the results of the restricted sample were virtually identical to the results of the whole sample, we only report the results of the latter.

Self-report measures

We created mood sum scores for each UWIST measure by adding the scores of the positive adjectives to the inversely coded scores of the negative items. Cronbach's α was .93 for both the pre-mood induction and post-mood induction score. Unexpectedly, the mood conditions differed before the mood manipulation, $F(2, 27) = 3.95$, $p = .03$,

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[3] Cell means and standard errors were as follows: $M = 8.32$ and $\mathrm{SE} = 2.11$ in the women-negative mood cell, $M = 4.18$ and $\mathrm{SE} = 1.39$ in the women-neutral mood cell, $M = 4.53$ and $\mathrm{SE} = 1.82$ in the women-positive mood cell, $M = 4.24$ and $\mathrm{SE} = 1.74$ in the men-negative mood cell, $M = -0.03$ and $\mathrm{SE} = 4.49$ in the men-neutral mood cell, and $M = 23.97$ in the men-positive mood cell.

MSE =101.78, $\eta_p^2 = .23$. Post-hoc comparisons showed that the neutral mood cell ($M = 46.20$, SE = 4.07) differed significantly from the negative mood cell ($M = 57.60$, SE = 1.98), $q(3, 27) = 3.57$, $p = .05$, and tended to differ from the positive mood cell ($M = 56.70$, SE = 3.17), $q(3, 27) = 3.29$, $p = .07$. The difference between the negative mood cell and the positive mood cell was not reliable ($p = .98$).

To analyze the effect of our mood induction procedure, we computed change scores for each participant by subtracting the pre-mood induction UWIST score from the post-mood induction UWIST score. Furthermore, to control for the unexpected difference in participant's baseline scores, we included the pre-mood induction scores as covariate. The resulting single factor between-persons ANCOVA showed only the expected effect of mood valence, $F(2, 26) = 4.28, p = .02$, MSE = 18.20, $\eta_p^2 = .25$, while the effect of the covariate was not significant, $F(1, 26) = 2.09, p = .16$. Pairwise comparisons revealed that the mood change scores were significantly higher in the positive mood cell ($M = 3.08$, SE = 1.37) than in the neutral mood cell ($M = -0.56$, SE = 1.47), $t(26) = 1.74, p = .05$, or the negative mood cell ($M = -2.42$, SE = 1.39), $t(26) = 2.88$, $p = .001$. Mood change scores did not differ significantly between the neutral mood cell and the negative mood cell ($p = .19$).[4]

Mood had a marginally significant effect on the probability of drawing a black ball, $F(2, 27) = 3.18$, $p = .06$, MSE = 2.56, $\eta_p^2 = .19$. Pairwise comparisons revealed a significant difference between the negative ($M = 2.90$, SE = 0.35) and the positive mood cells ($M = 4.70$, SE = 0.56), $t(27) = 2.52$, $p = .001$, as well as a marginally significant difference between the neutral ($M = 3.70$, SE = 0.58) and the positive mood cells, $t(27) = 1.40$, $p = .09$. The differences between the neutral and the negative mood cells was not reliable ($p = .14$). Mood valence did not significantly influence the post-task difficulty rating, $F(2, 27) = 0.06$, $p = .93$, MSE = 3.76. Cell means were as follows: $M = 6.10$ and SE = 0.46 in the negative mood cell, $M = 5.80$ and SE = 0.70 in the neutral mood cell, and $M = 5.90$ and SE = 0.66 in the positive mood cell.

Cardiovascular baselines

The arithmetic mean of the HR, SBP, and DBP measures obtained during the last 5 min of the habituation period constituted our cardiovascular baseline scores (Cronbach's αs were .99 for SBP, .96 for DBP, and .98 for HR). Mood valence had no significant effect on any cardiovascular baseline measure, $F\text{s}(2, 27) < 0.82$, $p\text{s} > .45$. Means and standard errors of the baseline values are presented in Table 1.

Cardiovascular reactivity

We computed change scores for each participant and each measure (Llabre et al. 1991). Mood induction reactivity scores were calculated by subtracting baseline values from the arithmetic mean of the values obtained during the 5 min of mood induction (Cronbach's αs were .98 for SBP, .98 for DBP, and .95 for HR). The difference between baseline values and the arithmetic mean of all values obtained during task performance (Cronbach's αs were .96 for SBP, .95 for DBP, and .96 for HR) constituted our task performance reactivity scores.

SBP reactivity

SBP baseline values did not significantly correlate with SBP reactivity during the mood inductions ($r = .20$, $p = .30$) or SBP reactivity during task performance ($r = -.10$, $p = .59$) and were, therefore, not considered as covariate in the analysis of SBP reactivity. The mixed-model ANOVA revealed the expected significant interaction, $F(2, 27) = 6.04$, $p = .006$, $\text{MSE}_{\text{between}} = 174.38$, $\text{MSE}_{\text{within}} = 43.69$, $\eta_p^2 = .31$, as well as a marginally significant effect for measurement period, $F(1, 27) = 3.89$, $p < .06$, $\eta_p^2 = .13$. The main effect of mood valence was not significant ($p = .81$). Most relevant, the interaction between the linear contrast and the measurement period was significant, $F(1, 27) = 11.97, p = .002, \eta_p^2 = .31$. SBP reactivity during the mood inductions did not show a significant mood valence effect, $F(2, 27) = 1.35$, $p = .28$, MSE = 86.41. Mood induction reactivity scores appear in Table 2. Since SBP reactivity during the mood inductions significantly correlated with SBP reactivity during task performance ($r = .48$, $p = .01$), we included the SBP mood induction reactivity scores as a covariate in the analysis of SBP task reactivity. The resulting single factor ANCOVA found the expected significant effect of mood valence, $F(2, 26) = 4.59$, $p = .02$, MSE = 85.40, $\eta_p^2 = .26$, and a significant covariate effect, $F(1, 26) = 15.62, p = .001$. SBP reactivity in the positive mood cell ($M = 16.74$, SE = 2.97) was significantly higher than in the neutral ($M = 8.65$, SE = 2.93), $t(26) = 1.95$, $p = .03$, or the negative mood cell

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[4] We also analyzed the number of letters that participants wrote during the mood induction procedure. Mood valence did not significantly affect this measures, $F(2, 27) = 0.12$, $p = .89$, MSE = 27136. Post-hoc comparisons indicated that the negative mood cell ($M = 550.30$, SE = 55.04), the neutral mood cell ($M = 533.20$, SE = 56.91), and the positive mood cell ($M = 569.20$, SE = 43.27) did not differ from one another ($p\text{s} > .87$). Furthermore, including the number of written letters as covariate in the analyses of mood change scores resulted in a nonsignificant effect of the covariate ($F \ll 1$) and did virtually not change the results. The correlation between the number of written letters and the baseline adjusted mood change score was low, $r = .08$, $p = .67$.

Table 1 Cell means and standard errors of cardiovascular baseline scores

	Mean			Standard error		
	Negative mood	Neutral mood	Positive mood	Negative mood	Neutral mood	Positive mood
HR baseline	72.43	80.37	76.73	4.06	4.53	4.56
SBP baseline	121.36	123.70	121.69	5.22	7.63	5.55
DBP baseline	65.97	66.34	65.52	3.60	5.48	3.70

Heart rate is in beats per minute, systolic blood pressure and diastolic blood pressure are in mmHg

$n = 10$, *HR* heart rate, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

Table 2 Cell means and standard errors of cardiovascular reactivity during the mood inductions

	Mean			Standard error		
	Negative mood	Neutral mood	Positive mood	Negative mood	Neutral mood	Positive mood
HR baseline	4.08	7.18	5.77	2.15	2.14	2.12
SBP baseline	10.23	5.27	3.69	2.89	3.36	2.51
DBP baseline	8.22	6.32	4.10	1.84	2.17	1.81

Heart rate is in beats per minute, systolic blood pressure and diastolic blood pressure are in mmHg. Heart rate reactivity is corrected for both the influence of baseline values and the influence of the number of letters written during mood induction

$n = 10$, *HR* heart rate, *SBP* systolic blood pressure, *DBP* diastolic blood pressure

($M = 3.88$, SE = 3.01), $t(26) = 2.98$, $p = .003$. The difference between the negative and the neutral mood cell was not reliable ($p = .14$). Figure 1 displays cell means and standard errors of SBP task reactivity.

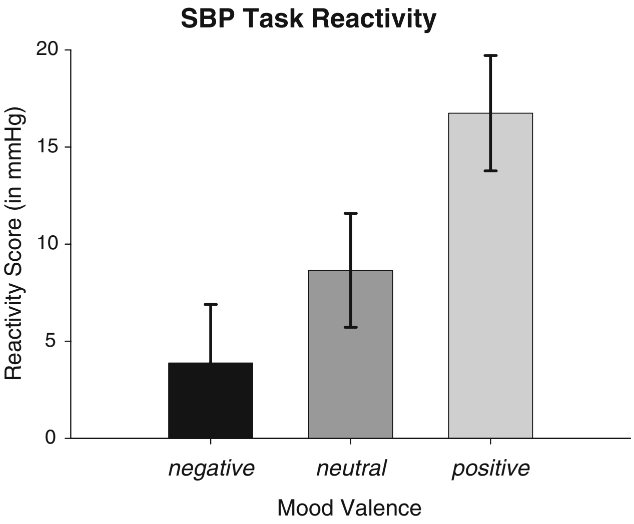

Fig. 1 Cell means and standard errors of adjusted systolic blood pressure reactivity during task performance. mmHg = millimeters of mercury

DBP reactivity

DBP baseline values did not significantly correlate with DBP reactivity scores during the mood induction ($r = .07$, $p = .70$) or task performance ($r = -.03$ $p = .88$). Therefore, we did not correct the DBP reactivity scores for DBP baselines. The mixed-model ANOVA revealed a significant interaction, $F(2, 27) = 6.81$, $p = .004$, $\mathrm{MSE}_{\mathrm{between}} = 86.26$, $\mathrm{MSE}_{\mathrm{within}} = 21.75$, $\eta_p^2 = .34$. The period effect, $F(1, 27) = 2.42$, $p = .13$, $\eta_p^2 = .08$, and the mood valence effect were not significant, $F(2, 27) = 0.11$, $p = .89$, $\eta_p^2 = .01$. The linear contrast × period interaction was significant, $F(1, 27) = 13.33$, $p = .001$, $\eta_p^2 = .33$. DBP reactivity scores during the mood inductions (see Table 2) were not influenced by mood valence, $F(2, 27) = 1.12$, $p = .34$, MSE = 37.94. Diastolic mood induction reactivity scores were included as covariate in the analysis of the task performance reactivity scores because both scores were significantly correlated ($r = .48$, $p = .008$). The single factor ANCOVA showed a significant covariate effect, $F(1, 26) = 16.71$, $p = .001$, MSE = 44.29, as well as a significant mood valence effect, $F(2, 26) = 5.50$, $p = .01$, $\eta_p^2 = .30$. Focused comparisons showed that the positive mood cell ($M = 13.62$, SE = 2.14) significantly differed from both the neutral ($M = 7.18$, SE = 2.10), $t(26) = 2.14$, $p = .02$, and the negative mood cells ($M = 3.46$, SE = 2.15), $t(26) = 3.28$, $p = .002$. The difference between the negative and the neutral mood cells was not reliable ($p = .11$).

Heart rate reactivity

HR reactivity during the mood inductions was significantly correlated with the HR baseline values, $r = -.47$, $p = .009$, and the number of letters written during the mood inductions, $r = .58$, $p = .001$. Therefore, we included HR baseline values and the number of letters as covariates in all analyses involving HR mood induction reactivity. The mixed-model ANCOVA showed a significant interaction between time and the number of written letters, $F(1, 25) = 9.10$, $p = .006$, $\text{MSE}_{\text{between}} = 55.39$, $\text{MSE}_{\text{within}} = 30.64$, $\eta_p^2 = .27$. All other effects were not reliable ($ps > .10$). The linear contrast x time interaction was not significant, $F(1, 25) = 0.67$, $p = .42$, $\eta_p^2 = .03$. The mood induction HR reactivity scores (see Table 2) were significantly related to both the number of written letters, $F(1, 25) = 8.48$, $p = .007$, $\text{MSE} = 44.70$, and HR baseline values, $F(1, 25) = 4.41$, $p = .05$. The mood valence effect was not significant, $F(1, 25) = 0.51$, $p = .61$, $\eta_p^2 = .04$. Mood valence did also not significantly influence HR reactivity during task performance, $F(1, 27) = 1.19$, $p = .32$, $\text{MSE} = 38.92$, $\eta_p^2 = .08$. No pairwise comparison was significant ($ps > .15$). Cell means were as follows: $M = 7.67$ and $\text{SE} = 1.78$ in the negative mood cell, $M = 3.44$ and $\text{SE} = 1.37$ in the neutral mood cell, and $M = 6.29$ and $\text{SE} = 2.58$ in the positive mood cell.

Task performance

Single factor ANOVAs did not find a significant mood effect on the total number of correctly noted letter series, $F(2, 27) = 1.44$, $p = .25$, $\text{MSE} = 4.37$, $\eta_p^2 = .10$. Post-hoc comparisons showed no differences between the mood cells ($ps > .26$). Cell means and standard errors were as follows: $M = 6.00$, $\text{SE} = 0.70$ (negative mood); $M = 4.80$, $\text{SE} = 0.63$ (neutral mood), $M = 4.50$, $\text{SE} = 0.65$ (positive mood). Moreover, cardiovascular reactivity during task performance was not significantly correlated with the number of correctly recalled letter series, $-.22 < rs < .24$, $ps > .20$.

Mediation analysis

To further examine the postulated mediation of mood effects on cardiovascular reactivity, we conducted mediation analyses using Sobel tests (Preacher and Hayes 2004). The indirect effect of mood valence on SBP reactivity was significant, Sobel test value $= 2.79$, $p = .05$, and the effect of mood valence on DBP reactivity approached significance, Sobel test value $= 1.84$, $p = .06$, when using the probability of drawing a black ball as mediator. The indirect effect on HR reactivity was not significant ($p = .66$). Furthermore, the indirect effect of mood valence on the cardiovascular measures was not significant when using the post-task difficulty rating as mediator ($ps > .92$).[5] To further examine the mediation of mood effects on systolic blood pressure, we conducted the steps proposed by Baron and Kenny (1986) for establishing mediation. Figure 2 shows the results of this analysis and demonstrates that the criteria for a complete mediation were met. Mood valence significantly affected both the probability of winning and SBP reactivity. When regressing SBP reactivity on both mood valence and the probability of winning, the beta was significant for the probability of drawing a black ball but not for mood valence. In sum, this reflects the expected mediation of mood effects on SBP reactivity by the probability of drawing a black ball.

Discussion

The present experiment supports our reasoning on a mood impact on appraisals of the instrumentality of success (which is, according to motivational intensity theory, one of the determinants of success importance) and effort mobilization. As predicted, mood valence determined the estimated probability of drawing a black ball (i.e., the probability of winning the monetary reward in the case of success). Both effort mobilization and the estimated probability of winning were low in the negative mood group and high in the positive mood group. A mediation analysis further supported our prediction that mood effects on SBP reactivity were mediated by the subjective probability of winning.

Regarding the cardiovascular measures, the mood manipulation had the predicted effect on SBP reactivity: Systolic reactivity increased across the three mood conditions from negative to positive mood. Effects on DBP were similar, whereas mood had no effect on HR reactivity. These findings are in accordance with preceding research on motivational intensity theory that reliably has found effects on blood pressure (especially on SBP) but not on HR. In some studies HR reactivity showed the pattern predicted by motivational intensity theory (e.g., Wright et al. 1992), in others it did not (e.g., Wright and Lockard 2006). From a physiological point of view it is reasonable that HR reactivity is only loosely connected to effort mobilization. According to Obrist (1976, 1981), task engagement is associated with increased activity of the sympathetic nervous system. Since HR is a function of both the sympathetic and the parasympathetic branch of the autonomous nervous system, HR reactivity can only indicate effort mobilization when sympathetic effects are stronger than parasympathetic effects.

At first sight our results resemble the results of Gendolla and Krüsken (2002a, Study 2) who found that positive mood leads to more effort mobilization than negative

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[5] Using bootstrapping instead of the Sobel test—as recommended by Preacher and Hayes (2004) for small samples—did virtually not change the results.

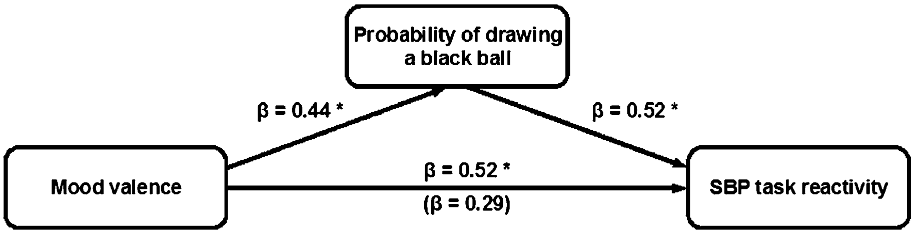

Fig. 2 Path coefficients of the mediation analysis. SBP reactivity is adjusted for the influence of SBP mood induction reactivity. The beta-weight in parentheses is the beta-weight of the regression that includes both mood valence and the probability of drawing a black ball as predictors. * $p < .05$

mood when task difficulty was relatively high. This similarity might cast doubt on our unclear difficulty manipulation. It is conceivable that we presented a challenge with clear and relatively high difficulty rather than one of unclear difficulty. In this case, we would have replicated the findings of Gendolla and Krüsken (2002a) and our effort effects should have been caused by mood congruency effects on subjective task difficulty (see Gendolla et al. 2007 for a review). However, the SBP reactivity increase across the three mood conditions and especially the moderate reactivity in the neutral mood cell make this interpretation unlikely. Under conditions of clear task difficulty one would expect that participants in the neutral mood group would either estimate the necessary effort for success as justified and mobilize effort or that they disengage because the necessary effort is not justified by success importance. The first case would imply that participants in the neutral mood condition mobilize more effort than participants in a positive mood due to higher subjective task difficulty, which does not fit with our pattern of systolic reactivity. The second case would imply that participants in the neutral mood condition mobilize low effort and do not differ from the negative mood condition. Even if our pattern of systolic reactivity showed an increase across the three mood conditions, which is not explicable by the second explanation, we can not rule out the second explanation. However, preceding research on unclear task difficulty has shown that unclear task difficulty effects can not be explained by the high task difficulty explanation (Richter and Gendolla 2006, 2007, 2009). Furthermore, according to our mediation analyses, mood effects on effort mobilization were not mediated by task difficulty appraisals but by the estimated probability of winning. Thus, we regard it as unlikely that our findings were due to a mood impact on task difficulty. Therefore, our results are distinct from preceding work on mood impact in effort mobilization (see Gendolla et al. 2007 for a review).

Our results extend the existent work on mood impact on effort mobilization by demonstrating a second path how mood can influence resource mobilization. Gendolla et al. (2007) have demonstrated that moods influence effort mobilization via subjective task difficulty. Our results show that mood may also affect effort mobilization via the probability of winning a reward after success—which determines success importance, the second major variable of motivational intensity theory (Brehm and Self 1989). At first sight, our results might seem to contradict the work of Gendolla and colleagues. However, it is of note that Gendolla's (2000) Mood-Behavior Model does not predict that mood impact on effort mobilization is always and only mediated by subjective task difficulty. According to the model—and in line with Martin's mood-as-input model (e.g., Martin 2001; Martin et al. 1993)—mood exerts its influence on behavior by providing information for the salient behavior-related judgment. Thus, mood should only have an impact on the judgment that is salient in a given situation. In most studies by Gendolla and colleagues, there were either extensive task difficulty instructions or pre-task manipulation checks that asked participants to reflect on task demand. Both situations render task difficulty salient and, correspondingly, it is not surprising that mood had an impact on task difficulty judgments that, in turn, influenced effort. In the present study, we avoided anything that could render task difficulty salient. In contrast, we tried to heighten the salience of the instrumentality of success by providing information about task reward and asking participants to rate the probability of drawing a black ball. Under these conditions, task instrumentality should be salient and influenced by mood. Consequently, it is not astonishing that we did not find the task difficulty mediation that Gendolla and colleagues have found.

It is of note that our data are incongruent with most theories postulating stable mood effects on behavior. For instance, the cognitive tuning hypothesis (Schwarz 1990) postulates that moods—if they have an impact on behavior—have the following effects: negative mood leads to high effort, positive mood results in low effort. The pattern that we have observed was reversed: positive mood resulted in higher effort than negative mood. Furthermore, most mood regulation theories would predict that winning a reward is more important in a negative mood than in a positive mood because of its potential for mood regulation (e.g., Gendolla 2000 for an overview). This implies that subjective success importance should be higher for individuals in a negative mood than for individuals in a positive mood. Correspondingly, individuals in a negative mood should invest more effort than individuals in a positive mood under conditions of unclear task difficulty—which was not the case in our study. Nevertheless, there may be contexts of unclear task difficulty in which a negative mood leads to more effort mobilization than a positive mood. We found that mood influenced the subjective probability of winning and resulted in corresponding behavioral effects. However, the probability appraisal was very salient in our experiment and participants were "forced" to reflect on this judgment. In a different context other determinants of subjective success importance might be more salient and guide effort mobilization. For instance, if a reward that is suitable to ameliorate the current mood is offered in a context that calls for mood regulation, success importance may be higher for individuals in a negative mood than for individuals in positive mood. Under these circumstances, a negative mood may lead to higher effort investment than a positive mood.

One might wonder how our results relate to the popular distinction between performance situations representing threat and performance situations representing challenge (e.g., Blascovich and Berry Mendes 2000; Blascovich and Tomaka 1996). Unfortunately, a comparison between our results and the predictions of Blascovich's biopsychosocial model of challenge and threat are difficult for a number of reasons. First, according to the latest version of the model, cardiac output—the volume of blood being pumped by the heart in a minute—and total peripheral resistance—the total resistance of the peripheral vasculature—are the cardiovascular parameters that distinguish challenge from threat. Under threat, both cardiac output and peripheral resistance should increase; under challenge cardiac output should increase but peripheral resistance should drop. The cardiovascular measures that we have assessed—heart rate and blood pressure—are of minor importance in Blascovich's model and are only used to indicate general task engagement (e.g., Berry Mendes et al. 2007; Blascovich et al. 2004). Second, according to the biopsychosocial model, challenge and threat are a function of the evaluation of resources and demand (determined by uncertainty, danger, and required effort). Given that we did not assess these parameters, we have no indicator if participants perceived the task as challenge or threat. Thus, we have assessed neither the subjective nor the physiological variables that are crucial for this model. Furthermore, the biopsychosocial model and our hypotheses apply to different kinds of psychological phenomena. We were concerned with effects on effort mobilization, whereas the biopsychosocial model of challenge and threat focuses on the qualitative differences between challenge and threat by postulating physiological indicators of these situations. Even if there is a certain overlap, a comparison of models that make predictions for different kind of phenomena is difficult. Given the above difficulties, we refrain from an integration of our results with the biopsychosocial model of challenge and threat. Future research that assesses the crucial variables of both models, may allow a comparison and an integration.

Even if our results supported our hypotheses, our study has some limitations. First, given that our sample included only a low number of men, generalizing our results to men might be preliminary. Future studies should test the mediation of mood effects on effort mobilization under conditions of unclear task difficulty using a more balanced sample. However, we know of no theoretical reason why our results should be limited to female participants. Second, the sample size was relatively low. With a higher sample size some of the statistical effects—for instance the relationship between mood and performance–might have been reliable. Especially, the mediation analysis would have profited from a higher sample size. Third, our physiological predications are based on Obrist's (1981) observation that task engagement is associated with beta-adrenergic impact on the heart. As explained by Wright (1996), SBP is a more valid indicator of myocardial beta-adrenergic impact than DBP or HR. However, SBP is not the best non-invasive indicator available. Since SBP is determined by both myocardial contractility and total peripheral resistance (e.g., Levick 2003), it can only reflect changes in myocardial beta-adrenergic activity if the changes in total peripheral resistance are negligible. Thus, future research should aim to test our predictions more precisely by considering more direct indicators of myocardial beta-adrenergic activity (e.g., pre-ejection period).

In summary, the present experiment demonstrates that moods can influence effort mobilization by means of a mood congruency effect on appraisals of the instrumentality of success: The subjective probability of winning a monetary reward after success mediated the effect of mood on effort mobilization. This suggests that moods do not only influence effort mobilization by their effect on demand appraisals. If the difficulty of a task is unclear, mood influences behavior-related judgments that refer to the importance of success and thereby determines effort intensity. In our study this lead to higher effort in positive mood than in a negative mood. Thus, mood may influence different kinds of behavior-related judgments, which in turn can have different effects on task engagement.

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