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Mazeres, F, Brinkmann, K and Richter, M (2021) Explicit achievement motive strength determines effort-related myocardial beta-adrenergic activity if task difficulty is unclear but not if task difficulty is clear. International Journal of Psychophysiology. ISSN 0167-8760

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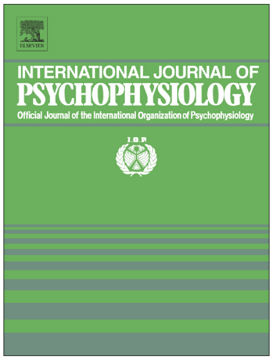

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PII: S0167-8760(21)00872-2

DOI: https://doi.org/10.1016/j.ijpsycho.2021.08.004

Reference: INTPSY 11964

To appear in: *International Journal of Psychophysiology*

Received date: 2 March 2021

Revised date: 24 August 2021

Accepted date: 24 August 2021

Please cite this article as: F. Mazeres, K. Brinkmann and M. Richter, Explicit achievement motive strength determines effort-related myocardial beta-adrenergic activity if task difficulty is unclear but not if task difficulty is clear, *International Journal of Psychophysiology* (2018), https://doi.org/10.1016/j.ijpsycho.2021.08.004

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Explicit Achievement Motive Strength Determines Effort-related Myocardial Beta-adrenergic Activity if Task Difficulty is Unclear but not if Task Difficulty is Clear

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Abstract

Work on physiological and other behavioral correlates of motives often assumes that motives exert a direct effect on behavior once activated. Motivational intensity theory, however, suggests that this does not always apply. In the context of task engagement, motive strength should exert a direct effect on myocardial beta-adrenergic activity if task difficulty is unclear, but not if task difficulty is known. The presented study tested this prediction for the impact of the explicit achievement motive on myocardial beta-adrenergic activity—assessed as pre-ejection period (PEP) reactivity during task performance. Seventy-eight participants performed one of two versions of a mental arithmetic task. After having completed the achievement motive scale of the Personality Research Form, participants were either informed about the difficulty of the task or not before working on it. Participants' PEP reactivity during task performance provided evidence for the predicted moderating impact of clarity of task difficulty: PEP reactivity increased with increasing achievement motive strength if task difficulty was unclear, but not if it was clear. These findings demonstrate that the explicit achievement motive impact on myocardial beta-adrenergic activity is moderated by clarity of task difficulty and suggest that motive strength does not always translate into direct effects on physiology and behavior.

Keywords: explicit achievement motive; clarity of task difficulty; myocardial sympathetic activity; effort; motivational intensity theory;

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1. Introduction

Empirical research on motives—dispositions to pursue certain types of incentives (McClelland, 1987)—has examined various physiological correlates of motives. For instance, Stanton and colleagues (Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007) reported positive relationships between women's implicit power motive strength and salivary estradiol levels. Similarly, Capa et al. (2008) demonstrated that the magnitude of the difference between the motive to achieve success and the motive to avoid failure predicted mid-frequency heart-rate variability changes in a visual memory search task. Other examples are Dufner et al. (2015) presenting positive correlations between affiliation motive strength and zygomaticus and corrugator muscle activity, Beh (1990) showing that a strong explicit achievement motive resulted in increased heart rate responses in vigilance tasks, and Quirin et al. (2013) reporting associations between power and affiliation motive strength and left prefrontal cortex and right putamen and pallidum activity. The aim of the present study was to contribute to this literature by examining the impact of the explicit achievement motive—the conscious disposition to experience meeting and surpassing standards of excellence as rewarding and correspondingly to seek to attain such standards (McClelland, 1987)—on effort-related myocardial sympathetic activity in the context of engagement in instrumental tasks.

1.1 Effort and Myocardial Sympathetic Activity

Given that active engagement and effort investment in tasks that are instrumental for goal attainment are characterized by increased myocardial sympathetic activity (Light, 1981; Obrist, 1981; Wright, 1996), research frequently quantified myocardial sympathetic activity to test effort-related predictions. One example is the work on motivational intensity theory (Brehm & Self, 1989; Richter, 2013; Wright, 1996, 2008). Motivational intensity theory suggests that task difficulty and success importance are the main determinants of effort investment in instrumental tasks. Moreover, it predicts that the relative impact of these two factors varies as a function of type of task (fixed vs.

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unfixed difficulty) and clarity of task difficulty (clear vs. unclear). First, if task difficulty is fixed and clear (i.e., if there is a performance standard that determines whether a task counts as success and if this performance standard is known to the individual performing the task), difficulty should be the main determinant of effort. Success importance should only exert an indirect impact by setting the maximum effort that one is willing to invest in the task. Effort should be a direct function of the difficulty of the task—the higher the difficulty, the higher the effort—but only if task success is possible and if the required effort does not exceed the amount of effort that is justified by success importance. If task success is impossible or the required effort not justified, no effort should be invested. Second, if task difficulty is either unclear (i.e., if no information about task demand is available to the individual performing the task) or unfixed (i.e., if the individual can freely choose amongst multiple performance standards), success importance should be the main determinant of effort: the higher the success importance, the higher the effort.

Many studies have tested these effort-related predictions using sympathetic-driven cardiovascular measures (mainly systolic blood pressure and pre-ejection period; Gendolla et al., 2019; Richter et al., 2016). For instance, Richter et al. (2008) observed that myocardial sympathetic activity—assessed as pre-ejection period reactivity—increased with increasing difficulty of a memory task but was low if the task was impossible. Silvia and colleagues (Silvia et al., 2010; Silvia et al., 2013) showed that variations in success importance caused by different levels of self-awareness did not result in systolic blood pressure response differences if tasks were easy or impossible but led to differences if tasks were moderately difficult. Individuals with low self-awareness disengaged from moderately difficult tasks whereas individuals with high self-awareness invested high effort and had high systolic blood pressure reactivity. Harper et al. (2018) demonstrated that differences in reward value—a manipulation of success importance—directly affected myocardial sympathetic activity if the difficulty of a task was not fixed. Participants in their study had a shorter pre-ejection period if they could earn 5 cents for each correct response in a parity task than if they could earn 1 cent per

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correct response. Richter and Gendolla (2009a) showed the same effect of a reward-related success importance manipulation in a delayed-matching-to-sample task with unclear task difficulty.

1.2 Motive Impact on Effort-related Sympathetic Myocardial Activity

Motivational intensity theory has already been used to examine the impact of motives on effort-related myocardial sympathetic activity. Brunstein and Schmitt (2010) discussed a study that addressed the impact of the implicit achievement motive on systolic blood pressure response during a memory task. They observed that a stronger achievement motive only led to a stronger blood pressure response if task difficulty was moderate. If task difficulty was low or high, systolic blood pressure response was weak and did not differ as a function of motive strength. The most recent evidence comes from a study by Mazeres et al. (2019) who examined the impact of the implicit achievement motive on myocardial sympathetic activity in a mental arithmetic task with two fixed difficulty levels. They found that pre-ejection period, systolic blood pressure, and diastolic blood pressures responses were low and did not differ as a function of achievement motive strength if the task was easy. However, at high task difficulty, participants with a strong achievement motive showed stronger cardiovascular responses than participants with a weak achievement motive. There are thus already two studies that examined the impact of achievement motive strength on myocardial sympathetic responses. However, both studies focused on the implicit achievement motive and tasks with fixed and clear difficulty. The aim of the present study was to extend this perspective to the explicit achievement motive and to myocardial sympathetic activity in tasks with an unclear difficulty standard.

Both the explicit and the implicit achievement motive refer to the striving to attain standards of excellence (McClelland, 1987) but differ in regards to the incentives to which they respond (i.e., the situations that promise motive satisfaction), the types of behavior that they predict, and how they are measured (Brunstein & Hoyer, 2002; Brunstein & Maier, 2005; Brunstein & Schmitt, 2010; Koestner et al., 1991; Spangler, 1992). The implicit achievement motive is activated and exerts an impact on behavior in situations where the demonstration of excellence is inherent to

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the activity, whereas the explicit achievement motive influences behavior in contexts where extrinsic, normative standards of excellence are salient. The implicit motive influences non-declarative, spontaneous behavior whereas the explicit motive exerts an impact on deliberate, respondent behavior. The explicit achievement motive refers to an individual's perception of her/his motives and can thus be accessed using self-reports. The implicit achievement motive, however, refers to the unconscious disposition to strive for excellence and can only be assessed using projective tests.

These differences between the explicit and implicit achievement motive should, however, not affect how the achievement motive influences effort-related myocardial sympathetic responses. Given that both subclasses of the achievement motive refer to the importance of attaining standards of excellence, they should both affect success importance. Being successful in a task that promises motive satisfaction should be more important for an individual with a strong (explicit or implicit) achievement motive than for an individual with a weak achievement motive. Consequently, achievement motive strength should exert its impact on myocardial sympathetic activity in the context of engagement in instrumental tasks like any other variable that affects success importance: 1) If task difficulty is clear and fixed, achievement motive strength should determine the maximum effort that is justified for a task but not exert a direct impact on effort-related myocardial sympathetic activity. 2) If task difficulty is unclear or unfixed, achievement motive strength should directly determine effort-related myocardial sympathetic activity.

The presented study tested this postulated moderation of the achievement motive impact on myocardial sympathetic activity for the explicit achievement motive. We expected participants' explicit achievement motive strength to differently affect their myocardial sympathetic activity in a mental arithmetic task depending on the clarity of task difficulty: If participants had to perform an easy arithmetic task and were well-aware that the task was easy, we expected participants' explicit achievement motive strength not to influence their myocardial sympathetic activity—operationalized as pre-ejection period reactivity. However, if participants were asked to perform the

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same type of arithmetic task without having received any specific information about the difficulty of the task, we expected pre-ejection period reactivity to increase as a function of participants' explicit achievement motive strength.

2. Methods

2.1 Participants and Design

Seventy-eight students (mean age = 23.72 years, *SD* = 4.46, 46 women) of the University of Geneva participated in the study for either course credit or 15 Swiss francs (about 15 USD).[1] They performed one of two versions of a mental arithmetic task varying in clarity of task difficulty (unclear vs. clear). Allocation to the clarity-of-task-difficulty conditions was random.

2.2 Measures and Materials

2.2.1 Personality Research Form

The explicit achievement motive was assessed with the French version of the achievement scale of the Personality Research Form (PRF; Jackson, 1984)—a questionnaire that is frequently used to assess explicit motives (e.g., Gröpel et al., 2016). The PRF achievement scale is composed of 16 items measuring preferences for difficult problems and hard, persistent work (for instance, "I enjoy difficult work" and "I often set goals that are difficult to reach"). For each item, participants had to indicate whether the statement applied to themselves using a dichotomous scale (“true” / “false”). Participants' achievement motive scores were computed by adding up all individual item scores (ω_t = .67) and ranged from 2 to 15 with a mean score of 9.36 (*SD* = 3.03). The mean condition scores were 9.05 (*SD* = 3.22) in the unclear-difficulty condition and 9.65 (*SD* = 2.85) in the clear-difficulty condition.

2.2.2 Cardiovascular Measures

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[1] Sample size was determined in an a priori power analysis using G*Power (Faul et al., 2007; alpha = .05, power = .80 for detecting the interaction between achievement motive and difficulty condition in a regression). The expected effect size of *f* = .37 was based on Mazeres et al.'s (2019) results. We recruited more participants than the required 60 to be able to compensate for potential poor ECG/ICG quality. There were 25 women and 15 men in the clear-difficulty condition and 21 women and 17 men in the unclear-difficulty condition.

Pre-ejection period (PEP, in ms), systolic blood pressure (SBP, in mmHg), diastolic blood pressure (DBP, in mmHg), and heart rate (HR, in bpm) were assessed during two periods: baseline period and task performance. PEP constituted our primary variable given that it is the best non-invasive indicator of myocardial sympathetic activity that is available (Sherwood et al., 1990). SBP was assessed to enable comparisons with preceding research on motivational intensity theory that strongly relied on SBP. DBP and HR were used to verify that PEP responses reflected changes in myocardial sympathetic activity and not pre- or afterload effects (Obrist, 1981; Obrist et al., 1987; Sherwood et al., 1990). To collect the four cardiovascular measures, we used a CardioScreen 1000 impedance cardiograph (medis, Illmenau, Germany) and a Dinamap Procare blood pressure monitor (GE Medical Systems, Milwaukee, WI). The blood pressure monitor assessed SBP and DBP in one-minute intervals using the oscillometric method and a blood pressure cuff placed over the brachial artery above the elbow of the participant's nondominant arm. The impedance cardiograph collected impedance cardiograph (ICG) and electrocardiograph (ECG) signals for the quantification of PEP and HR with a sampling rate of 1000 Hz. The impedance cardiograph electrodes were placed on the right and left sides of the base of the participant's neck and on the right and left middle axillary lines at the level of the xiphoid.

2.2.3 Mental Arithmetic Task

All participants worked on a mental arithmetic task similar to the tasks used by LaGory et al. (2011) and Mazeres et al. (2019). Each task consisted of 10 trials, and each trial started with a fixation cross that was presented for 500 ms and followed by the presentation of several digits that participants had to mentally add up. The digits were presented one after another on the screen for 600 ms, separated by blank screens. The duration of the presentation of the blank screens varied between conditions and trials to keep the total trial duration constant. After the presentation of the last digit of a series, participants had eight seconds to enter the total. If participants entered an incorrect number, a beep informed them that the response was not correct, and they could enter a new number. After eight seconds or after entering a correct response, a final feedback was

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presented that informed participants whether their response had been correct or not. The duration of the presentation of the feedback was 10 seconds minus the time that it took participants to enter the correct response. In the case of a participant not entering the correct response during the eight-second response window the feedback was thus presented for two seconds. The duration of a single trial was 40.50 seconds, and the total task duration was six minutes and 40 seconds.

In the clear-difficulty condition, each digit series comprised six single digits and the digits were 1s or 2s. The duration of the blank screen between the presentation of two consecutive digits was 4400 ms. In the unclear-difficulty condition, the digits series included single digits from 1 to 9. Moreover, the ten trials included one series of six digits (4400 ms blank screen duration), three series of 12 digits (1900 ms blank screen duration), four series of 15 digits (1400 ms blank screen duration), and two series of 30 digits (400 ms blank screen duration). The 10-digit series were presented in random order. All participants were informed about the general task structure before working on the task but participants in the clear-difficulty condition also received detailed information about the number of digits per trial and the presentation times. Following previous work that has used tasks with unclear difficulty (e.g., Brinkmann & Franzen, 2013; Franzen et al., 2019; Richter & Gendolla, 2009a; Richter et al., 2021), participants in the unclear-difficulty condition did not receive any specific information about task difficulty and were additionally informed that the number of digits and presentation times would vary randomly between trials to prevent participants from forming an impression about task difficulty.

2.3 Procedure

Participants participated individually in sessions of about 35 minutes. Inquisit Lab (version 4.0, Millisecond Software, Seattle, WA) presented all stimuli and collected participants' responses (the script is available at https://doi.org/10.26037/yareta:sjaagdq6fjexhcqlls3i3qpv6y). At the beginning of the session, the experimenter, who was hired and blind to the hypotheses, explained the study procedure to the participant and collected informed consent. The experimenter then attached the electrodes and cuff for the cardiovascular measures, started the software, and left the room to monitor the experiment from a control room. Participants first indicated their age and gender and completed the PRF achievement scale. Participants then watched for eight minutes a relaxing movie showing underwater landscapes. During this time cardiovascular baseline measures were collected.

After the baseline period, participants received instructions for the mental arithmetic task—including the information related to the clarity-of-task-difficulty manipulation presented in section 2.2.3—and performed two practice trials. To increase the likelihood that the mental arithmetic task activated the explicit achievement motive and made success relevant to individuals with a high explicit achievement motive, we provided participants in both clarity-of-task-difficulty conditions with the opportunity for social comparison and norm-referenced feedback—the type of information that individuals with a high explicit achievement motive should strive for to assess their own attainment of excellence (Brunstein & Hoyer, 2002; Brunstein & Maier, 2005; Brunstein & Schmitt, 2004). Participants were informed that other students had already shown good performance in the task and that they would receive feedback about the performance of these students and their own overall performance at the end of the task. To further increase the relevance of the task for individuals with a high achievement motive, the task was described as a task in which performance was indicative of cognitive capacity. After the arithmetic task, participants rated subjective task difficulty (“How difficult was the task?”) and their engagement during the task (“To what extent did you try to continuously add the presented digits?”) on 7-point scales ranging from 1 (*not at all*) to 7 (*very much*). Finally, participants were carefully debriefed and received their remuneration.

2.4 Data Processing and Analysis

The ECG and ICG signals collected by the impedance cardiograph were analyzed off-line with BlueBox 2 software (Richter, 2010). R-peaks of the ECG signal were first identified using a peak-threshold algorithm, and location of the R-peaks was visually confirmed. The detected R-peaks were used to compute HR for one-minute intervals and to construct one-minute ensemble averages of the first derivative (dZ/dt) of the ICG signal (Kelsey & Guethlein, 1990). The dZ/dt signal was filtered with

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a 50 Hz low-pass Butterworth filter before ensemble averaging (Hurwitz et al., 1993). Two independent raters scored R-onset and B-point for each resulting ensemble average following the guidelines by Sherwood and colleagues (Sherwood et al., 1990). PEP scores were computed for each rater and ensemble average as difference between R-onset and B-point. The arithmetic mean of both raters' PEP values was used for the analysis (ICC[2, 1] = .93; Shrout & Fleiss, 1979). Following preceding work on motivational intensity theory (e.g., Mazeres et al., 2019), the values obtained during the last four minutes (ω_ts > .96) were averaged to obtain baseline scores and the values of the first six minutes of task performance (ω_ts > .97) were averaged to obtain task scores. Change scores were then calculated to quantify cardiovascular reactivity by subtracting baseline scores from task scores (Llabre et al., 1991).

We tested our hypothesis about the moderating influence of clarity of task difficulty on the impact of explicit achievement motive strength on myocardial sympathetic activity using three different testing strategies that allowed us to examine different aspects of our hypothesis. We first examined the interaction between achievement motive strength and clarity-of-task-difficulty condition in linear regressions that predicted the individual cardiovascular reactivity scores as a function of z-standardized achievement motive scores, the clarity-of-task-difficulty condition, and the interaction between the two factors. Given that the regression interaction term does not provide a specific test of the predicted moderation, we also calculated for each clarity-of-task-difficulty condition correlation coefficients reflecting the associations between achievement motive scores and cardiovascular reactivity scores, and tested whether the associations were more positive—more negative in the case of pre-ejection period reactivity—in the unclear-difficulty condition than in the clear-difficulty condition using Fisher's *z*. The third statistical analysis compared the relative performance of the predicted interaction model with a model that predicted an achievement motive main effect. For this purpose, we followed the approach suggested by Glover and Dixon (2004) and calculated a likelihood ratio that contrasted the likelihood of the data under a

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model that used the regression interaction term as sole predictor of cardiovascular reactivity with the likelihood of the data under a model that used achievement motive score as sole predictor.

3. Results

3.1 Cardiovascular Responses

Means and standard errors of cardiovascular baseline and reactivity scores are shown in Table 1.[2] The regression model was significant for PEP reactivity, $F(3, 73) = 3.34$, $p = .02$, $R^2 = .12$, $R^2_{\text{adjusted}} = .09$.[3] The interaction term, $b = -2.14$, $t(73) = -2.69$, $p = .01$, was the only significant predictor ($b = 1.05$, $t[73] = 1.79$, $p = .08$, for achievement motive scores and $b = -1.33$, $t[73] = -1.68$, $p = .10$, for the clarity-of-task-difficulty condition). As predicted, achievement motive scores were more negatively associated with PEP reactivity in the unclear difficulty condition ($r = -.28$) than in the clear-difficulty condition ($r = .33$), $z = 2.68$, $p = .004$. Figure 1 illustrates this moderation of the relationship between explicit achievement motive scores and PEP reactivity by clarity-of-task-difficulty condition. The comparison of the interaction model with the achievement motive main effect model resulted in a likelihood ratio of 32.60, providing strong evidence in favor of our interaction hypothesis.[4]

The regression model was not significant for SBP reactivity, $F(3, 73) = 1.72$, $p = .17$, $R^2 = .07$, $R^2_{\text{adjusted}} = .03$ (all predictor ps > .26), DBP reactivity, $F(3, 73) = 2.13$, $p = .10$, $R^2 = .08$, $R^2_{\text{adjusted}} = .04$ ($b = 1.35$, $t[73] = 2.10$, $p = .04$, for the clarity-of-task-difficulty condition, all other predictor ps > .19), or

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[2] Except for PEP reactivity in the clear-difficulty condition ($t[39] = -0.41$, $p = .34$), all reactivity scores differed significantly from 0 (ps < .03).

[3] One participant in the unclear-difficulty condition was excluded from the analysis of PEP and HR reactivity because her/his PEP and HR reactivity values deviated by more than three standard deviations from the PEP and HR reactivity grand means. Two other participants in the unclear-difficulty condition had either an SBP or DBP reactivity score more than three standard deviations greater than the SBP/DBP grand mean. These two participants were also excluded from the associated analyses. Inclusion of these three participants did not significantly change any of the reported results.
Including the baseline scores, age, or gender in the analysis did also not significantly change any of the reported results.

[4] Using the interval between R-peak and B-point (PEP_r, RB-interval) instead of the interval between R-onset and B-point did virtually not change the results. The regression model was significant, $F(3, 73) = 3.13$, $p = .03$, $R^2 = .11$, $R^2_{\text{adjusted}} = .08$, with the interaction term being the only significant predictor, $b = -2.09$, $t(73) = -2.62$, $p = .01$ (all other ps > .08). The correlation with achievement motive scores was more negative in the unclear-difficulty condition ($r = -.27$) than in the clear-difficulty condition ($r = .33$), $z = 2.63$, $p = .004$, and the likelihood ratio in favor of the interaction model was 27.90.

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HR reactivity, *F*(3, 73) = 0.52, $p = .67$, $R^2 = .02$, $R^2_{\text{adjusted}} = -.02$ (all predictor *p*s > .40). The relationship between achievement motive strength and reactivity scores did not differ as a function of clarity-of-task-difficulty condition for SBP ($r = .29$ in the unclear-difficulty condition and $r = .12$ in the clear-difficulty condition, $z = 0.74$, $p = .23$), DBP ($r = .10$ in the unclear-difficulty condition and $r = -.20$ in the clear-difficulty condition, $z = 1.30$, $p = .10$), and HR ($r = .17$ in the unclear-difficulty condition and $r = -0.04$ in the clear-difficulty condition, $z = 0.88$, $p = .19$). Likelihood ratios favored the interaction model over the achievement motive main effect model but were small (λ = 1.40 for SBP reactivity, λ = 2.35 for DBP reactivity, and λ = 1.42 for HR reactivity).

3.3 Self-reports and Task Performance

Correlations between self-reports, task performance, and cardiovascular reactivity scores are presented in Table 2. Participants rated the task as being easier in the clear-difficulty condition ($M = 1.62$, $SE = 0.22$) than in the unclear-difficulty condition ($M = 4.21$, $SE = 0.24$), $t(75.29) = 8.02$, $p < .001$, $d = 1.82$. Moreover, participants solved more equations correctly in the clear-difficulty condition ($M = 9.50$, $SE = 0.16$) than in the unclear-difficulty condition ($M = 7.16$, $SE = 0.24$), $t(63.55) = 8.11$, $p < .001$, $d = 1.85$. Self-reported engagement did not significantly differ between the clear-difficulty ($M = 5.40$, $SE = 0.32$) and unclear-difficulty conditions ($M = 5.45$, $SE = 0.25$), $t(72.04) = 0.12$, $p = .91$, $d = 0.03$.

4. Discussion

Three pieces of evidence supported the predicted moderation of the explicit achievement motive impact on task-related myocardial sympathetic activity by clarity of task difficulty. First, we found a significant interaction between achievement motive score and clarity-of-task-difficulty condition on pre-ejection period reactivity in our regression analysis. Achievement motive score or clarity-of-task-difficulty alone were not significant predictors of pre-ejection period reactivity. Second, the correlation between achievement motive scores and pre-ejection period reactivity was more negative in the unclear-difficulty condition than in the clear-difficulty condition. Pre-ejection period reactivity increased with increasing achievement motive strength in the unclear-difficulty

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condition, but not in the clear-difficulty condition. Third, the data were more than 32 times more likely under a model that predicted an interaction of achievement motive and clarity of task difficulty than under a model that predicted an achievement motive main effect.

Given that task-induced decreases in pre-ejection period were not paralleled by decreases in heart rate or diastolic blood pressure—the correlation coefficients between pre-ejection period reactivity and heart rate and diastolic blood pressure reactivity were in both conditions negative—it is likely that the observed pre-ejection period changes were driven by changes in myocardial sympathetic activity (Obrist, 1981; Sherwood et al., 1990). A parallel decrease in heart rate would have led to increased ventricular filling and an increase in myocardial contraction force via the Frank-Starling mechanism, which would have resulted in pre-ejection period shortening without any underlying changes in myocardial sympathetic activity. A parallel decrease of diastolic blood pressure would have suggested decreases in afterload, which would also have led to pre-ejection period shortening without any changes in myocardial sympathetic activity. Both decreased heart rate and decreased blood pressure would thus have led to the same pre-ejection period pattern as the postulated changes in myocardial sympathetic activity and prevented us from interpreting pre-ejection period changes as reflecting changes in myocardial sympathetic activity. However, the absence of any evidence for parallel reductions in heart rate and diastolic blood pressure makes it unlikely that the observed pre-ejection period changes were due to changes in preload or afterload, and suggests that the observed pre-ejection period effects reflected the predicted changes in myocardial sympathetic activity.

The other cardiovascular parameters did not show the same effects as pre-ejection period. The regression models were not significant, the correlation coefficients did not differ between the two clarity-of-task-difficulty conditions, and the likelihood ratios did not provide decisive evidence in favor of the interaction model. Even if preceding research on motivational intensity theory has frequently reported effects on systolic blood pressure (e.g., Chatelain & Gendolla, 2016; Szumowska et al., 2017), heart rate (e.g., Mlynski et al., 2017; Mlynski et al., 2020; Silvestrini, 2015), and diastolic

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blood pressure (e.g., Silvestrini & Gendolla, 2011; Silvia et al., 2010), it is not surprising that pre-ejection period was more responsive to achievement motive strength and clarity-of-task-difficulty effects. Pre-ejection period is more likely to reflect changes in myocardial sympathetic activity than the other three cardiovascular parameters. Decreases in pre-ejection period directly reflect increases in myocardial contraction force driven by increases in myocardial sympathetic activity if there are no parallel increases in preload or decreases in afterload (Newlin & Levenson, 1979; Sherwood et al., 1990; see also the discussion in the preceding paragraph). Heart rate is an ambiguous indicator of myocardial sympathetic activity given that it is determined by both sympathetic and parasympathetic activity (Klabunde, 2012). Effects of increased sympathetic activity can be counteracted by increasing parasympathetic activity leading to no change or even a decrease in heart rate. Moreover, decreased parasympathetic activity can lead to a heart rate increase without any increases in sympathetic activity.

Systolic and diastolic blood pressure are a function of heart rate, stroke volume (determined amongst others by myocardial contraction force), and total peripheral resistance (Klabunde, 2012). Even if the relative contribution of these three variables differs between systolic and diastolic blood pressure (Segers et al., 2001), the fact that blood pressure depends on heart rate and myocardial contraction force—the main determinant of pre-ejection period—implies that systolic and diastolic blood pressure inherit all the threats to an interpretation as indicator of myocardial sympathetic activity that heart rate and pre-ejection period are exposed to. Myocardial sympathetic changes on systolic and diastolic blood pressure can be masked or mimicked by parasympathetic activity changes because they depend on heart rate, and they can be masked or mimicked by changes in pre- and afterload (Bugge-Asperheim & Kiil, 1973) because they depend on stroke volume. Moreover, in contrast to heart rate and pre-ejection period, systolic and diastolic blood pressure also depend on total peripheral resistance, which is not systematically associated with myocardial sympathetic activity (Klabunde, 2012). Consequently, systolic and diastolic blood pressure are influenced by one additional factor that can mask or mimic myocardial sympathetic effects.

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Given the described physiological mechanisms, pre-ejection period can be expected to respond more sensitively to changes in myocardial sympathetic activity than heart rate or blood pressure. Correspondingly, it is not surprising to find effects of achievement motive strength and clarity of task difficulty—which were expected to influence myocardial sympathetic activity—on pre-ejection period but not on the other cardiovascular parameters. It is noteworthy that our findings are not the first in the context of the work on motivational intensity theory that revealed effects on pre-ejection period in the absence of effects on systolic or diastolic blood pressure (e.g., Brinkmann & Franzen, 2013; Freydefont & Gendolla, 2012; Richter et al., 2012; Richter & Knappe, 2014). Finding effects on pre-ejection period in the absence of effects on heart rate and blood pressure makes thus not only sense for physiological reasons but is also not uncommon.

Even if we did not observe effects on systolic blood pressure as many other studies on motivational intensity theory (Gendolla et al., 2019, Richter et al., 2016, for overviews), our findings replicate previous work on motivational intensity theory that has demonstrated success importance effects on cardiovascular response under conditions of unclear task difficulty (Brinkmann et al., 2014; Brinkmann et al., 2009; Franzen & Brinkmann, 2016; Richter & Gendolla, 2006, 2007, 2009a, 2009b). Like these preceding studies, we found that variables that determine success importance—explicit achievement motive strength in our case—directly influence task-related myocardial activity if participants have no information about the difficulty of the task and cannot predict the difficulty of the upcoming trial. Our results also replicate the moderating impact of clarity of task difficulty observed for a reward manipulation by Richter and Gendolla (2006). Similar to our findings, they observed that differences in the attractiveness of the reward that participants could earn for a successful task performance only resulted in differences on cardiovascular responses if task difficulty was unclear but not if it was clear.

The observation that achievement motive strength did not under all conditions influence myocardial sympathetic activity might not be surprising from the point of view of motivational intensity theory. However, a large part of the achievement motive literature still builds on the notion

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that motives exert a uniform impact on behavior once that they are aroused (e.g., Bettschart et al., 2020; Lang & Fries, 2006; Müller & Cañal-Bruland, 2020). There are a number of models that provided more complex predictions taking into account how situational characteristics influence the motive-behavior relationship (McClelland et al., 1989; Schultheiss, 2007, 2008; Stanton et al., 2010) but many publications still assume that a motive only needs to be activated to exert a direct, visible impact on behavior.

The main limitation of our study refers to our interpretation of the clarity-of-task-difficulty manipulation. Our interpretation follows directly from our experimental manipulation that aimed to provide participants either with information that allowed them to know the difficulty of the next task trial or not. However, in contrast to the preceding study by Richter and Gendolla (2006) that only varied the amount of task difficulty information presented to participants to manipulate clarity of task difficulty, we also varied the difficulty of the task trials that participants had to perform. This led to a confound of clarity of task difficulty with overall task difficulty. In the clear-difficulty condition, only easy task trials were presented, and the overall difficulty of the task was correspondingly low. In the unclear-difficulty condition, we presented easy trials together with more difficult trials. This obviously made the task overall more difficult. Participants' task difficulty ratings and performance scores reflected this: Task difficulty was perceived to be higher in the unclear condition than in the clear condition, and participants solved more trials correctly in the clear condition than in the unclear condition. Our results would still be explicable by motivational intensity theory if our clarity-of-task-difficulty manipulation was interpreted as a difficulty manipulation. Under conditions of clear, easy task difficulty, the theory would not predict an effect of achievement motive strength because even a weak achievement motive should make task success important enough to warrant the effort required to perform the easy task. However, a weak achievement motive should not be sufficient to justify the effort required to perform the unclear, difficult task. Correspondingly, participants with a lower achievement motive strength could have disengaged from the task in the unclear-difficulty condition and not have invested any effort.

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However, from a theoretical point of view, a task with fixed and clear, high difficulty should lead to a twofold pattern where low achievement motivated participants disengage whereas high achievement motivated participants mobilize effort. Inspection of Figure 1 shows that PEP reactivity did not show such a twofold pattern but rather increased proportionally with achievement motive strength, as would be expected for an unclear-difficulty condition. Therefore, despite the confound of clarity of task difficulty with overall task difficulty in our study, the results correspond to the interpretation of the task in terms of unclear difficulty.

There is a second confound that needs to be mentioned and that is directly relevant to the conclusions that can be drawn from our study regarding the mechanisms that underlie achievement motive effects on task-related myocardial sympathetic activity. Given that the achievement motive refers to experiencing meeting and surpassing standards of excellence as rewarding (McClelland, 1987), the achievement motive should only be activated in situations that promise attaining or surpassing standards of excellence. One could argue that only the unclear-difficulty condition represented such a condition because of its higher overall difficulty. The clear-difficulty condition might not have constituted a situation that participants perceived as suitable to demonstrate excellence because it was too easy. Following this interpretation, our study would not have examined the moderating impact of clarity of task difficulty on the motive-behavior link but the moderating impact of motive activation. We think, however, that this critique would be more relevant if we had examined the impact of the implicit achievement motive, and not the impact of the explicit achievement motive. According to McClelland et al. (1989), the intrinsic challenge provided by the task itself (for instance, task difficulty level) is crucial to activate the implicit achievement motive. For the activation of the explicit achievement motive, task-intrinsic factors are supposed to be less relevant. The explicit achievement motive should be activated by externally imposed challenges and social norms. For this reason, we presented to all our participants—independent of the clarity-of-task-difficulty condition—the same type of social-extrinsic incentive by explaining that the task was indicative of cognitive capacity, that previous participants had

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performed well, and that we would provide them with information enabling a comparison of their own performance with the performance of these previous participants. Providing this type of information should have equally activated the explicit achievement motive in all conditions and prevented the explicit achievement motive from not being activated in the clear-difficulty condition.

Additional aspects that may limit the conclusions that can be drawn from our study are the sample that included only young adults studying at the University of Geneva, the relatively low blood pressure baseline values, and the lack of comprehensive control for extraneous variables that may influence cardiovascular reactivity (e.g., Busch et al., 2017; Gendolla et al., 2019). First, the fact that our sample was composed of young, Swiss University students obviously implies that we only demonstrated the predicted moderating influence of clarity of task difficulty on the relationship between achievement motive strength and myocardial sympathetic activity for this particular population. While we are unaware of any theoretical reason why this relationship should be different in other populations, further research might aim at replicating our findings with more diverse samples. Second, the observed blood pressure baseline values were below the norm values for young adults. The only explanation that we have to offer for this finding is that our sample included a large proportion of young women, which tend to have a lower blood pressure than young men (Ji et al., 2020; Syme et al., 2009). We do not think that the lower blood pressure baseline values constitute a serious limitation of our findings given that the results for blood pressure reactivity did virtually not change when including baseline values in the statistical analysis (see Footnote 3). Moreover, there are a number of other publications on motivational intensity theory that also examined student populations and found blood pressure baseline values considerably lower than 120/80 mmHg (Czarnek et al., 2019; Mlynski et al., 2020; Silvestrini, 2015; Silvia, 2012).

Third, the lack of a comprehensive set of control variables—we only controlled for the effect of baseline values, age, and gender—may also be considered a limitation. Observing the predicted effect without controlling for other variables that may influence cardiovascular responses suggests that the moderating influence of clarity of task difficulty was strong enough to be detectable despite

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the noise that other factors might have introduced. However, it obviously leaves the possibility that random variations in extraneous variables may have caused the observed effects on cardiovascular reactivity. For instance, our participants with a high achievement motive score in the unclear task condition might have had hypertensive parents whereas all other participants might have had normotensive parents. Given that children of hypertensive parents tend to show stronger cardiovascular responses to mental arithmetic tasks (Manuck et al., 1985), a potentially unequal distribution of parents' hypertension status could explain why we found the strongest reactivity amongst high-achievement-motive participants in the unclear task condition. However, a more comprehensive set of control variables would not have offered a general protection against the suggestion that uncontrolled extraneous variables caused the observed effects: It is practically impossible to control for all the variables that have been demonstrated to influence cardiovascular reactivity (for instance, personality traits, Bongard et al., 1998; parents' hypertension status, Manuck et al., 1985; race of the experimenter, Murphy et al., 1986; mood, Richter & Gendolla, 2009b). Given the multitude of potential control variables, it would be desirable to have a consensus amongst researchers working on cardiovascular reactivity regarding the variables that should be controlled for in work on cardiovascular reactivity.

Our study adds to the emerging literature on physiological correlates of motives (e.g., Dufner et al., 2015; Quirin et al., 2013; Stanton & Edelstein, 2009; Stanton & Schultheiss, 2007) by demonstrating the impact of the explicit achievement motive on myocardial sympathetic activity. Drawing on motivational intensity theory, a theory on effort investment in instrumental tasks, we showed that the impact of the explicit achievement motive on myocardial sympathetic activity is not stable but depends on the clarity of task difficulty. If task difficulty was unknown (or unpredictable), a strong explicit achievement motive led to higher myocardial sympathetic activity than a weak explicit achievement motive. If task difficulty was clear (and easy), motive strength and myocardial sympathetic activity were not positively related. Our findings thus show that the impact of the

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explicit achievement motive on physiology is variable and depends on contextual factors like clarity of task difficulty.

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References

Beh, H. C. (1990). Achievement motivation, performance and cardiovascular activity. *International Journal of Psychophysiology*, *10*(1), 39-45. https://doi.org/10.1016/0167-8760(90)90043-D

Bettschart, M., Herrmann, M., Wolf, B. M., & Brandstätter, V. (2020). Investigating the Unified Motive Scales. *European Journal of Psychological Assessment*, 1-5. https://doi.org/10.1027/1015-5759/a000571

Bongard, S., al'Absi, M., & Lovallo, W. R. (1998). Interactive effects of trait hostility and anger expression on cardiovascular reactivity in young men. *International Journal of Psychophysiology*, *28*(2), 181-191. https://doi.org/10.1016/S0167-8760(97)00095-0

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology*, *40*(1), 109-131. https://doi.org/10.1146/annurev.ps.40.020189.000545

Brinkmann, K., & Franzen, J. (2013). Not everyone's heart contracts to reward: Insensitivity to varying levels of reward in dysphoria. *Biological Psychology*, *94*(2), 263-271. https://doi.org/10.1016/j.biopsycho.2013.07.003

Brinkmann, K., Franzen, J., Rossier, C., & Gendolla, G. H. E. (2014). I don’t care about others’ approval: Dysphoric individuals show reduced effort mobilization for obtaining a social reward. *Motivation and Emotion*, *38*(6), 790-801. https://doi.org/10.1007/s11031-014-9437-y

Brinkmann, K., Schüpbach, L., Ancel Joye, I., & Gendolla, G. H. (2009). Anhedonia and effort mobilization in dysphoria: reduced cardiovascular response to reward and punishment. *International Journal of Psychophysiology*, *74*(3), 250-258. https://doi.org/10.1016/j.ijpsycho.2009.09.009

Brunstein, J. C., & Hoyer, S. (2002). Implizites versus explizites Leistungsstreben: Befunde zur Unabhängigkeit zweier Motivationssysteme. *Zeitschrift für Pädagogische Psychologie*, *16*(1), 51-62. https://doi.org/10.1024//1010-0652.16.1.51

Journal Pre-proof

Brunstein, J. C., & Maier, G. W. (2005). Implicit and self-attributed motives to achieve: Two separate but interacting needs. *Journal of Personality and Social Psychology*, *89*(2), 205-222.

Brunstein, J. C., & Schmitt, C. H. (2004). Assessing individual differences in achievement motivation with the Implicit Association Test. *Journal of Research in Personality*, *38*(6), 536-555. https://doi.org/10.1016/j.jrp.2004.01.003

Brunstein, J. C., & Schmitt, C. H. (2010). Assessing individual differences in achievement motivation with the implicit association test: Predictive validity of a chronometric measure of the self-concept “me = successful”. In O. C. Schultheiss & J. C. Brunstein (Eds.), *Implicit motives* (pp. 151-185). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195335156.003.0006

Bugge-Asperheim, B., & Kiil, F. (1973). Preload, contractility, and afterload as determinants of stroke volume during elevation of aortic blood pressure in dogs. *Cardiovascular Research*, *7*(4), 528-541. https://doi.org/10.1093/cvr/7.4.528

Busch, L. Y., Possel, P., & Valentine, J. C. (2017). Meta-analyses of cardiovascular reactivity to rumination: A possible mechanism linking depression and hostility to cardiovascular disease. *Psychol Bull*, *143*(12), 1378-1394. https://doi.org/10.1037/bul0000119

Capa, R. L., Audiffren, M., & Ragot, S. (2008). The interactive effect of achievement motivation and task difficulty on mental effort. *International Journal of Psychophysiology*, *70*(2), 144-150. https://doi.org/10.1016/j.ijpsycho.2008.06.007

Chatelain, M., & Gendolla, G. H. E. (2016). Monetary incentive moderates the effect of implicit fear on effort-related cardiovascular response. *Biological Psychology*, *117*, 150-158. https://doi.org/10.1016/j.biopsycho.2016.03.014

Czarnek, G., Kossowska, M., & Richter, M. (2019). Aging, effort, and stereotyping: The evidence for the moderating role of self-involvement. *International Journal of Psychophysiology*, *138*, 1-10. https://doi.org/10.1016/j.ijpsycho.2019.01.009

Journal Pre-proof

Dufner, M., Arslan, R. C., Hagemeyer, B., Schönbrodt, F. D., & Denissen, J. J. A. (2015). Affective contingencies in the affiliative domain: Physiological assessment, associations with the affiliation motive, and prediction of behavior. *Journal of Personality and Social Psychology*, *109*(4), 662-676. https://doi.org/10.1037/pspp0000025

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175-191. https://doi.org/10.3758/bf03193146

Franzen, J., & Brinkmann, K. (2016). Wanting and liking in dysphoria: Cardiovascular and facial EMG responses during incentive processing. *Biological Psychology*, *121*(Pt A), 19-29. https://doi.org/10.1016/j.biopsycho.2016.07.018

Franzen, J., Brinkmann, K., Gendolla, G. H. E., & Sentissi, O. (2019). Major depression impairs incentive processing: evidence from the heart and the face. *Psychological Medicine*, *49*(6), 922-930. https://doi.org/10.1017/S0033291718001526

Freydefont, L., & Gendolla, G. H. (2012). Incentive moderates the impact of implicit anger vs. sadness cues on effort-related cardiac response. *Biological Psychology*, *91*(1), 120-127. https://doi.org/10.1016/j.biopsycho.2012.04.002

Gendolla, G. H. E., Wright, R. A., & Richter, M. (2019). Advancing issues in motivation intensity research: Updated insights from the cardiovascular system. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation* (pp. 373-392). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190666453.013.21

Glover, S., & Dixon, P. (2004). Likelihood ratios: a simple and flexible statistic for empirical psychologists. *Psychonomic Bulletin & Review*, *11*(5), 791-806. https://doi.org/10.3758/bf03196706

Gröpel, P., Wegner, M., & Schüler, J. (2016). Achievement motive and sport participation. *Psychology of Sport and Exercise*, *27*, 93-100. https://doi.org/10.1016/j.psychsport.2016.08.007

Journal Pre-proof

Harper, K. L., Silvia, P. J., Eddington, K. M., Sperry, S. H., & Kwapil, T. R. (2018). Conscientiousness and effort-related cardiac activity in response to piece-rate cash incentives. *Motivation and Emotion*, *42*(3), 377-385. https://doi.org/10.1007/s11031-018-9668-4

Hurwitz, B. E., Shyu, L.-Y., Lu, C.-C., Reddy, S. P., Schneiderman, N., & Nagel, J. H. (1993). Signal fidelity requirements for deriving impedance cardiographie measures of cardiac function over a broad heart rate range. *Biological Psychology*, *36*(1-2), 3-21. https://doi.org/10.1016/0301-0511(93)90076-k

Jackson, D. N. (1984). *Personality Research Form manual* (3rd ed.). Sigma Assessment Systems.

Ji, H., Kim, A., Ebinger, J. E., Niiranen, T. J., Claggett, B. L., Bairey Merz, C. N., & Cheng, S. (2020). Sex differences in blood pressure trajectories over the life course. *JAMA Cardiology*, *5*(3), 19-26. https://doi.org/10.1001/jamacardio.2019.5306

Kelsey, R. M., & Guethlein, W. (1990). An evaluation of the ensemble averaged impedance cardiogram. *Psychophysiology*, *27*(1), 24-33. https://doi.org/10.1111/j.1469-8986.1990.tb02173.x

Klabunde, R. E. (2012). *Cardiovascular physiology concepts* (2nd ed.). Lippincott Williams & Wilkins.

Koestner, R., Weinberger, J., & McClelland, D. C. (1991). Task-intrinsic and social-extrinsic sources of arousal for motives assessed in fantasy and self-report. *Journal of Personality*, *59*(1), 57-82. https://doi.org/10.1111/j.1467-6494.1991.tb00768.x

LaGory, J., Dearen, B. B., Tebo, K., & Wright, R. A. (2011). Reported fatigue, difficulty, and cardiovascular response to an auditory mental arithmetic challenge. *International Journal of Psychophysiology*, *81*(2), 91-98. https://doi.org/10.1016/j.ijpsycho.2011.05.005

Lang, J. W. B., & Fries, S. (2006). A revised 10-item version of the Achievement Motives Scale. *European Journal of Psychological Assessment*, *22*(3), 216-224. https://doi.org/10.1027/1015-5759.22.3.216

Journal Pre-proof

Light, K. C. (1981). Cardiovascular responses to effortful active coping: Implications for the role of stress in hypertension development. *Psychophysiology*, *18*(3), 216-225. https://doi.org/10.1111/j.1469-8986.1981.tb03021.x

Llabre, M. M., Spitzer, S. B., Saab, P. G., Ironson, G. H., & Schneiderman, N. (1991). The reliability and specificity of delta versus residualized change as measures of cardiovascular reactivity to behavioral challenges. *Psychophysiology*, *28*(6), 701-711. https://doi.org/10.1111/j.1469-8986.1991.tb01017.x

Manuck, S. B., Proietti, J. M., Rader, S. J., & Polefrone, J. M. (1985). Parental hypertension, affect, and cardiovascular response to cognitive challenge. *Psychosomatic Medicine*, *47*(2), 189-200. https://doi.org/10.1097/00006842-198503000-00011

Mazeres, F., Brinkmann, K., & Richter, M. (2019). Implicit achievement motive limits the impact of task difficulty on effort-related cardiovascular response. *Journal of Research in Personality*, *82*. https://doi.org/10.1016/j.jrp.2019.06.012

McClelland, D. C. (1987). *Human motivation*. Cambridge University Press.

McClelland, D. C., Koestner, R., & Weinberger, J. (1989). How do self-attributed and implicit motives differ? *Psychological Review*, *96*(4), 690-702. https://doi.org/10.1037/0033-295X.96.4.690

Mlynski, C., Wright, R. A., Agtarap, S. D., & Rojas, J. (2017). Naturally-occurring fatigue and cardiovascular response to a simple memory challenge. *International Journal of Psychophysiology*, *119*, 73-78. https://doi.org/10.1016/j.ijpsycho.2017.02.011

Mlynski, C., Wright, R. A., & Kelly, K. (2020). Ability influence on effort and associated cardiovascular responses: Nocebo-Placebo evidence that perception is key. *Biological Psychology*, *152*, 107867. https://doi.org/10.1016/j.biopsycho.2020.107867

Müller, F., & Cañal-Bruland, R. (2020). Motivation in the wild: A critical review of the relationship between motives and motor performance. *Motivation Science*, *6*(2), 93-109. https://doi.org/10.1037/mot0000141

Journal Pre-proof

Murphy, J. K., Alpert, B. S., Moes, D. M., & Somes, G. W. (1986). Race and cardiovascular reactivity. A neglected relationship. *Hypertension*, *8*(11), 1075-1083. https://doi.org/10.1161/01.hyp.8.11.1075

Newlin, D. B., & Levenson, R. W. (1979). Pre-ejection period: measuring beta-adrenergic influences upon the heart. *Psychophysiology*, *16*(6), 546-553. https://doi.org/10.1111/j.1469-8986.1979.tb01519.x

Obrist, P. A. (1981). *Cardiovascular psychophysiology: A perspective*. Plenum Press.

Obrist, P. A., Light, K. C., James, S. A., & Strogatz, D. S. (1987). Cardiovascular responses to stress: I. Measures of myocardial response and relationship to high resting systolic pressure and parental hypertension. *Psychophysiology*, *24*(1), 65-78. https://doi.org/10.1111/j.1469-8986.1987.tb01864.x

Quirin, M., Meyer, F., Heise, N., Kuhl, J., Küstermann, E., Strüber, D., & Cacioppo, J. T. (2013). Neural correlates of social motivation: An fMRI study on power versus affiliation. *International Journal of Psychophysiology*, *88*(3), 289-295. https://doi.org/10.1016/j.ijpsycho.2012.07.003

Richter, M. (2010). *BlueBox 2*. In (Version v1.22)

Richter, M. (2013). A closer look into the multi-layer structure of motivational intensity theory. *Social and Personality Psychology Compass*, *7*(1), 1-12. https://doi.org/10.1111/spc3.12007

Richter, M., Friedrich, A., & Gendolla, G. H. E. (2008). Task difficulty effects on cardiac activity. *Psychophysiology*, *45*(5), 869-875. https://doi.org/10.1111/j.1469-8986.2008.00688.x

Richter, M., & Gendolla, G. H. E. (2006). Incentive effects on cardiovascular reactivity in active coping with unclear task difficulty. *International Journal of Psychophysiology*, *61*(2), 216-225. https://doi.org/10.1016/j.ijpsycho.2005.10.003

Richter, M., & Gendolla, G. H. E. (2007). Incentive value, unclear task difficulty, and cardiovascular reactivity in active coping. *International Journal of Psychophysiology*, *63*(3), 294-301. https://doi.org/10.1016/j.ijpsycho.2006.12.002

Journal Pre-proof

Richter, M., & Gendolla, G. H. E. (2009a). The heart contracts to reward: monetary incentives and preejection period. *Psychophysiology*, *46*(3), 451-457. https://doi.org/10.1111/j.1469-8986.2009.00795.x

Richter, M., & Gendolla, G. H. E. (2009b). Mood impact on cardiovascular reactivity when task difficulty is unclear. *Motivation and Emotion*, *33*(3), 239-248. https://doi.org/10.1007/s11031-009-9134-4

Richter, M., Gendolla, G. H. E., & Wright, R. A. (2016). Three decades of research on motivational intensity theory. In *Advances in motivation science* (Vol. 3, pp. 149-186). Academic Press. https://doi.org/10.1016/bs.adms.2016.02.001

Richter, M., & Knappe, K. (2014). Mood impact on effort-related cardiovascular reactivity depends on task context: Evidence from a task with an unfixed performance standard. *International Journal of Psychophysiology*, *93*(2), 227-234. https://doi.org/10.1016/j.ijpsycho.2014.05.002

Richter, M., Mazeres, F., & Brinkmann, K. (2021). Clarity of task difficulty moderates the impact of the explicit achievement motive on physical effort in hand grip tasks. *PLoS One*, *16*(6). https://doi.org/10.1371/journal.pone.0252713

Schultheiss, O. C. (2007). A memory systems approach to the classification of personality tests: Comment on Meyer and Kurtz (2006). *Journal of Personality Assessment*, *89*(2), 197-201. https://doi.org/10.1080/00223890701357431

Schultheiss, O. C. (2008). Implicit motives. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (3rd ed., pp. 603-633). Guilford Press.

Segers, P., Steendijk, P., Stergiopulos, N., & Westerhof, N. (2001). Predicting systolic and diastolic aortic blood pressure and stroke volume in the intact sheep. *Journal of Biomechanics*, *34*(1), 41-50. https://doi.org/10.1016/S0021-9290(00)00165-2

Sherwood, A., Allen, M. T., Fahrenberg, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. (1990). Methodological guidelines for impedance cardiography. *Psychophysiology*, *27*(1), 1-23. https://doi.org/10.1111/j.1469-8986.1990.tb02171.x

Journal Pre-proof

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, *86*(2), 420-428. https://doi.org/10.1037/0033-2909.86.2.420

Silvestrini, N. (2015). The effort-related costs of implicit pain. *Motivation Science*, *1*(3). https://doi.org/10.1037/mot0000020

Silvestrini, N., & Gendolla, G. H. (2011). Beta-adrenergic impact underlies the effect of mood and hedonic instrumentality on effort-related cardiovascular response. *Biological Psychology*, *87*(2), 209-217. https://doi.org/10.1016/j.biopsycho.2011.02.017

Silvia, P. J. (2012). Mirrors, masks, and motivation: Implicit and explicit self-focused attention influence effort-related cardiovascular reactivity. *Biological Psychology*, *90*(3), 192-201. https://doi.org/10.1016/j.biopsycho.2012.03.017

Silvia, P. J., McCord, D. M., & Gendolla, G. H. E. (2010). Self-focused attention, performance expectancies, and the intensity of effort: Do people try harder for harder goals? *Motivation and Emotion*, *34*(4), 363-370. https://doi.org/10.1007/s11031-010-9192-7

Silvia, P. J., Moore, L. C., & Nardello, J. L. (2013). Trying and quitting: How self-focused attention influences effort during difficult and impossible tasks. *Self and Identity*, *13*(2), 231-242. https://doi.org/10.1080/15298868.2013.796086

Spangler, W. D. (1992). Validity of questionnaire and TAT measures of need for achievement: Two meta-analyses. *Psychological Bulletin*, *112*(1), 140-154. https://doi.org/10.1037/0033-2909.112.1.140

Stanton, S. J., & Edelstein, R. S. (2009). The physiology of women's power motive: Implicit power motivation is positively associated with estradiol levels in women. *Journal of Research in Personality*, *43*(6), 1109-1113. https://doi.org/10.1016/j.jrp.2009.08.002

Stanton, S. J., Hall, J. L., & Schultheiss, O. C. (2010). Properties of motive-specific incentives. In O. Schultheiss & J. Brunstein (Eds.), *Implicit motives* (pp. 245-278). Oxford University Press.

Journal Pre-proof

Stanton, S. J., & Schultheiss, O. C. (2007). Basal and dynamic relationships between implicit power motivation and estradiol in women. *Hormones and Behavior*, *52*(5), 571-580. https://doi.org/10.1016/j.yhbeh.2007.07.002

Syme, C., Abrahamowicz, M., Leonard, G. T., Perron, M., Richer, L., Veillette, S., . . . Pausova, Z. (2009). Sex differences in blood pressure and its relationship to body composition and metabolism in adolescence. *Archives of Pediatrics and Adolescent Medicine*, *163*(9), 818-825. https://doi.org/10.1001/archpediatrics.2009.92

Szumowska, E., Szwed, P., Kossowska, M., & Wright, R. (2017). Multifaceted effects of need for cognitive closure on effort: A cardiovascular response study. *Motivation Science*, *3*(4), 369-382. https://doi.org/10.1037/mot0000053

Wright, R. A. (1996). Brehm's theory of motivation as a model of effort and cardiovascular response. In P. M. Gollwitzer & J. A. Bargh (Eds.), *The psychology of action: Linking cognition and motivation to behavior* (pp. 424-453). Guilford Press.

Wright, R. A. (2008). Refining the prediction of effort: Brehm's distinction between potential motivation and motivation intensity. *Social and Personality Psychology Compass*, *2*(2), 682-701. https://doi.org/10.1111/j.1751-9004.2008.00093.x

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This work was supported by the Swiss National Science Foundation grant 100019_162389 awarded to Kerstin Brinkmann and Michael Richter. This study was not explicitly pre-registered, but predictions, methods, and analyses had been described in the Swiss National Science Foundation grant 100019_162390 before data collection started. We did not have any conflict of interest. We are not able to share data, because the consent forms and project approved by the IRB restrict data access to the researchers directly involved in study design and data acquisition. Florence Mazeres was involved in study design, data collection, data processing, data analysis, and manuscript writing. Kerstin Brinkmann was involved in study design, data analysis, and manuscript writing. Michael Richter was involved in study design, data analysis, and manuscript writing.

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Declaration of interest

Declarations of interest: none.

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Table 1

Means and Standard Errors of Cardiovascular Baselines and Reactivity Scores

Variable	unclear		clear	
	M	*SE*	*M*	*SE*
		Baseline		
PEP	99.62	1.66	102.29	1.93
SBP	104.14	1.99	100.56	1.83
DBP	55.26	1.27	54.51	1.02
HR	73.85	1.84	74.01	1.83
		Reactivity		
PEP	-1.48	0.68	-0.19	0.47
SBP	3.00	0.73	2.11	0.58
DBP	2.48	0.50	1.10	0.40
HR	3.71	0.61	3.00	0.66

Note. n = 37 in the unclear-difficulty condition and 40 in the clear-difficulty condition. PEP is in ms, SBP and DBP in mmHg, and HR in bpm.

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Table 2

Pearson Correlation Coefficients for the Relationships Between Self-reports, Performance, and Cardiovascular Reactivity

Variable	1	2	3	4	5	6	7	8
1. Achievement motive	—	.19 [-.13, .48]	-.14 [-.44, .18]	.14 [-.18, .43]	.33 [.03, .59]	.12 [-.11, .42]	-.20 [-.48, .12]	-.04 [-.35, .27]
2. Difficulty	.19 [-.14, .48]	—	.10 [-.22, .40]	-.48 [-.69, -.19]	.11 [-.41, .21]	.02 [-.30, .33]	-.07 [-.37, .25]	.19 [-.13, .47]
3. Engagement	.02 [-.30, .34]	.27 [-.05, .55]	—	.01 [-.30, .32]	-.33 [-.58, -.02]	.18 [-.14, .46]	.11 [-.21, .41]	.03 [-.28, .34]
4. Performance	-.14 [-.44, .19]	-.16 [-.46, .17]	.45 [.15, .67]	—	.03 [-.29, .34]	.15 [-.17, .44]	.12 [-.20, .41]	.20 [-.12, .48]
5. PEP reactivity	-.28 [-.55, .05]	.19 [-.14, .48]	.08 [-.25, .39]	-.08 [-.39, .25]	—	-.33 [-.48, -.03]	-.46 [-.67, -.17]	-.51 [-.71, -.23]
6. SBP reactivity	-.30 [-.03, .57]	-.14 [-.44, .20]	.15 [-.18, .45]	.41 [.10, .65]	-.56 [-.75, -.29]	—	.34 [.04, .60]	.44 [.15, .66]
7. DBP reactivity	.13 [-.21, .43]	-.17 [-.47, .16]	-.09 [-.40, .25]	.35 [.02, .602]	-.43 [-.66, -.12]	.54 [.26, .74]	—	.54 [.27, .73]
8. HR reactivity	.17 [-.16, .47]	-.01 [-.33, .32]	.25 [-.08, .53]	.29 [-.04, .56]	-.40 [-.64, .09]	.51 [.23, .72]	.38 [.06, .63]	—

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Note. Correlation coefficients in the unclear-difficulty condition are presented below the diagonal. Correlation coefficients in the clear-difficulty condition are presented above the diagonal. 95% confidence interval limits are presented in square brackets. *n* = 37 for all correlation coefficients involving cardiovascular reactivity scores and *n* = 38 for all other correlation coefficients in the unclear-difficulty condition. *n* = 40 for all correlation coefficients in the clear-difficulty condition.

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Figure 1

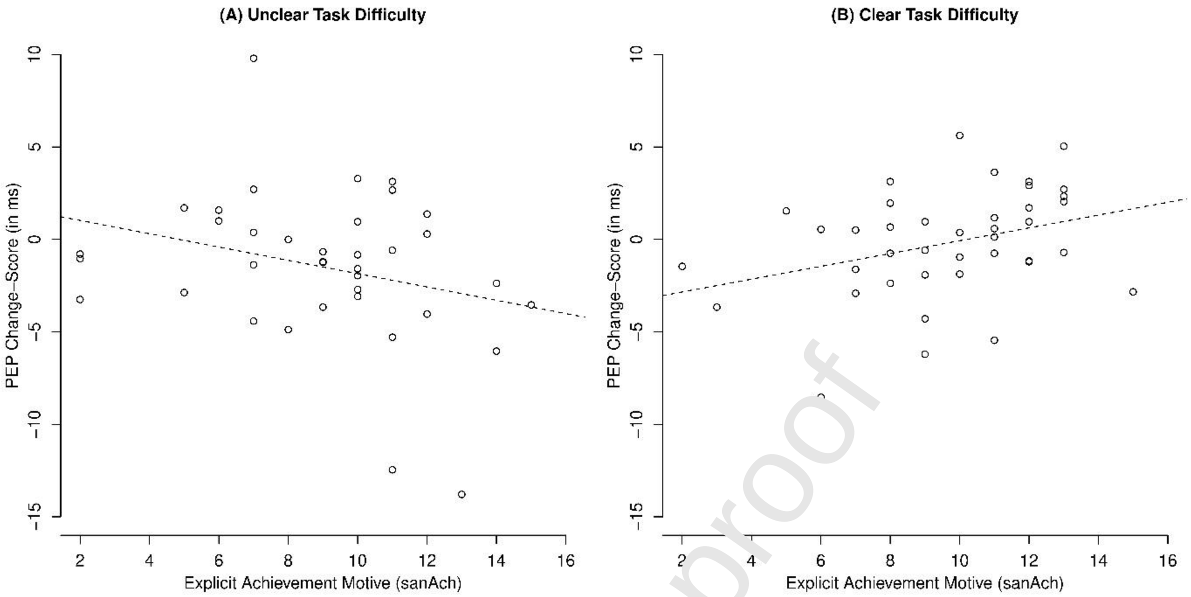

Figure 1. Relationship Between Explicit Achievement Motive Strength and PEP Reactivity as a Function of Clarity of Task Difficulty.

Note. Dashed lines are best fit regression lines.

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Highlights

- Explicit achievement motive (sanAch) strength affects PEP response
- Clarity of task demand moderates the sanAch-PEP relationship
- Higher sanAch is associated with stronger PEP response if task demand is unclear

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