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It's About Effort: Implicit Affect's Impact on Cardiovascular Response is Context-Dependent

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Abstract

Based on the Implicit-Affect-Primes-Effort model (Gendolla, 2012), we tested whether implicitly processed affect primes’ effect on cardiovascular responses is limited to settings that call for effort and in which implicit affect can inform about subjective task demand. Participants were presented with letter series and briefly flashed sadness vs. happiness primes. Half of the participants were asked to memorize the presented vowels (achievement context), while the other half merely watched the series (watching context). Responses of cardiac pre-ejection period, heart rate, systolic, and diastolic blood pressure supported the predictions. As expected, in the challenging achievement-context condition, happiness primes led to stronger cardiovascular reactivity than sadness-primes. By contrast, reactivity was modest in both affect prime conditions when the participants merely watched the stimuli. That is, affect primes’ impact on cardiovascular responses was limited to a setting that directly called for effort mobilization.

Keywords: Implicit Affect, Automaticity, Effort, Cardiovascular,
1. Introduction

Research on the Implicit-Affect-Primes-Effort (IAPE) model (Gendolla, 2012) has revealed ample evidence that affective stimuli that are implicitly processed during cognitive tasks systematically influence effort-related responses in the cardiovascular system (see Gendolla, 2015 for an overview). The theoretical idea behind these findings was that people learn in everyday life that coping with challenges is easier in some affective states than in others. That way ease and difficulty become available features of individuals’ mental representations of different affective states. Based on the semantic priming principle (see Förster & Liberman, 2007; Neely, 1977), implicitly processed affect primes can thus render the performance ease and difficulty concepts accessible and influence experienced task demand and consequently effort. This is because effort mobilization is grounded in a resource conservation principle (Gibson, 1900), which holds that organisms avoid doing more than necessary for attaining their goals. Therefore, effort rises with experienced task demand as long as success is possible and the necessary effort is justified (Brehm & Self, 1989).

Importantly, the IAPE model posits that affect primes only influence effort and related physiological responses when the ease and difficulty features of affective states’ mental representations are applicable information in a given situational context—automaticity depends on the availability, accessibility, and applicability of activated knowledge (Förster & Liberman, 2007). That is, affect primes should only influence effort-related physiological responses in achievement contexts—i.e. when ideas about performance ease and difficulty are applicable for complying with the principle of resource conservation. In such settings, sadness and fear primes should render experienced task demand high, because both are associated with low coping potential, while happiness and anger primes should reduce subjective demand, since they are
associated with high coping potential (see Fredrickson, 2002; Lerner & Keltner, 2001; Smith & Lazarus, 1990).

Ample evidence has supported the IAPE model. Priming sadness or fear in easy tasks leads to stronger effort-related responses in the cardiovascular system than priming happiness or anger (e.g., Chatelain & Gendolla, 2015; Framorando & Gendolla, 2018; Gendolla & Silvestrini, 2011; Lasauskaite, Gendolla, & Silvestrini, 2013). By contrast, when people work on objectively difficult tasks, these affect prime effects are inversed: Happiness and anger primes generate stronger cardiovascular reactivity than sadness and fear primes (e.g., Chatelain, Silvestrini & Gendolla, 2016; Framorando & Gendolla, 2019; Freydefont, Gendolla, & Silvestrini, 2012; Lasauskaite Schüpbach, Gendolla, & Silvestrini, 2014; Silvestrini & Gendolla, 2011a; see also Blanchfield, Hardy, & Marcera, 2014; Silvestrini, 2018). This is because people use all available information to comply with the resource conservation principle. Therefore, the information about objective difficulty is added up with the ease and difficulty information that is made accessible by the affect primes. Consequently, in difficult tasks happiness and anger primes result in high but still feasible subjective demand resulting in high effort, while sadness and fear primes lead to the experience of excessive demand and thus disengagement.

To date, our experiments have always tested affect primes’ effects on cardiovascular responses in achievement contexts that required effort. The reason is that the IAPE model posits that ease and difficulty are applicable information in this context, since people should consider all available information about task demand in order to avoid wasting resources (Gendolla, 2012). Accordingly, the affect primes-related performance ease and difficulty information is only relevant in settings in which resources are engaged. The present experiment was designed as a conclusive test of this
hypothesis by manipulating the context in which affect primes were processed: We contrasted the effect of implicit affect on cardiovascular responses in an achievement context that directly called for effort, and in which implicitly activated information about task demand was applicable, with a context in which participants were rather passive. In the latter setting, affect primes should have no impact on cardiovascular responses, because performance ease or difficulty information is hardly applicable.

In addition to the primary goal of testing the context-dependency of implicit affect’s impact on effort, this study also tested an alternative explanation for affect primes’ effects on the cardiovascular system. Some studies found that the mere presentation of emotional pictures is sufficient to produce changes in sympathetic nervous system activity (e.g., Critchley et al., 2005; Lang, Greenwald, Bradley, & Hamm, 1993). This was explained by amygdala responses to emotive stimuli (e.g., Büchel, Morris, Dolan, & Friston, 1998; Critchley, Mathias, & Dolan, 2002; Phelps, O’Connor, Gatenby, Gore Grillon & David, 2001; Williams et al., 2001), which influenced sympathetic activity (e.g., Iwata, Chida, & LeDoux, 1987; LeDoux, Iwata, Cicchetti & Reis, 1998). Given that the cardiovascular activity measures we have usually assessed to monitor effort also reflect sympathetic nervous system activity, one could argue that the observed cardiovascular adjustments in fact reflected direct effects of the presented emotional stimuli we had used as affect primes rather than effort.

However, according to the IAPE model (Gendolla, 2012), affect primes’ effect on sympathetically mediated responses in the cardiovascular system should be limited to settings that directly call for effort mobilization. Keeping with this, a manipulation of the context in which affect primes are processed could answer the question whether cardiovascular responses indeed reflect effort. According to the IAPE model logic, affect primes should only systematically influence cardiovascular adjustments in an
achievement context, in which implicit affect can inform about task demand, but not in a rather neutral context that does not call for effort mobilization. That is, task context should moderate affect primes’ effect on cardiovascular responses.

1.1 Effort-Related Cardiovascular Response

According to Wright’s (1996) integration of motivational intensity theory (Brehm & Self, 1989) with the active coping approach (Obrist, 1981), effort is reflected by beta-adrenergic sympathetic nervous system activity on the heart. Beta-adrenergic activity especially influences cardiac contractility, reflected by pre-ejection period (PEP)—the time interval between the onset of the left ventricular depolarization and the opening of the left aortic valve (Berntson, Lozano, Chen, & Cacioppo, 2004). In support of this reasoning, PEP sensitively responds to manipulations of task demand (Richter, Friedrich, & Gendolla, 2008), incentive (Richter & Gendolla, 2009), and combinations of both (Silvestrini & Gendolla, 2011b).

Due to cardiac contractility’s impact on cardiac output (the volume of blood pumped by the ventricles per minute), several studies also assessed systolic blood pressure (SBP) to monitor effort (see Wright & Kirby, 2001; Richter, Gendolla, & Wright, 2016 for reviews). Still other studies relied on heart rate (HR) as effort measure (e.g., Eubanks, Wright, & Williams, 2002). Nevertheless, PEP is the more reliable effort measure, because it can directly mirror beta-adrenergic sympathetic impact (Kelsey, 2012). However, PEP should always be assessed together with HR and blood pressure to monitor possible preload (ventricular filling) or afterload (arterial pressure) effects on PEP (Sherwood et al., 1990): One can attribute PEP responses to beta-adrenergic sympathetic impact if decreases in PEP are not accompanied by simultaneous decreases of HR or blood pressure.
1.2 The Present Study

Participants were presented with letter series and briefly flashed sadness vs. happiness primes. To test whether affect primes influence cardiovascular responses only in an achievement context that directly calls for effort mobilization, half of the participants were asked to correctly memorize the vowels that occurred in the letter series. To correctly perform the task, participants in the achievement-context condition had to try to memorize 19 vowels—which is a challenging task. By contrast, the other half of the participants were asked to merely watch the letter series. This resulted in a 2 (Prime: sadness vs. happiness) x 2 (Context: achievement vs. watching) between persons-design.

In line with the IAPE model (Gendolla, 2012, 2015), we expected that the task context would moderate the affect primes’ effect: The affect primes should only influence effort-related cardiovascular reactivity, especially PEP, in the achievement-context condition. Specifically, given that the task was challenging, we predicted stronger responses in the happiness-prime than in the sadness-prime condition (e.g., Lasauskaite et al., 2014; Silvestrini & Gendolla, 2011a; see also Blanchfield et al., 2014). This is because happiness-primes should render the ease concept accessible, resulting in high but feasible subjective demand, while sadness-primes should activate the difficulty concept, resulting in very high subjective demand and thus disengagement. By contrast, the affect primes should not influence cardiovascular responses in the mere watching context. This results in a 3:1 pattern of cardiovascular reactivity with stronger responses in the happiness-prime/achievement condition than in the other three cells.

2. Method

2.1 Participants and Design
We aimed to collect data of 30 participants per condition to comply with the recommendation of having valid data of at least 20 participants per cell in between-persons designs (Simmons, Nelson, & Simonsohn, 2011). Thus, we randomly assigned 123 university students (87 women, 36 men; average age 22.62 ± 4.04) to the experimental conditions of a 2 (Prime: sadness vs. happiness) x 2 (Context: achievement vs. watching) design. However, 3 participants had to be excluded, because they did not follow the task instructions and 6 more participants were lost due to problems with the ICG monitor signal, leaving a final sample of \( N = 114 \). According to a sensitivity analysis run with G*power (Faul, Erdfelder, Lang, & Buchner, 2007), this sample size was sufficient to detect significant effects of a moderate size with 80% power in our design.

### 2.2 Affect Primes

We used grey scale, low frequency, averaged neutral (MNES: male neutral straight gaze, FNES: female neutral straight gaze), sad (MSAS: male sad straight gaze, FSAS: female sad straight gaze), and happy (MHAS: male happy straight gaze, FHAS: female happy straight gaze), front perspective face pictures (50% male, 50% female faces) of the Averaged Karolinska Directed Emotional Faces (AKDEF) database (Lundqvist & Litton, 1998) as affect primes.

### 2.3 Apparatus and Physiological Measures

We noninvasively measured impedance cardiogram (ICG) and electrocardiogram (ECG) signals with a Cardioscreen 1000 system (medis, Ilmenau, Germany) to assess HR and PEP. Four pairs of electrodes (Ag/AgCl, Medis, Ilmenau, Germany) were placed on the left and right sides of participants’ neck and chest. The signals were amplified, transformed into digital data with a sampling rate of 1000 Hz, and analyzed offline (50 Hz low pass filter) with BlueBox 2.V1.22 software (Richter, 2010). The first derivative of
the change in thoracic impedance was calculated, and the resulting $dZ/dt$ signal was ensemble averaged in 1-min intervals. B-point location was estimated based on the RZ interval of valid heart beat cycles (Lozano et al., 2007), visually inspected, and if necessary manually corrected as recommended (Sherwood et al., 1990). PEP (in ms) was determined as the interval between R-onset and B-point (Berntson et al., 2004). HR was determined on the basis of IBIs assessed with the Cardioscreen system. Additionally, SBP and diastolic blood pressure (DBP) were oscillometrically assessed in 1-min intervals with a Dinamap ProCare monitor (GE Healthcare, Milwaukee, WI). We placed the blood pressure cuff over the brachial artery above the elbow of participant’s non-dominant arm. For readers who are interested in a fuller picture of hemodynamic responses, which were not related to our hypotheses, we also assessed cardiac output and total peripheral resistance (see Supplementary Material).

2.4 Procedure

The experiment was approved by the local ethics committee. To prevent expectancy effects (e.g., Gilder & Heerey, 2018), the experimenter was hired and unaware of both the hypotheses and the experimental conditions. Participants were seated in a comfortable chair, gave signed consent, and were equipped with the physiological sensors. Then the experimenter started the computer program running the experiment (E-Prime, Psychology Software Tools, Pittsburgh, PA) and went to an adjacent control room. Participants first answered biographical questions (age, gender, etc.) and rated their affective state before the exposure to the affect primes (2 sadness items: down, sad; 2 happiness items: happy, joyful) on 7-point scales (1—*not at all*, 7—*very much*). To prevent suspicion, these affect measures were introduced as standard assessment, because people enter the laboratory in different feeling states. Next, participants watched a hedonically neutral documentary film about Norway (10 min) to
assess cardiovascular baseline values followed by a memory task (5 min) during which we assessed cardiovascular activity.

To test our hypotheses, we exposed all participants to the same implicit affect primes, but with one group accomplishing an achievement task while the other group did not. Therefore, we created a task that asked for continuous cognitive work with one response at the end rather than multiple reactions to single trials. All participants were presented with 36 different 4-letter series consisting of only consonants (e.g., “GDTC”, “LPQT”) or consonants and vowels (e.g., “WURN”, “HTOC”), which were preceded by briefly flashed and masked primes. In total, the 36 4-letter series contained 19 vowels (3 x A; 6 x I; 4 x E; 2 x O; 4 x U).

After the baseline assessment period, participants in the achievement-context condition were explicitly asked to memorize the vowels that would appear in the letter series and to note them thereafter. For instance, if participants saw the following series: “WUHC”; “DAUT”; “TXLP” they should memorize and later note the vowels “U, A, U”. Those in the watching-condition were instructed to just watch the letter series that would be presented. Given that this procedure asked for continued attention and memorizing for the entire task period, the task was considered as challenging.

Each trial of the task started with a fixation cross (750 ms), followed by a briefly flashed face picture (affect prime) that centrally appeared for 25 ms (i.e. 3 frames of a 120 Hz computer screen), followed by a grey random dot picture mask (133 ms). Half of the participants were presented with sadness expressions, while the other half were presented with happiness expressions. These emotional faces appeared in only 1/3 of the trials in order to prevent prime-habituation effects (Silvestrini & Gendolla, 2011a); neutral faces were presented in the other trials. The mask was followed by a second fixation cross (750 ms) and the series of 4 letters, which appeared for 4 sec. The inter-
trial interval randomly lasted from 2000 to 4000 ms. The task comprised 36 trials and took 5 min. All participants were presented with the same letter series in randomized order. Before the main task, participants performed 6 practice trials to familiarize with the procedure.

At the end of the task, all participants were asked to note the vowels they could remember from the formerly presented series—with the information that the exact order was not important. Next, participants rated subjective task difficulty, success importance, and the same affect items as at the procedure’s onset, using scales ranging from 1 (not at all) to 7 (very much). Moreover, they indicated whether they were taking any medication or suffered from cardiovascular health problems. Finally, participants were asked in a funnel debriefing to guess the study’s purpose and to describe a trial of the task. Those who mentioned flickers were asked to describe their content.

2.5 Data Analysis

We applied contrast analysis to test our theory-based predictions about the affect prime and task context effects on cardiovascular response, which is the most powerful and thus appropriate statistical tool to test predictions about patterns of means (Rosenthal & Rosnow, 1985; Wilkinson and the Task Force for Statistical Inference, 1999). As outlined above, we expected stronger cardiovascular responses (especially PEP) in the happiness-prime/achievement-context condition (contrast weight +3) than in the other three cells (contrast weights -1). Other variables, for which we had no theory-based a priori predictions, were analyzed with conventional exploratory ANOVAs. The alpha-error level for all tests was 5%. For reasons of consistency and easier comparability of effect sizes, we transformed effect size coefficients $r$ for tests with 1 degree of freedom (between participants) to coefficients $\eta^2$.

3. Results
3.1 Cardiovascular Baselines

As usual in our studies, we aimed at creating reliable cardiovascular baseline values by integrating as many 1-minute scores that were stable towards the end of the habituation period—it is typical that values at the beginning of habituation are significantly higher than at its end. Indeed, repeated-measures ANOVAs of the 10 1-min scores of PEP, HR, SBP and DBP assessed during the habituation period revealed significant Time main effects, $F$s(9, 1017) > 1.91, $p$s < .047, $\eta^2$ > .01, due to higher cardiovascular activity at the beginning of habituation. We calculated the cardiovascular baselines by averaging the last six minutes, which did not differ significantly according to Tukey tests ($p$s > .142) and proved high internal consistency (Cronbach's $\alpha$s > .98). Cell means and standard errors appear in Table 1.

Preliminary 2 (Prime) x 2 (Context) ANOVAs of the cardiovascular baseline scores revealed only a Context main effect on the DBP baselines, $F$(1, 110) = 5.22, $p$ = .024, $\eta^2$ = .05. Participants in the later Watching-Context condition had higher DBP baseline values ($M$ = 58.01, $SE$ = 1.09) than participants in the later Achievement-Context condition ($M$ = 54.66, $SE$ = 0.91). No other significant effects emerged for the other cardiovascular baselines ($p$s > .097).

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3.2 Cardiovascular Reactivity

Reactivity scores (Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991) were created by subtracting the baseline values from the averaged 1-min scores of cardiovascular activity assessed during the task. We ran preliminary ANCOVAs of the cardiovascular reactivity scores with the respective baseline scores as covariates to test
for possible associations. These analyses found a significant association between baseline and reactivity scores of DBP, $F(1, 109) = 10.23, p = .002, \eta^2 = .09$, and HR, $F(1, 109) = 3.98, p = .049, \eta^2 = .04$. Therefore, we further analyzed baseline-adjusted reactivity scores of DBP and HR in order to prevent possible carryover or initial values effects. No other significant associations between baseline and reactivity scores emerged for the other cardiovascular measures ($ps \geq .455$).

### 3.2.1 PEP Reactivity

Our theory-based a priori contrast for PEP reactivity, our primary effort-related measure, was highly significant, $F(1, 110) = 13.94, p < .001, \eta^2 = .11$, 95% CI [4.424; 14.435]. Cell means of the PEP responses are depicted in Figure 1 (A). As expected, and further supported by cell contrasts, PEP reactivity in the happiness-prime/achievement-context condition ($M = -4.52; SE = 1.27$) was significantly stronger than in the sadness-prime/achievement-context cell ($M = -2.40; SE = 0.48$), the happiness-prime/watching-context condition ($M = -0.66; SE = 0.32$), and the sadness-prime/watching-context cell ($M = -1.08; SE = 0.39$), $ts(110) > 2.01, ps \leq .047, \eta^2 > .03$. Within the watching-context condition, the affect primes had no significant effect ($p = .682$) and the low PEP reactivity in the sadness-prime/achievement-context condition did not significantly differ from that in the two watching-context conditions ($ps > .102$).

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### 3.2.2 HR Reactivity

Similar to PEP, also the a priori contrast for HR was highly significant, $F(1, 110) = 20.25, p < .001, \eta^2 = .16$, 95% CI [6.773; 17.434], and the pattern of the cell means depicted in Figure 1 (B) corresponded to our effort-related predictions. Cell contrasts revealed that HR reactivity in the happiness-prime/achievement-context condition ($M = 5.15; SE = 1.28$) was significantly stronger than in the sadness-prime/achievement-
context cell \((M = 2.78; SE = 0.67)\), the happiness-prime/watching-context condition \((M = 0.54; SE = 0.39)\), and the sadness-prime/watching-context cell \((M = -0.11; SE = 0.51)\), \(t(110) > 2.08, ps < .039, \eta^2 > .03\). Simultaneously, no significant prime effect emerged in the watching-context condition \((p = .478)\). Moreover, HR reactivity in the sadness-prime/achievement-context condition was significantly stronger than in the sadness-prime/watching context condition, \(t(110) = 2.61, p = .010, \eta^2 = .06\), but did not significantly differ from the happiness-prime/watching-context condition \((p = .060)\).

### 3.2.3 SBP Reactivity

The a priori contrast was also significant for SBP reactivity, \(F(1, 110) = 25.38, p < .001, \eta^2 = .19\), 95% CI \([8.176; 18.782]\), and, as depicted in Figure 1 (C), the pattern of systolic reactivity corresponded to our effort-related predictions. According to cell contrasts, SBP reactivity in the happiness-prime/achievement-context cell \((M = 5.89; SE = 1.14)\) was significantly stronger than in the sadness-prime/achievement-context \((M = 3.43; SE = 0.72)\), the happiness-prime/watching-context \((M = -0.02; SE = 0.60)\), and the sadness-prime/watching-context conditions \((M = 0.80; SE = 0.49)\), \(t(110) > 2.20, ps < .029, \eta^2 > .04\). Within the watching-condition, the affect primes had no significant effect \((p = .447)\) and reactivity in the sadness-prime/achievement-context condition was significantly stronger than in both watching-context conditions, \(t(110) > 2.36, ps < .019, \eta^2 > .04\).

### 3.2.4 DBP Reactivity

Also the a priori contrast for baseline-adjusted DBP reactivity was significant, \(F(1, 110) = 15.22, p < .001, \eta^2 = .13\), 95% CI \([3.219; 9.867]\). Cell means are depicted in Figure 1 (D). Focused cell contrasts revealed significantly stronger diastolic reactivity in the happiness-prime/achievement-context cell \((M = 3.59; SE = 0.69)\) than in the happiness-prime/watching-context \((M = 0.13; SE = 0.39)\), and the sadness-
Affect Primes and Task Context

prime/watching-context conditions ($M = 0.30; SE = 0.36$), $t(110) > 4.10$, $ps < .001$, $\eta^2 > .13$. However, within the achievement-context condition, the happiness-prime and sadness-prime cells ($M = 2.49; SE = 0.54$) did not significantly differ ($p = .764$). In addition, responses in the sadness-prime/achievement-context condition were significantly stronger than in both watching-context conditions, $t(110) > 2.86$, $ps < .005$, $\eta^2 > .06$.

3.3 Task Performance

A 2 (Prime) × 2 (Context) ANOVA of the number of correctly remembered vowels only found a significant Context main effect, $F(1, 110) = 334.12$, $p < .001$, $\eta^2 = .75$, 95% CI [9.298; 11.559], (other $ps > .648$). In the Achievement-Context condition, participants remembered far more vowels ($M = 13.76, SE = 0.50$) than in the Watching-Context condition ($M = 3.32, SE = 0.28$).

Moreover, a correlation analysis revealed that PEP reactivity during the task was negatively correlated with the number of correctly remembered vowels, $r = -.33$, $p < .001$, indicating a link between effort and performance—participants performed better when their PEP became shorter during the task. SBP, DBP, and HR were positively correlated with memory performance ($rs > .41$, $ps < .001$), which can be interpreted as a further indication of an effort-performance link in this study.

3.4 Experienced Affect

We created pre-task and post-task affect scores by summing the happiness and the reversed sadness ratings at both times of measure (Cronbach’s alphas ≥ .70). A 2 (Prime) x 2 (Context) x 2 (Time) mixed-model ANOVA only revealed a Time main effect, $F(1, 110) = 23.21$, $p < .001$, $\eta^2 = .17$, 95% CI [0.771, 1.849], reflecting slightly higher affect scores before ($M = 21.47, SE = 0.33$) than after the task ($M = 20.16, SE = 0.39$). Most relevant, ANCOVAs of all cardiovascular reactivity contrasts (PEP, HR, SBP, DBP)
with the post task affect scores as covariate remained significant ($p < .001$). This lends no support to the possibility that the affect primes had induced conscious feelings which in turn influenced the cardiovascular responses.

### 3.5 Task Ratings

A 2 (Prime) × 2 (Context) ANOVA of the success importance ratings revealed a significant Context main effect, $F(1, 109) = 14.95$, $p < .001$, $\eta^2 = .12$, 95% CI [0.457; 1.419]. No other effect was significant ($p > .558$). Participants in the Achievement-Context condition ($M = 5.70$, $SE = 0.15$) rated success importance as higher than those in the Watching-Context condition ($M = 4.76$, $SE = 0.18$). An ANOVA of the task difficulty ratings did not reveal any significant effects ($p > .143$). In general, the task was rated as relatively difficult ($M = 4.42$, $SE = 0.15$). The grand mean was significantly higher than the difficulty scale’s midpoint (3.5) according to a one-sample $t$-test, $t(110) = 6.22$, $p < .001$, $\eta^2 = .26$, 95% CI [0.63; 1.22].

### 3.6 Funnel Debriefing

In the funnel debriefing, no participant correctly guessed the purpose of the study. When asked to describe a trial, only 37 of the 114 participants reported to have seen an emotional face. This suggests that the large majority of the participants processed the primes implicitly. Moreover, the above reported a priori contrasts on the cardiovascular reactivity measures remained significant when they were run with the restricted sample of the 77 participants who had not reported to have seen emotional faces (see Supplementary Material).

### 4. Discussion

The present results support our predictions and provide evidence for the IAPE model (Gendolla, 2012, 2015) idea that implicit affect primes’ effect on cardiovascular responses is context-dependent and only applies to settings that call for effort.
mobilization. In the achievement-context condition, in which participants worked on a challenging memory task, briefly flashed happiness-primes resulted in stronger cardiovascular reactivity (PEP, HR, SBP, DBP) than sadness-primes, as indicated by significant a priori contrasts. This effect was predicted, because happiness-primes should have rendered the performance ease concept accessible, leading to high but still feasible task demand and thus the mobilization of high effort. By contrast, the sadness-primes should render the difficulty concept accessible and thus lead to disengagement due to excessive subjective demand—resulting in low effort. This replicates previous studies that contrasted the effects of happiness vs. sadness primes in easy vs. difficult tasks (e.g., Lasauskaite Schüpbach et al., 2014; Silvestrini & Gendolla, 2011a; see also Blanchfield et al., 2014). Other studies found corresponding effects for anger (related to ease) vs. sadness and fear primes (related to difficulty), showing that the affect primes’ effects are emotion-category specific rather than valence specific (e.g., Chatelain & Gendolla, 2015, 2016a; Freydefont et al., 2012; see also Chatelain & Gendolla, 2016; Framorando & Gendolla, 2018; Freydefont & Gendolla, 2012). Therefore, it is not a shortcoming that the present study administered affect primes of different valence—the corresponding effects of primes of different types of negative affect have been demonstrated before.

Most relevant for the present study’s purpose, when participants were exposed to the affect primes in a setting that merely asked for watching the letter series, the cardiovascular system did not respond. That is, as expected, affect primes’ impact on cardiovascular reactivity was context-dependent. Implicit affect only influenced the cardiovascular system in a context in which it could inform about task demand. Moreover, PEP reactivity—our primary measure of effort mobilization (Kelsey, 2012; Wright, 1996)—was not accompanied by simultaneous decreases in blood pressure or
HR, making it implausible to attribute the PEP responses to cardiac preload or vascular afterload effects rather than beta-adrenergic sympathetic nervous system impact (see Sherwood et al., 1990).

Furthermore, focused cell contrasts revealed that the manipulation effects were most pronounced for PEP, which is not surprising because PEP is the most sensitive measure of beta-adrenergic sympathetic impact and thus effort among the assessed indices. The significant a priori contrast for PEP was accompanied by significant cell contrasts, which further supported significantly stronger reactivity in the happiness-prime/achievement context condition than in the other three cells, which did not differ significantly from one another. This also means that there was no evidence that PEP reactivity in the sadness-prime/achievement-context condition was stronger than in the passive watching-context condition. We interpret the low PEP reactivity in the sadness-prime/achievement-context condition as indicating reduced effort due to too high subjective demand during performance. One could argue that the low reactivity in that condition differed, however, not from zero, as visible in the error bars. However, disengagement does not mean that participants fell back to complete passivity—they stayed in front of the computer screen and did not leave the laboratory. That is, participants remained involved in the experimental procedure, but—according to our interpretation—the weak reactivity, which was on a comparable level to that in the passive watching-context condition, indicates that they did not stay highly engaged in the task. We interpret this as disengagement.

The present context-dependency of the affect prime effects on cardiovascular responses speaks against the alternative idea that these autonomic adjustments actually reflect direct affective responses to visual emotive stimuli (see Lang et al., 1993; Critchley et al., 2005). Likewise, the context-dependency does also not support the idea
that the reported cardiovascular adjustments actually reflect the activation of embodied representations of happiness and sadness. The embodiment perspective suggests that activating the representation of an emotion instigates the simulation of that emotion, meaning a partly re-experience of it (e.g., Niedenthal, 2007). However, if the affect primes should have activated embodied representations of happiness and sadness, this should have happened in both the achievement-context and the watching-context conditions. Obviously, this was not the case.

Regarding our subjective measures, participants’ task difficulty ratings assessed after the task did not reveal any significant manipulation effects. Rather, all participants rated the task as relatively difficult. This may be surprising at first sight, as one could have expected at least a task-context main effect: Participants in the achievement-context condition could have rated task demand as higher than participants in the watching-context condition. However, it is to note that difficulty was rated after the task, i.e. after all participants had been asked to remember the previously presented vowels. This means that participants in the watching-context condition tried to remember vowels they had not intended to memorize in beforehand. Remembering this material should have been perceived as difficult—as in the achievement-context condition. Moreover, also the lack of a significant affect prime effect on the post task measure of difficulty is not surprising, given that the IAPE model is concerned with implicit effects on task demand during performance, rather than thereafter. In this context it is of note that studies by Lasauskaite, Gendolla, Bolmont, and Freydefont (2017) directly tested for implicit associations between happiness and ease vs. sadness and difficulty in a sequential priming paradigm and found clear evidence for the affect-demand associations posited in the IAPE model (Gendolla, 2012, 2015). Moreover, the observed significant task-context main effect on participants’ success importance ratings speaks
for the efficiency of the task-context manipulation, since only participants in the achievement-context condition worked on a cognitive challenge during the task, while those in the other condition were asked to be rather passive and merely watched the computer screen.

Also the task-context effect on the number of recalled vowels advocates for an efficient manipulation. Participants in the achievement-context condition performed better than those in the watching-context condition—which should be the case if only participants in the former condition had actively tried to memorize the presented vowels. Moreover, participants’ performance was correlated with the strength of their cardiovascular responses, reflecting a link between effort and performance in this study.

Finally, participants’ affect ratings did not reveal any evidence that the affect primes had induced affective states which in turn elicited cardiovascular arousal—which is consistent with all of our previous studies (see Gendolla, 2012, 2015 for overviews). Although zero-effects do not permit firm conclusions, the lack of evidence for prime effects on conscious affect supports the IAPE model idea that affect primes do not require conscious affect to influence effort. Nevertheless, in a broader perspective, our findings fit with research on consciously experienced mood states’ effects on resource mobilization (de Burgo & Gendolla, 2009). Also consciously experienced affect influenced cardiovascular responses only in a setting that directly called for effort and in which participants could use their moods as task-relevant information for assessing subjective demand during performance (Gendolla & Brinkmann, 2005). Similarly, the present study revealed that implicitly processed affect primes themselves are not sufficient for letting the cardiovascular system react. Rather, this only happened in a settings in which performance ease or difficulty were applicable features of individuals’ implicitly activated mental representations of different affective states.
In summary, the present findings provide evidence for the IAPE model (Gendolla, 2012, 2015) idea that implicit affect primes’ systematic effect on cardiovascular adjustments is context-dependent: Implicitly processed affect primes influence cardiovascular reactivity only in settings that call for effort mobilization and in which implicit affect can thus inform about task demand during performance.
References


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Footnotes

1 For readers who may be interested in gender differences in cardiovascular activity, we ran additional 2 (Prime) x 2 (Context) x 2 (Gender) ANOVAs. These analyses found a significant main effect of Gender on both the PEP, $F(1, 106) = 8.97, p = .003, \eta^2 = .08$, and the SBP baselines, $F(1, 106) = 18.36, p < .001, \eta^2 = .15$, as well as a Context x Gender interaction effect on the SBP baselines, $F(1, 106) = 7.96, p = .006, \eta^2 = .07$. Men had higher SBP ($M = 110.02, SE = 2.59$) than women ($M = 100.65, SE = 1.02$), which is a common finding (Wolf et al., 1997). Surprisingly, men had also longer PEP ($M = 106.65, SE = 1.92$) than women ($M = 100.66, SE = 0.99$), which seems to be conflicting with the result of SBP. In addition, Tukey tests revealed that men in the watching-context condition had stronger SBP baseline values ($M = 116.55, SE = 4.81$) than both men and women in the achievement-context ($M = 103.85, SE = 0.99; M = 100.40, SE = 1.60; ps < .005$) and women in the watching-context condition ($M = 100.87, SE = 1.33; p < .001$). No significant effects emerged for the other cardiovascular baselines ($ps > .086$).

2 The reported effects on cardiovascular reactivity were not moderated by participants’ gender, since no contrast x gender interaction was significant ($ps > .160$). Gender had also no significant main effects on cardiovascular response ($ps \geq .311$).
Author Note

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### Table 1
Means and Standard Errors (in parentheses) of the Cardiovascular Baseline Values.

<table>
<thead>
<tr>
<th></th>
<th>Achievement-Context</th>
<th>Watching-Context</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sadness Primes</td>
<td>Happiness Primes</td>
</tr>
<tr>
<td>PEP</td>
<td>101.92(1.62)</td>
<td>104.38(1.80)</td>
</tr>
<tr>
<td></td>
<td>102.63(1.86)</td>
<td>100.99(2.16)</td>
</tr>
<tr>
<td>SBP</td>
<td>103.40(1.87)</td>
<td>99.85(1.31)</td>
</tr>
<tr>
<td></td>
<td>104.41(2.19)</td>
<td>106.40(3.15)</td>
</tr>
<tr>
<td>DBP</td>
<td>56.29(1.60)</td>
<td>53.20(0.89)</td>
</tr>
<tr>
<td></td>
<td>58.18(1.37)</td>
<td>57.84(1.74)</td>
</tr>
<tr>
<td>HR</td>
<td>73.96(2.23)</td>
<td>73.76(1.95)</td>
</tr>
<tr>
<td></td>
<td>73.70(1.55)</td>
<td>75.36(2.02)</td>
</tr>
</tbody>
</table>

Note: PEP = pre-ejection period (in ms), SBP = systolic blood pressure (in mmHg), DBP = diastolic blood pressure (in mmHg), HR = heart rate (in beats/min).
Figure Captions

**Figure 1.** Cell means and ±1 standard errors underlying the Prime x Context interaction effects on cardiac pre-ejection period reactivity (in ms), HR reactivity (in beats/min), SBP (in mmHg), and DBP (in mmHg) during task performance.