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Individual Differences in Action-State Orientation Moderate Task Difficulty Effects on Effort-Related Cardiac Response

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Impact Statement

Individual Differences in Action-State Orientation Moderate

Task Difficulty Effects on Effort-Related Cardiac Response

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Action-control theory predicts that individual differences in action-state orientation—an action-control capacity—moderate task difficulty effects on effort intensity. Our experiment found the first conclusive evidence for this idea. As predicted, action-oriented individuals showed stronger cardiac pre-ejection period reactivity in a difficult short-term memory task, while state-oriented participants did so when the task was easy. That is, action-state orientation moderates task difficulty effects on effort-related cardiac response.

Abstract

A quasi experiment (N = 100 university students) tested whether individual differences in action-state orientation moderate task difficulty effects on resource mobilization assessed as cardiovascular response. According to action control theory (Kuhl, 1994a), action-oriented individuals have higher self-regulation capacities in demanding situations than state-oriented persons. Action-orientated individuals should also self-generate positive affect in face of obstacles. Therefore, drawing on Wright's (1998) ability extension of motivational intensity theory (Brehm & Self, 1989) and research on affective influences on effort-related cardiovascular response (Gendolla, 2012), we expected that action-orientation should lead to stronger effort-related cardiovascular responses in a difficult task, while state-orientation should do so in an easy task. Reactivity of cardiac pre-ejection period (PEP) during performance on a short-term memory task corroborated this hypothesis. The present findings provide the first evidence of a link between action-state orientation and effort-related responses in the cardiovascular system.

Keywords: Action-state orientation, Effort, Pre-ejection period, Task difficulty, Cardiovascular reactivity

1. Introduction

Grounded in classic will psychology (Ach, 1935; Lewin, 1926), Kuhl's (1994a) action control theory posits that individuals differ in their abilities to form and maintain intentions and to execute goal-directed actions. This study tested if this has effects on effort-related responses in the cardiovascular system. Action-orientation refers to the capacity to enact an intention and to stay focused on and committed to one’s goals. By contrast, state-orientation indicates individuals who ruminate and have difficulties with initiating and maintaining goal-directed behavior. In other words, state-oriented individuals tend to inhibit the enactment of their intentions. As a consequence, action control theory holds that action-oriented individuals have higher self-regulation capacities—especially, volitional enactment, action shielding, and affect-regulation skills—in face of demanding challenges (Beckmann, 1994; Kazén & Kuhl, 2022; Koole, 2004; Koole et al., 2012; Kuhl & Koole, 2004). As shown by Koole et al. (2012), this has effects on self-regulation: Action-oriented individuals demonstrated more efficient self-regulation under demanding conditions. By contrast, self-regulation was impeded in face of difficulties in state-oriented individuals.

To date, most of the studies on the effects of action-state orientation and task demand have only used behavioral measures (e.g., Jostmann & Gieselmann, 2014; Jostmann & Koole, 2007; Kazén et al., 2008). A link between action-state orientation and effort—the mobilization of resources for action execution (Gendolla & Wright, 2009)—is frequently posited in that literature. But it remained empirically unclear if action-state orientation really moderates task-demand effects on physiological indicators of resource mobilization. The present study aimed at closing this gap.

1.1 Action-State Orientation, Ability, and Effort

Considering that action-state orientation refers to self-regulation *capacities*, drawing on Wright's (1998) ability extension of motivational intensity theory (Brehm & Self, 1989) permits clear predictions about how action-state orientation should influence effort. According to Wright (1998), both objective capacities and subjective ability beliefs moderate the effect of objective task difficulty on effort-related responses in the cardiovascular system. On each level of objective task difficulty, low ability individuals should evaluate subjective demand as higher than people with high ability. In other words, because of their lower self-regulation capacity, state-oriented individuals should evaluate any task as more difficult than action-oriented individuals. Resources are then mobilized according to the principles of motivational intensity theory (Brehm & Self, 1989): Effort rises proportionally with subjective demand as long as success is possible and the necessary resources are justified. Given that ability functions as a difficulty buffer, high ability individuals should thus mobilize high effort in face of objectively difficult challenges. This is because they experience those tasks as difficult but feasible, and for them the necessary high effort is justified. By contrast, low ability persons should disengage when task demand is objectively high. This occurs because they should experience higher subjective difficulty (as compared to high ability individuals). Consequently, they should disengage, unless the very high subjectively necessary effort is justified by very high success importance. However, if a task is objectively easy, this pattern is predicted to turn around. Here, low ability individuals should mobilize higher effort than high ability persons. This is because low ability results in high but feasible subjective demand when the task is objectively easy, while high ability leads to low subjective demand and thus low effort.

The predictions of Wright’s (1998) ability extension of motivational intensity theory have received ample empirical support (e.g., Mlynski et al., 2020; Nolte et al., 2008; Wright et al., 2012; Wright & Dill, 1993; Wright & Dismukes, 1995). The well documented ability effects on effort-related cardiovascular responses perfectly fit the predictions made by Koole et al. (2012) for action-state orientation effects on the behavioral level in easy and difficult challenges. However, beside self-regulation ability, also affect should play a role.

1.2 The Role of Affect

The differences in self-regulation capacities between action- and state-orientated individuals should originate in their socialization (e.g., Koole et al., 2006; Koole & Jostmann, 2004; Kuhl, 1982). If the early environment favors autonomy rather than external control, children should develop strong links between personal events and affective reactions. As a result, people differ in their intuitive affect regulation skills (see Koole & Jostmann, 2004; Kuhl, 2000, for a more detailed discussion). Consequently, when facing obstacles in the pursuit of their goals, action-oriented individuals (but not state-oriented ones) tend to generate positive affect themselves, which helps them to cope with difficulties and to attain their goals (e.g., Kazén & Kuhl, 2022).

Interestingly, there is converging evidence for the facilitating effect of both consciously experienced and implicit positive affect on effort-related cardiovascular responses from research on the Mood-Behavior-Model (Gendolla, 2000) and the Implicit-Affect-Primes-Effort (IAPE) model (Gendolla, 2012, 2015). In objectively difficult tasks, positive affect leads to stronger effort-related cardiovascular responses than negative affect (especially fear and sadness), while the opposite is true for objectively easy tasks (e.g., Gendolla & Krüsken, 2001, 2002; Lasauskaite Schüpbach et al., 2014; Silvestrini & Gendolla, 2012). This perfectly fits the predictions of Koole et al. (2012) about the interactive effect of action-state orientation and objective task difficulty on resource mobilization and is compatible with Wright's (1998) ability extension of motivational intensity theory (Brehm & Self, 1989).

1.3 Effort-Related Cardiovascular Response

To quantify effort, Wright (1996) has integrated motivational intensity theory (Brehm & Self, 1989) with Obrist's (1976, 1981) active coping approach. Accordingly, β-adrenergic sympathetic impact on the cardiovascular system—or in other words effort-related cardiovascular response—reacts proportionally to the level of experienced task demand as long as success is possible and justified. Noninvasively, β-adrenergic sympathetic impact is best measured as cardiac pre-ejection period (PEP)—a cardiac contractile force index assessed as the interval (in ms) between the beginning of left ventricular depolarization and the opening of the aortic valve (Berntson et al., 2004). PEP becomes shorter with increasing cardiac contractile force. Wright's integration permitted the identification of numerous moderator variables of objective task difficulty effects on effort (see Gendolla, Wright et al., 2012, 2019; Richter et al., 2016; Wright & Kirby, 2001, for reviews). The present study extended this research to the effects of individual differences in action-state orientation.

Several studies have also quantified effort in terms of performance-related reactivity of systolic blood pressure (SBP). This was done because SBP is systematically influenced by cardiac contractility through its impact on cardiac output (Gendolla & Richter, 2010; Wright & Kirby, 2001). Nonetheless, SBP, and to a higher degree diastolic blood pressure (DBP), also rely on peripheral vascular resistance, which is not systematically influenced by β-adrenergic sympathetic impact (Levick, 2010). Other studies have quantified effort also as changes in heart rate (HR) (e.g., Eubanks et al., 2002). However, HR is controlled by both sympathetic and parasympathetic impact and should only reflect resource mobilization when the sympathetic impact is stronger (Berntson et al., 1993). Thus, PEP is the most reliable noninvasive measure of effort among these cardiovascular activity indices (Kelsey, 2012; Richter et al., 2008). However, it should always be assessed together with HR and blood pressure to control for possible preload (ventricular filling) and afterload (arterial pressure) effects on PEP (Sherwood et al., 1990).

1.4 The Present Study

We tested the combined effect of objective task difficulty and individual differences in action-state orientation (Kuhl, 1994a) on effort-related cardiovascular response—especially PEP. Participants completed a memory task adapted from Bijleveld (2018), which was either objectively easy or difficult. We drew our hypothesis on two complementary approaches on self-regulation: (1) Our application of Wright's (1998) ability-extension of motivational intensity theory (Brehm & Self, 1989) to action-state orientation effects on effort. (2) The evidence for positive affect's systematic moderation of task difficulty effects on effort-related cardiovascular response (see Gendolla, 2012; Gendolla & Brinkmann, 2005). Consequently, we predicted a difficulty x action-state orientation interaction effect: In the difficult task condition, we expected that action-oriented individuals' PEP responses would be stronger than those of state-oriented persons. This pattern should be inverted in the easy task condition. Here, state-oriented individuals' PEP responses should be stronger than those of action-oriented persons. Finding support for our predictions would provide, to our knowledge, the first evidence that action-state orientation indeed moderates task difficulty effects on effort.

2. Method

2.1 Participants and Design

An a priori power analysis using G*-Power (Faul et al., 2009) for a multiple regression analysis (single regression coefficient, 3 predictors, medium effect size $f^2 = .15$, $\alpha = .05$ two-tailed, power .80) suggested a minimal sample size of $N = 55$ for the present study. To assure sufficient variance in the individual difference measures of action-state orientation and to prevent power loss due to possible technical problems or health issues of invited participants, we decided to recruit $N = 100$ participants from different Faculties of the University of Geneva (average age 24 years) who received 10 Swiss Francs (about 11 USD) for their voluntary participation. We asked recruited participants not to consume caffeine or eat heavy meals 2 hours before their experimental session. In a between persons design, participants were randomly assigned to the easy or difficult task condition. The gender distributions were balanced (easy task: 33 women, 17 men; difficult task: 30 women, 20 men). Two participants were excluded, because they exceeded 3 *SDs* from their group means of all cardiovascular measures—leaving a final sample of $N = 98$ for SBP, DBP, and performance data. Due to technical problems with the ICG and ECG signals for two other participants, the final sample size for the PEP and HR measures was $N = 96$.

2.2 The Action Control Scale (ACS-Fr)

To assess individual differences in action-state orientation, Kuhl (1994b) developed the Action Control Scale. As we recruited French speaking participants, we used a recently validated French version of the Action Control Scale—the ACS-Fr (Bouzidi & Gendolla, 2022). This questionnaire consists of 3 subscales assessing individual differences in different aspects of volition of Kuhl's (1994a) action control theory. The Preoccupation subscale comprises 10 items and both the Hesitation and the Volatility subscales comprise 7 items. All action-oriented answers are summed up so that subscale scores range from 0 to 7 (or 10, respectively). A higher score indicates that individuals are more action-oriented.

Each item of the ACS-Fr describes a situation of everyday life and respondents choose between two alternatives illustrating what they would do. In theory, as well as empirically supported, the Hesitation subscale—also called AOD for demand-related action-orientation in the literature—is the most relevant scale for assessing individual differences in action-state orientation in the context of demanding situations. The Hesitation subscale is usually administered to assess action-state orientation and predict individual differences in terms of coping abilities in high-demanding context (see Baumann et al., 2005; Kazén & Kuhl, 2022; Koole et al., 2012; Schlinkert & Koole, 2018). Therefore, we only used this subscale to assess the extent of participants' action-state orientation in the present study (Cronbach's α = .74, *M* = 2.74, *SD* = 2.14; see Table S1 in the Online Supplementary Material for further information and results concerning the other two ACS-Fr subscales).

2.3 Apparatus and Physiological Measurement

All cardiovascular measures were recorded and stored on computer disk during an 8-min habituation period and during 5 minutes of task performance. We assessed HR (in beats per minute [bpm]) and PEP (in milliseconds [ms]) noninvasively with a Cardioscreen 1000 hemodynamic monitoring-system (medis, Ilmenau, Germany) to continuously measure electrocardiogram (ECG) and impedance cardiogram (ICG) signals. We placed four pairs of spot electrodes (Ag/AgCl, medis, Ilmenau, Germany) on the right/left side of the base of participants' neck and on the right/left middle axillary line at the height of the xiphoid. Signals were amplified, digitalized (with a sampling rate of 1000 Hz) and examined offline with BlueBox 2.V1.22 software (Richter, 2010) using a 50 Hz low pass filter. We first identified ECG R-peaks applying a threshold peak-detection algorithm, which was visually confirmed. Then, the first derivative of the change in thoracic impedance was calculated and the resulting dZ/dt-signal was ensemble averaged in 1-min intervals (Kelsey et al., 1998; Kelsey & Guethlein, 1990). PEP was determined as the interval between R onset and B-point (Berntson et al., 2004). Following Lozano et al. (2007), the B-point was located based on the RZ interval of valid cardiac cycles, visually inspected, and if necessary manually corrected as recommended by Sherwood et al. (1990). HR was determined based on IBIs assessed with the same software.

In addition, we assessed SBP and DBP (in millimeters of mercury [mmHg]) with a Dinamap ProCare monitor (GE Healthcare, Milwaukee, WI) that uses oscillometry. A blood pressure cuff placed over the brachial artery above the elbow of participant's non-dominant arm automatically inflated in 1-min intervals and stored the assessed blood pressure values.

2.4 Procedure

This study had been approved by the local ethical committee and followed the ethical guidelines of the University of Geneva. The study was announced by flyers in the university hall. Interested students contacted the authors and were first asked to complete an online version of the ACS-Fr questionnaire (Bouzidi & Gendolla, 2022) some days before their experimental session. The main study's experimental protocol was computerized (E-Prime 2, Psychology Software Tools, Pittsburgh, PA) and run in individual sessions of 30 minutes. Participants were greeted by the experimenter (who was hired and unaware of both the hypotheses and the experimental conditions), seated in a comfortable chair in front of a computer, read and signed the consent form, and were equipped with the physiological sensors. To control for conscious moods, which can systematically influence effort-related cardiovascular responses (see Gendolla & Brinkmann, 2005; Gendolla, Brinkmann et al., 2012, for reviews), participants first answered 4 items regarding their actual affective state ("Right now, I'm feeling…"). Specifically, participants rated two positive affect (happy, joyful) and two negative affect items (downcast, sad) on continuous scales (0—*not at all* to 100—*very much*) by moving the cursor. To prevent suspicion, the affect measures were introduced as standard assessment because people enter the laboratory in different feeling states. The mood measure was followed by a cardiovascular baseline assessment period of 8 minutes. Participants were instructed to find a comfortable seating position and to relax and watched a hedonically neutral documentary video about Portugal.

Next, we administered a 5-min short-term memory task adapted from Bijleveld (2018). Participants were instructed to respond correctly and as fast as possible to 30 trials. Each trial began with a fixation cross (1000 ms) followed by a first string of 7 digits that were presented for either 4000 ms in the easy condition vs. 1000 ms in the difficult condition. Next, participants saw a string of 7 distractor letters (2000 ms), followed by a second string of 7 digits which remained on the screen until the participant responded within 2000 ms. Participants indicated whether the second string was identical with the first one by pressing respective response keys with two fingers of their choice of their dominant hand. The message "response entered" was displayed after a response while "please answer more quickly" appeared if participants did not answer within the 2000 ms response time window. These messages where displayed for 2500 ms (easy condition) or for 5500 ms (difficult condition) minus participant's reaction time, so that all trials in both the easy and difficult conditions had the same length and all participants worked for the same time. The inter-trial interval randomly varied from 500 to 1000 ms. To avoid possible feedback-related affective reactions (e.g., Kreibig et al., 2012) that could be confounded with the difficulty manipulation, no correctness feedback was given during the main task.

Before the main task, participants completed 6 practice trials with correctness feedback. Moreover, they rated two items related to their commitment/willingness to do the task ("How much do you want to do well on the cognitive task?"; "How unhappy would you be if you performed poorly on the cognitive task?"; 0—*not at all* to 100—*very much*), subjective task difficulty (continuous scale from 0—*very easy* to 100—*very difficult*), and the same affect items as at the beginning of the procedure on continuous scales using a slider (0—*not at all* to 100—*very much*). Then participants answered biographical questions (age, sex, etc.) and indicated possible medication and their cardiovascular health status. Finally, participants were thanked, debriefed, and received their remuneration.

2.5 Statistical Analysis

We tested our hypothesis of an action-state-orientation x difficulty interaction effect on cardiovascular reactivity with hierarchical regression analyses. Predictor variables were *z*-scores of the ACS-Fr Hesitation scale, the dummy-coded task difficulty variable (-1, +1), and their interaction. The self-report and performance measures were regressed to the same variables (though we run non-parametric regressions analyses for response accuracy and reaction times to account for their distributions and extreme values). Before testing the predicted effect on cardiovascular reactivity, we regressed the cardiovascular baseline scores to the same variables as the reactivity scores to test for potential unexpected a priori differences between the later difficulty conditions and possible links between action-state orientation and cardiovascular baseline activity.

In addition, we explored for interested readers gender differences in cardiovascular baseline and reactivity scores with independent samples *t*-tests. We did not include gender as a factor in our main analyses because we had no gender-related hypotheses and there were more women than men in our sample.

3. Results

3.1 Cardiovascular Baselines

Given that cardiovascular activity usually declines during rest, we had decided a priori to constitute the cardiovascular baseline scores of PEP, SBP, DBP, and HR by averaging values of the last three minutes of the habituation period. This also complied with Shapiro et al.'s (1996) recommendation to average at least three blood pressure measures. The internal consistency was high for all parameters (Cronbach's αs > .95). Means and standards errors appear in Table 1. Exploratory regression analyses of baseline scores revealed no significant effects (*p*s > .057).

For readers interested in gender differences in cardiovascular activity, we additionally compared the baseline values of women and men with *t*-tests. There was a significant gender difference in the SBP baseline scores, $t(96) = 3.96$, $p < .001$, $\eta^2 = .14$, reflecting higher values for men ($M = 108.90$, $SE = 1.64$) than for women ($M = 100.40$, $SE = 1.32$), which is usual (e.g., Martins et al., 2001). No further gender differences in cardiovascular baseline scores were significant (*t*s < 1.31, *p*s > .195).

3.2 Cardiovascular Reactivity

Following Llabre et al. (1991), we calculated reactivity scores for each cardiovascular index by subtracting participants' baseline values from the 1-min scores of cardiovascular activity during task performance, which were averaged (Cronbach's αs > .89). The zero-order correlations between the cardiovascular reactivity scores, task difficulty, and action-state orientation are reported in Table 2. Further exploratory correlation analyses did not reveal any significant associations between the cardiovascular baseline and reactivity scores (*p*s > .140).

As for the cardiovascular baseline values, we additionally compared the reactivity scores of women and men with *t*-tests. These analyses found gender differences in SBP and DBP reactivity (*t*s > 2.24, *p*s < .027, $\eta s^2 > .05$). Men's blood pressure reactivity (SBP: $M = 6.91$, $SE = 1.00$; DBP: $M = 3.85$, $SE = 0.72$) was generally stronger than that of women (SBP: $M = 4.47$, $SE = 0.59$; DBP: $M = 2.16$, $SE = 0.35$). Therefore, we included gender as covariate entered in the first step in the hierarchical regression analyses of SBP and DBP reactivity.

PEP Reactivity. As presented in Table 3, the linear regression analysis revealed the predicted significant action-state orientation x difficulty interaction effect in absence of significant main effects. The PEP responses that were predicted by the regression equation are depicted in Figure 1. PEP reactivity described the expected crossover interaction pattern. In the difficult task condition, PEP responses became stronger with increasing action-orientation, reflecting intensifying effort, while the opposite was the case in the easy condition. That is, as predicted, action-oriented individuals mobilized higher resources in the difficult task, while state-oriented individuals did so in the easy task.

SBP, DBP, and HR Reactivity. We found no significant effects on the other cardiovascular reactivity measures (*p*s > .070). The predicted means and standard errors of these variables are presented in Table 4 and detailed results of the linear regression analyses are presented in Tables S2 to S4 in the Online Supplementary Material.

3.3 Task Performance

Non-parametric linear regressions[1] with the Hesitation scale z-scores, task difficulty, and their interaction as predictors revealed a difficulty main effect for both response accuracy—β = -0.46, $t(94) = -5.11$, $p < .001$, $f^2 = .28$—and reaction times—β = -0.32, $t(94) = -3.33$, $p = .001$, $f^2 = .12$. Participants made more correct responses in the easy (*M* = 84%, *SE* = 1) than in the difficult condition (*M* = 68%, *SE* = 3) and they responded faster in the difficult (*M* = 1141 ms, *SE* = 32) than the easy condition (*M* = 1276 ms, *SE* = 25).

3.4 Affect, Commitment, and Task Difficulty Ratings

Regression analyses found no significant effects on the commitment ratings (*p*s > .052).[2] However, there was a difficulty manipulation main effect on participants' subjective difficulty ratings—β = -0.34, $t(94) = -3.58$, $p < .001$, $f^2 = .14$. Participants rated subjective task demand in the easy condition as being lower (*M* = 60.30, *SE* = 2.30) than in the difficult condition (*M* = 49.98, *SE* = 1.74). Together with the difficulty effects on response accuracy, this indicates a successful task difficulty manipulation.

To assess participants' affective states, we calculated mood sum scores for the pre-task (average *M* = 289, *SE* = 7) and post-task (average *M* = 272, *SE* = 7) measures (negative items were reverse-coded; Cronbach's αs > .85). Regression analyses of baseline affect and affect change (with baseline affect as covariate) revealed only a baseline affect main effect on affect change—$\beta = -0.41$, $t(93) = -4.31$, $p < .001$, $f^2 = .20$. This effect occurred because the higher participants scored in the pre-task measure, the lower they scored on the post-task measure.[3] No other effects were significant (*p*s > .254).

4. Discussion

To our knowledge, this study found the first evidence that individual differences in action-state orientation (Kuhl, 1994a) moderate task difficulty's effect on effort-related response in the cardiovascular system. Given that action-state orientation has been conceptualized as being linked to self-regulation capacities—i.e. volitional action shielding and affect-regulation skills (e.g., Kazén & Kuhl, 2022; Koole et al., 2012; Kuhl & Koole, 2004) —we drew on Wright's (1998) ability-extension of motivational intensity theory (Brehm & Self, 1989) and on evidence for the impact of affect on effort from research on the Mood-Behavior-Model (Gendolla, 2000) and the Implicit-Affect-Primes-Effort model (Gendolla, 2012, 2015). As predicted, action-state orientation moderated the effect of task difficulty on cardiac PEP—our main dependent variable assessing effort (Kelsey, 2012; Richter et al., 2008; Wright, 1996). More specifically, we found a significant crossover interaction effect between action-state orientation and task difficulty in absence of significant main effects. Our PEP data show that higher action-orientation led to higher effort when the task was objectively difficult. By contrast, state-oriented individuals tended to disengage in the difficult condition. The opposite pattern emerged in the easy condition. There, effort increased with state-orientation. Action-oriented individuals only mobilized low effort when the task was easy.

In a larger perspective on Kuhl's (1994a) action control theory, our findings advocate for higher volitional capacities of action-oriented individuals—as it has been posited in the literature (Beckmann, 1994; Koole, 2004; Kuhl, 1994a; Kuhl & Koole, 2004). Multiple studies have supported the action control theory idea that action-oriented individuals possess better coping capacities than state-oriented persons when facing difficult tasks (e.g., Beckmann, 1994; Kazén & Kuhl, 2022; Koole, 2004; Koole et al., 2012; Schlinkert & Koole, 2018). Nonetheless, to our knowledge, evidence for action-state orientation effects on objective physiological indicators of effort has been lacking so far. Our present study has closed this gap.

Regarding our self-report mood measures, it is of note that we found no evidence for a significant link between participants' conscious affect and effort-related cardiovascular responses in the present study. However, we cannot exclude that action-oriented individuals self-generated *implicit* positive affect (Kazén & Kuhl, 2022; Kuhl, 2000). In this case, our results would be completely concordant with predictions made by the Implicit-Affect-Primes-Effort model (Gendolla, 2012, 2015) as well as with the assumption that action-oriented individuals possess higher affect-regulation skills (Koole et al., 2012). Nonetheless, at this point our findings do not permit the conclusion that it is indeed *intuitive affect regulation* that is at the origin of the differing self-regulation efficiency of action- and state-oriented individuals (Greenberg et al., 2004).

One could also be tempted to interpret our results in light of individual differences in behavioral inhibition/activation systems (BIS/BAS systems) sensitivity (Carver & White, 1994), although we do not think that this is warranted. First, BIS/BAS sensitivity refers to individuals' reactivity to punishment and reward, but there were no explicit punishments or rewards in the present study. Our study procedure prompted individuals to self-regulate, rather than reacting to punishment or reward. Thus, we do not regard BIS/BAS sensitivity as a relevant variable in our procedure or as a possible alternative explanation for the observed PEP reactivity effect. Moreover, other studies found that action-state orientation explains a unique part of individual differences variance beyond BIS/BAS sensitivity (e.g., Bjørnebekk, 2007; Düsing et al., 2016; Haehl et al., 2021). However, we cannot exclude that BIS/BAS sensitivity accounted for a part of the effort variance in our study. Ultimately, this is an empirical question that can only be addressed in future research.

Regarding our cardiovascular measures, we found the predicted effort effects on PEP reactivity, but not on responses of SBP, DBP, and HR. This is not surprising and fits with the view that PEP is the most sensitive noninvasively assessable index of β-adrenergic sympathetic activity—and thus effort (Kelsey, 2012; Richter et al., 2008; Wright, 1996). Most relevant, our present PEP effects cannot be attributed to cardiac preload or vascular afterload effects. PEP reactivity was not accompanied by decreases in HR or blood pressure, meaning that we can ascribe our PEP effects to β-adrenergic sympathetic activity (Sherwood et al., 1990).

Our performance measures only revealed difficulty main effects, but no interaction with action-state orientation. Independently of their action-state orientation, participants were in general more accurate in the easy than in the difficult task condition—speaking for an effective task difficulty manipulation, which was also evident in participants' subjective task difficulty ratings. Maybe more surprisingly, the reaction times in the administered short-term memory task showed that participants in the difficult condition responded faster than those in the easy condition. We believe that this result occurred because of the task settings—the stimulus presentation time was shorter in the difficult condition than in the easy one. In other words, the faster stimulus presentation rhythm in the difficult condition could have prompted participants to respond more quickly. That would be a case of procedural priming.

One could also interpret the performance results for state-oriented participants as a sign for higher efficiency—i.e., even though state-oriented individuals physiologically disengaged in the difficult condition, they performed as good as action-oriented participants.

Nonetheless, we do believe that such an interpretation is not warranted. The present study was designed to assess physiological indicators of effort intensity and thus administered a between-persons design. Performance effects were out of our scope, and thus, should be interpreted with caution. Studies designed to assess reliable performance effects usually run within-persons designs and ask participants to perform many practice trials to account for individual differences in response speed and accuracy. Participants in cognitive performance studies usually also respond to far more task trials in repeated blocks than in our study. With the relatively low number of task trials and the between-persons design, the performance measures—in contrast to the cardiovascular measures—cannot be regarded as highly reliable. The reported PEP (and HR) effects are based on the integration of about 350-450 cardiac cycles, while the performance effects are based on only 30 trials. For these reasons, we believe that interpreting performance results would be venturous and could lead to mis- or over-interpretations.

In a more general perspective, the differing effects on PEP reactivity and the performance measures also illustrate the conceptual differences between effort and performance. According to Gendolla and Wright (2009), "*it is important to bear in mind that achievement is an outcome associated with effort, not effort itself*". While effort refers to the mobilization of resources—a behavioral input variable—performance describes the outcome of behavior and is therefore influenced by a variety of variables, such as persistence, capacity, and strategy use (Locke & Latham, 1990). That is, performance can be dissociated from effort intensity (see Gendolla & Richter, 2010, for a more detailed discussion).

4.1 Conclusion

We interpret the present results as the first evidence for the moderating effect of individual differences in action-state orientation of task difficulty effects on effort-related response in the cardiovascular system. While action-oriented persons mobilized high resources under this condition, state-oriented individuals tended to disengage.

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Footnotes

[1] We analyzed task performance with regression analyses with non-parametric permutation tests (see Kherad-Pajouh & Renaud, 2015) because of four outliers (1 for RTs, 3 for response accuracy). Given that task performance was not in focus of our study, we did not want to further reduce our sample size by eliminating the respective participants. Unlike casual linear regression analysis, non-parametric permutation tests are robust (i.e., not subject to an inflated type I error) regarding the potential impact of outliers (see Anderson & Robinson, 2001). Specifically, we applied the *freedman_lane* method (Freedman & Lane, 1983) for non-parametric regression analyses of the *permuco* package in R (Frossard & Renaud, 2018).

[2] Cronbach's α = .37, we thus analyzed the two items separately. There was only a marginal main effect of the ACS-Fr hesitation subscale on the second item ("How unhappy would you be if you performed poorly on the cognitive task?")—$\beta = -0.20$, $t(94) = -1.97$, $p = .052$, $f^2 = .04$, and no other significant effects (ps > .094).

[3] It is of note that we also analyzed PEP reactivity with affect as covariate (pre-task affect and affect change separately). These covariates were not significant (ps > .46). Of main interest, the action-state orientation x task difficulty interaction remained significant in both analyses—$\beta = -0.21$, $t(91) = -2.05$, $p = .044$, $f^2 = .05$ and $\beta = -0.22$, $t(91) = -2.10$, $p = .039$, $f^2 = .05$, respectively.

Table 1

Means and standard errors (in parentheses) of the baseline of the cardiovascular parameters in the easy and difficult task conditions.

	Easy	*Difficult*
PEP	101.29 (1.52)	98.45 (1.48)
SBP	102.07 (1.51)	104.81 (1.60)
DBP	57.61 (0.92)	57.18 (0.96)
HR	73.51 (1.39)	73.33 (1.34)

Note. PEP = pre-ejection period (in ms), SBP = systolic blood pressure (in mmHg), DBP = diastolic blood pressure (in mmHg), HR = heart rate (in bpm), State = score at the Hesitation scale equal to 1, Action = score at the Hesitation scale equal to 6.

Table 2

Correlation matrix of task difficulty, Hesitation subscale and cardiovascular reactivity measures.

Variable	*M* (*SD*)	1	2	3	4	5
1. Task Difficulty	-					
2. ACS-Fr Hesitation	2.74 (2.12)	.02				
3. PEP reactivity	-2.20 (4.31)	.15	.07			
4. SBP reactivity	5.23 (5.21)	-.19	.04	-.54**		
5. DBP reactivity	2.73 (3.46)	-.06	.06	-.40**	.67**	
6. HR reactivity	3.22 (3.85)	-.12	.12	-.22*	.33**	.40**

Note. N = 98.
* $p < .05$. ** $p < .01$.

Table 3

Results of the linear regression analysis of PEP reactivity.

Predictor	*B* (*SE*)	β	*SE* (β)	95% CI	*p*
Difficulty	0.64 (0.43)	0.15	0.10	[-0.05 ; 0.35]	.142
ACS-Fr Hesitation	0.17 (0.44)	0.04	0.10	[-0.16 ; 0.24]	.705
Interaction	-0.91 (0.44)	-0.21	0.10	[-0.41 ; -0.01]	.042
$R^2/\Delta R^2$			.070/.043		

Note. β = standardized coefficient, CI = confidence interval, R^2 = variance explained by the full model, ΔR^2 = variance explained by the interaction term. 92 degrees of freedom.

Table 4

Means and standard errors (in parentheses) of predicted systolic blood pressure, diastolic blood pressure, and heart rate reactivity during task performance as function of task difficulty and individuals' action-state orientation.

	Easy		*Difficult*	
	State-oriented	*Action-oriented*	*State-oriented*	*Action-oriented*
SBP	5.98 (0.94)	6.64 (1.33)	4.03 (1.01)	5.27 (1.43)
DBP	2.63 (0.62)	3.47 (0.88)	2.52 (0.68)	2.78 (0.95)
HR	2.81 (0.67)	5.21 (0.95)	2.88 (0.73)	2.57 (1.03)

Note. SBP = systolic blood pressure (in mmHg), DBP = diastolic blood pressure (in mmHg), HR = heart rate (in bpm), State-oriented = -1 *SD* at the Hesitation scale, Action-oriented = +1 *SD* at the Hesitation scale.

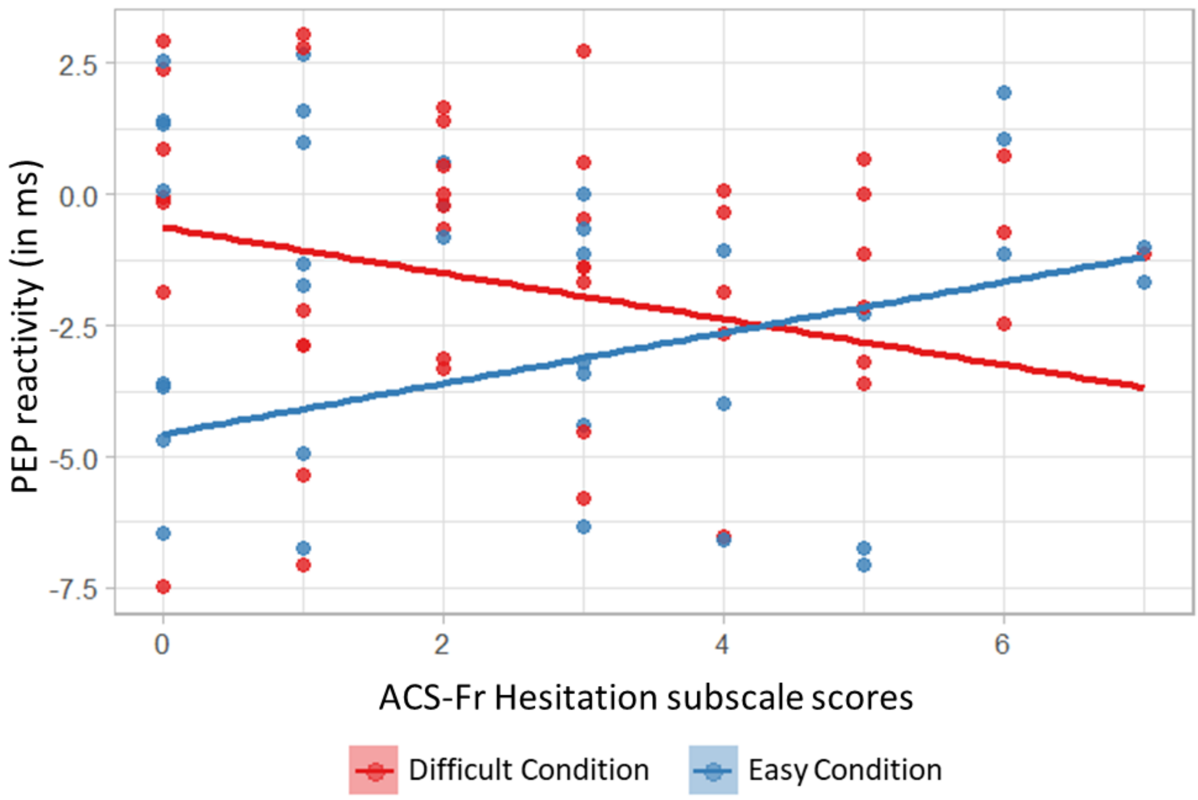

Figure 1. PEP reactivity as a function of task difficulty (easy vs. difficult) and action-state orientation (scores at the ACS-Fr Hesitation subscale). More negative PEP reactivity reflects higher effort.