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High-approach and low-approach positive affect influence physiological responses to threat and anger

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ABSTRACT

Positive affect has been related to faster cardiovascular recovery from stress. Although the family of positive affective states is diverse, no study examined whether high-approach positive affect (e.g., desire) has a different impact on peripheral physiological processes than more frequently studied low-approach positive affect (e.g., amusement). Building upon prior work on emotions and motivation, we expected that after controlling for arousal and valence, positive affect with higher motivational intensity would facilitate weaker recovery when compared to positive affect with lower motivational intensity. Across two experiments (N = 179 for Study 1, N = 220 for Study 2), we measured cardiovascular, respiratory, and electrodermal responses to positive stimuli that differed in approach intensity. We measured responses during recovery from stress and during reactivity to threat and anger. These studies partially replicated previous findings regarding the soothing function of positive affect (e.g., in respect to diastolic blood pressure recovery and reactivity). However, we found that high-approach and low-approach positive affect produced comparable effects. In summary, these findings suggest that positive valence rather than motivational intensity produces the main soothing effect on peripheral physiology.

1. Introduction

Positive emotions, such as contentment and amusement, evolved to assist individuals in accelerating physiological (Fredrickson and Levenson, 1998; Fredrickson et al., 2000), cognitive (Fredrickson and Branigan, 2005), and emotional (Monfort et al., 2015) recovery from stress and negative emotions. This soothing or undoing effect is hypothesized to originate from grooming behaviors that associate soothing with comfort and pleasure (Levenson, 1999). Faster recovery from stress is beneficial because it minimizes the expenditure of physiological resources and shifts the organism from catabolic to anabolic processes (McEwen and Lasley, 2003). Consequently, positive emotions serve a health protecting function that has been evidenced in the literature (Pressman and Cohen, 2005; Davidson et al., 2010).

However, there is another class of understudied positive emotions that are infused with high-approach positive affect, such as enthusiasm or desire, that assist individuals in the pursuit of goals (Griskevicius et al., 2010). Several studies have shown that high-approach positive affect differs from low-approach positive affect in neural correlates (Harmon-Jones et al., 2008), and in their effects on cognition (Gable and Harmon-Jones, 2008; Gable and Harmon-Jones, 2010b; Li et al., 2018). However, little is known how high-approach positive affect differs from low-approach positive affect in their effect on peripheral physiology, e.g., the cardiovascular, pulmonary, and electrodermal stress responses that are initiated when individuals pursue goals (Mendes and Park, 2014). In two experiments, we examined how high-approach positive emotions differ from low-approach positive emotions in their effects on a wide range of physiological processes during reactivity to and recovery from stress. The outcomes of this examination are likely to inform positive emotions theory (Shiota et al., 2017), as well as interventions that use positive affect to optimize health and well-being (Quoidbach et al., 2015). There have been calls for more research on different types of positive emotions based on the likelihood that low-arousal positive affect will have a more uniform beneficial influence on physiological health-related processes (Pressman et al., 2019). There are also recent concerns that, thus far, empirical evidence for the undoing effect is limited (Cavanagh and Larkin, 2018).

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1.1. Valence and the approach-avoidance motivation

Theorists have been discussing the motivational function of emotions for centuries (e.g., Darwin, 1965; Levenson, 1994). The role of positive emotions, however, was often underestimated by theorists and little functional differentiation had been made within the family of positive emotions for decades (see Fredrickson, 1998; Shiota et al., 2017). Notable theoretical advancement was achieved with the broaden-and-build theory of positive emotions (Fredrickson, 2001). The main point in the broaden-and-build theory is that the experience of positive emotions broadens momentary thought-action repertoire (Fredrickson and Branigan, 2005), which, in turn, helps individuals in acquiring long-term informational, social, and material resources (Fredrickson et al., 2008). One of notable aspects of this theory is that positive emotions serve as a resilience factor that helps individuals to oppose or undo the effects of negative experiences and to bounce back from adversity (Fredrickson and Levenson, 1998; Tugade and Fredrickson, 2004; Fredrickson et al., 2003).

Recent findings regarding anger and desire have resulted in a new model for the core qualities of affect, namely, the Motivational Dimensional Model of Affect (Gable and Harmon-Jones, 2010a). First, the model draws on observations that left, and right frontal cortical regions are differentially involved in positive affect and negative affect, as well as approach and avoidance motivation (Davidson, 1998). Left frontal cortical activity is associated with greater approach motivation intensity rather than valence (Harmon-Jones and Gable, 2017). For instance, desire and anger increase left frontal cortical activity despite their differences in valence (Peterson et al., 2010; Schöne et al., 2016). Second, the model accounts for differential effects of high-approach and low-approach positive affect in their influence on cognitive scope. Previous theories suggested that all positive emotions broaden the cognitive scope (Fredrickson, 2001; Fredrickson and Branigan, 2005; Isen and Daubman, 1984). More recent research revealed that this is true only for low approach intensity positive affect (e.g., amusement or satisfaction). In contrast, positive affect high in approach motivational intensity (e.g., desire or interest) narrows the cognitive scope (Gable and Harmon-Jones, 2008).

The Motivational Dimensional Model of Affect presents valence, arousal, and approach-avoidance motivational intensity as the distinct building blocks of human affective experience. The ‘motivational direction intensity of affect’ refers to the urge to move toward or away from an object without specifying the valence of the stimuli toward which the impulse is directed (Harmon-Jones et al., 2013). Positive valence and approach motivation are usually highly correlated (Cacioppo et al., 1999; Marchewka et al., 2014). Individuals are likely to approach stimuli (e.g., objects, events, or possibilities) that elicit positive feelings and likely to avoid stimuli that elicit negative feelings (Gray, 1981; Kahneman, 1999). However, this general relationship between valence and approach-avoidance motivation, observed across the majority of situations, can be different for some specific emotions. The objects of anger are negatively valenced, but individuals are nonetheless motivated to approach the objects of anger, e.g., to intervene or punish the anger-provoking agents (Carver and Harmon-Jones, 2009). Furthermore, despite a linear relationship between valence and approach motivation, for some emotions, approach motivation can be stronger than valence (such as with desire), or it can be weaker than valence (as with amusement; Gable and Harmon-Jones, 2008).

Differentiation between high-approach and low-approach positive affect helped to explain a wide range of phenomena and provided a better functional distinction between emotions (Gable and Harmon-Jones, 2008; Gable and Harmon-Jones, 2010b). There is, however, little systematic examination of how affect and motivational intensity operate together to produce different outcomes in peripheral physiology. Accounting for the interplay between valence and approach-avoidance motivation in their impact on healthy physiological responses is essential to explain the primary functional differences between various forms of positive affect (Shiota et al., 2017).

1.2. Approach-related physiological responses

There are theoretical reasons to believe that high-approach positive emotions might influence healthier stress onsets. This is because approach motivation has been related to challenge-type physiological responses whereas avoidance motivation has been related to threat-type responses (Beltzer et al., 2014). The state of anger has also been related to the challenge-type response (Herrald and Tomaka, 2002; Jamieson et al., 2013). Challenge appraisal is characterized by a faster onset and offset of responses, which indicates that the physiological resources for action are mobilized and demobilized efficiently. In contrast, the threat appraisal is dominated by the hypothalamic-pituitary-adrenal axis and leads to increased cortisol secretion; a catabolic hormone that results in a prolonged stress response. Thus, elicited high-approach positive affect is likely to promote challenge responses.

Challenge and threat appraisals occur when individuals are motivated to engage in active goal pursuits and do their best, e.g., while taking school exams (Seery et al., 2010), negotiating prices (Scheepers et al., 2012), or learning new skills (Moore et al., 2014). Cognitive evaluations of the self and the environment influence the motivational system that mobilizes the physiological resources which are necessary for successful action (Mendes and Park, 2014). When challenged or threatened, individuals respond with changes in several physiological systems along the sympathetic-adrenal-medullary axis and hypothalamic-pituitary-adrenal axis (Mendes and Park, 2014). Increased goal-oriented motivation leads to increased sympathetic activation in the autonomous nervous system. Individuals with stronger motivational intensity display higher HR reactivity. This initial physiological response is likely to be modulated when individuals further evaluate their personal action resources (e.g., skills, knowledge, and abilities) as well as situational demands. Challenge motivation occurs when individuals perceive the sufficiency of available resources to overcome situational demands. After adrenaline is released into the bloodstream, blood vessels widen, and this produces lower total peripheral resistance (Brownley et al., 2000), and higher cardiac output, i.e., the amount of blood pumped by the heart. When demands are higher than the coping resources, individuals evaluate the situation as threatening. Consequently, the autonomous nervous system inhibits adrenaline and releases cortisol. This causes the arteries to narrow despite the increased heart rate, which results in higher total peripheral resistance and decreases cardiac output.

1.3. A multivariate approach to the measurement of emotions

Emotions engage complex subjective, physiological, and behavioral responses that optimize bodily preparedness for effective coping (Levenson, 1994; Gross, 2015). Despite some evidence for the coherence between systems involved in affective responding (Lazarus, 1991; Levenson, 1994), there are usually weak relationships between physiological responses and subjective or behavioral outcomes (Mauss et al., 2005). A multivariate approach is necessary to make sure that meaningful affective responses are elicited and to identify specific affective subsystems that are significantly engaged (Mauss and Robinson, 2009; Thayer and Friedman, 2000).

A multivariate approach to physiology is crucial for the interpretation of outcomes because there are several components of cardiovascular arousal that have different prognostic value for the development of cardiovascular disease (Hughes, 2007; Guzik et al., 2010). Furthermore, although the physiological signals studied in the context of psychophysiology are influenced by the autonomous nervous system activity, these physiological parameters are often linked to different emotional and motivational processes (Blascovich et al., 2011). For instance, cardiac output and total peripheral resistance have been uniquely related to motivated performance due to their contribution to building increased cardiac efficiency (Behnke and Kaczmarek, 2018; Jamieson et al., 2012; Seery, 2011). Cardiac output (the amount of blood ejected from the heart during a minute) and total peripheral resistance (a measure of total vascular resistance) have been used as markers for the evaluation of threat-and-challenge physiological response (Seery, 2011). Decreases in cardiac output and increases in total peripheral resistance worsen cardiac efficiency and are observed when individuals are threatened (Jamieson et al., 2012; Seery, 2011). Surprisingly, none of these critical action-oriented parameters have ever been explored in the context of positive emotions in recovery from stress (c.f., Cavanagh and Larkin, 2018). Accounting for these hemodynamic parameters is likely to provide a more nuanced analysis of physiological arousal in the context of the soothing function of positive affect.

Furthermore, few studies on the undoing effect have accounted for electrodermal responses (Medvedev et al., 2015; Monfort, 2012). This is a noteworthy limitation of the empirical evidence for the undoing hypothesis. Skin conductance is a unique measure of sympathetic arousal that is related to affective processing (Nagai et al., 2004; Waugh et al., 2011). It supplements other biosignals that are mostly under the combined sympathetic and parasympathetic influence (Blascovich et al., 2011). Thus, accounting for skin conductance provides more information that can help to interpret complex physiological responses, i.e., whether they are more likely to reflect sympathetic withdrawal (e.g., decreases in skin conductance levels) or activation of the parasympathetic/vagal break. For instance, two studies on the undoing hypothesis have been conducted revealing no effects of elicited positive affect on skin conductance levels (Monfort, 2012; Medvedev et al., 2015). This seems to suggest that the undoing effects might be attributed mostly to the vagal influences.

Similarly, only one undoing hypothesis study investigated the effects of positive affect on respiration rate; with no significant effects observed (Purdum, 2010). Increased respiration rate results from sympathetic activation and/or vagal withdrawal (Berntson et al., 1993). Furthermore, only one study has investigated effects on fingertip temperature (Yuan et al., 2010), an indicator of sympathetic activity that results in peripheral vasoconstriction (Kistler et al., 1998): finger temperature increases in positive circumstances and decreases in threatening situations (Rimm-Kaufman and Kagan, 1996). In that study, fingertip temperature was measured as a compound of several physiological signals (Yuan et al., 2010). Thus, we can say little about its unique contribution to the observed positive effects.

Finally, despite some work on the undoing effects where different biosignals were averaged to calculate one index of physiological arousal (Fredrickson and Levenson, 1998; Yuan et al., 2010), a recent literature review on the undoing hypothesis indicated that the effects of positive affect on specific physiological responses are somewhat scattered and inconsistent (Cavanagh and Larkin, 2018). Thus, it is problematic to predict which biological systems or physiological parameters are most likely to reflect the influence of positive emotions. Consequently, this might suggests that more exploratory work with several signals analyzed separately is still needed to study positive emotions and their effects on the physiological arousal. Such an approach is likely to result in a more coherent, multifaced description of the phenomenon and more reliable conclusions in future meta-analyses.

2. Study 1

In Study 1, we examined how high-approach and low-approach positive emotions influence recovery from stress. We aimed to test whether presenting high-approach positive pictures (vs. low-approach positive pictures) will help participants to down-regulate their physiological arousal after a stressful task. Despite several studies that have documented the undoing or soothing effects of positive emotions on peripheral physiology (Fredrickson and Levenson, 1998; Fredrickson et al., 2000), no research has examined how physiological recovery depends on the motivational intensity of current affective experience. We expected that high-approach positive emotions are likely to be less efficient in the recovery process because they elicit high-approach motivation along with physiological mobilization required for an active pursuit of further goals (Mendes and Park, 2014). Based on the previous literature (Cavanagh and Larkin, 2018), we expected the down-regulation effects to occur for systolic blood pressure, diastolic blood pressure, and heart rate. We also explored whether similar effects are likely to occur for other understudies physiological parameters such as cardiac output, total peripheral resistance, fingertip temperature, respiration, and skin conductance.

2.1. Method

2.1.1. Participants

This study involved 171 volunteers (71.4% female) between the ages of 19 and 32 years old (M = 21.84, SD = 2.42). Power analysis with G*Power 3.1 (Faul et al., 2009) indicated that a sample size of 159 participants is required to detect moderate effect sizes of $f = 0.25$, type I error probability of $\alpha = 0.05$ for ANOVA with three groups and power of 0.80. Previous research has documented that positive emotions produce medium-to-large effect sizes for the physiological undoing effects (Fredrickson and Levenson, 1998; Monfort et al., 2015), as well as for the cognitive differences between high-approach and low-approach positive affect (Gable and Harmon-Jones, 2008). Volunteers were Caucasian undergraduates with Body Mass Index (BMI) between 16.51 and 29.96 kg/m^2 (M = 22.33, SD = 2.63). Nine persons were excluded from the sample due to BMI > 30. Other exclusion criteria were significant health problems, use of drugs or medications that might affect cardiovascular functions, and prior diagnosis of cardiovascular disease or hypertension. Participants were asked to reschedule if they experienced illness or a major negative life event. We instructed participants to avoid eating for at least 1 h before the experiment and to refrain from physical exercise and the intake of caffeine, nicotine, alcohol, or non-prescription drugs for at least 2 h before the experiment. Each participant received a cinema ticket for their involvement. The study was approved by the Institutional Ethics Committee.

2.1.2. Measures

2.1.2.1. Heart rate. Electrocardiogram was sampled at 1 kHz with BioAmp and a Powerlab 16/35 AD converter (ADInstruments, NewZealand). ECG was recorded with Ag–AgCl surface electrodes on the chest, and stored on a computer with other physiological variables using a computer-based data acquisition and analysis system (LabChart 8.1; ADInstruments, NewZealand). R peaks were identified automatically by ECG Analysis 2.4 module in LabChart 8.1, inspected visually, and corrected manually when necessary. Based on the RR intervals we calculated heart rate (HR). HR was reported in beats per minute (BPM).

2.1.2.2. Hemodynamic parameters. Systolic blood pressure (SBP), diastolic blood pressure (DBP), cardiac output (CO) and total peripheral resistance (TPR) were recorded continuously beat-by-beat using a Finometer MIDI (Finapres Medical Systems, Netherlands). Measurements are produced by the Finometer based on the volume-clamp method first developed by Penaz (1973). Finger arterial pressure waveforms were recorded with finger cuffs. The data were analyzed with BeatScope 2.0 (Finapres Medical Systems, Netherlands) (Wesseling et al., 1995). CO was reported in liters per minute (l/min), and total peripheral resistance in centimeter-gram-seconds (mmHg· min/l).

2.1.2.3. Fingertip temperature. Fingertip temperature was measured with a temperature probe attached to a Thermistor Pod (ADInstruments, New Zealand) at the distal phalange of the V finger of the left hand, sampled at 1 kHz, and reported in degrees Celsius.

2.1.2.4. Respiration. We measured chest circumference changes during respiration with a piezo-electric belt, Pneumotrace II (UFI, USA). The number of respiratory cycles was computed using the Cyclic Measurements module in LabChart 8.1 (ADInstruments, New Zealand). The number of respiratory cycles per minute provided the respiratory rate.

2.1.2.5. Skin conductance. Electric skin conductance levels (SCL) were sampled with the GSR Amp (ADInstruments, New Zealand) at 1 kHz and reported in micro siemens (μS). We used electrodes with a contact area of 8 mm diameter filled with a TD-246 sodium chloride skin conductance paste that was attached with adhesive collars and sticky tape to the medial phalanges of digits II and IV of the left hand.

2.1.3. Affective pictures

We selected pictures from the Nencki Affective Pictures System, an extensive database of photos that provides a rating of valence, arousal, and approach-avoidance motivational intensity as well as basic emotions for most of the pictures (Marchewka et al., 2014). For positive pictures, we selected two groups of items: high-approach positive affect and low-approach positive affect.

To distinguish between these two groups, we first selected pictures that were one standard deviation above (6.63) the mean for valence. From these pictures, we selected those that had the highest and the lowest approach motivation -to -valence ratios. The high-approach pictures featured luxury goods, desserts, and physically attractive people. The low-approach pictures presented happy elderly individuals, children, and animals. For the neutral pictures, we selected 30 items with valence ratings and approach motivations closest to the mean (e.g., street passers-by, buildings, ordinary objects, and neutral individuals) and similar arousal ratings as the positive pictures. The final set consisted of 30 pictures for each condition. Manipulation checks confirmed that the pictures did not differ in arousal, F (2, 87) = 0.63, $p > .05$ but, as intended, differed in valence, F (2, 87) = 302.43, $p < .001$. High-approach and low-approach sets did not differ from one another in valence, $p > .05$, but differed from the neutral set, all $ps < .001$. Finally, the sets also differed in approach motivation, F (2, 87) = 285,12, $p < .001$, such that the high-approach set had higher approach intensity than the low-approach or neutral sets, all $ps <$ .001, with the low-approach set exhibiting higher motivational intensity than the neutral set, $p < .001$.

Participants reported retrospectively on emotions they experienced while watching the pictures based on a hybrid discrete-dimensional model of affect that accounts for lower-order discrete emotions and higher-order affective dimensions (Stephens et al., 2010; Shiota et al., 2011). Using a MANOVA, we confirmed that groups differed in their emotional responses, F (34, 296) = 9.44, $p < .01$. Individuals in the high-approach group experienced more desire, excitement, and enthusiasm compared to the low-approach group, and less fear, disgust, and anger compared to the neutral group (Table 1). Individuals in the low-approach group experienced more amusement than individuals in the high-approach positive emotions group. Individuals in the high-approach and low-approach groups experienced similar levels of happiness that were higher than in the control group. Groups did not differ in surprise. These findings supported our expectation that there would be more high-approach positive emotions (desire, enthusiasm, and excitement) in response to the pictures in the high-approach group, as well as stronger low-approach emotions (amusement) in the low-approach group.

2.1.4. Threat elicitation

To generate significant physiological stress responses, we administered a well-validated social threat protocol (Fredrickson et al., 2000; Mendes et al., 2008; Wager et al., 2009). Participants were given 30 s to prepare a 2-minute speech (on the topic "Why are you a good friend?") that would be recorded. We informed participants that after the speech preparation they would be randomly selected to deliver the speech or not. After 30 s of preparations (anticipatory stress), each participant was informed that they were selected not to deliver the speech.

2.1.5. Procedure

Upon arrival, volunteers provided written informed consent. We attached the biosensors and the experiment began with a 5-min baseline (Fig. 1). Afterward, participants completed the speech preparation stressor. Later, depending on randomization, affective pictures were presented on the PC screen to elicit high-approach motivation positive affect, low-approach motivation positive affect, or the neutral state.

2.1.6. Analytic strategy

To investigate the physiological recovery from the anticipated threat in response to elicited affect, we conducted Analyses of Variance (ANOVA) with physiological responses as dependent variables and affect as the factor (with three levels: high-approach positive affect, low-approach positive affect, and neutral). To control for Type I errors, we corrected each p-value for false discovery rate (Benjamini and Hochberg, 1995) regarding hypothesized outcomes, and used Tukey's HSD test for post hoc pairwise comparisons. For each dependent variable, we calculated a residualized change score that accounted for individual differences in baseline and reactivity. We regressed the recovery score of each dependent variable on its baseline and reactivity levels and saved regression residuals. Residualized change scores informed whether particular affect facilitated recovery above expectations based on the baseline and reactivity of each individual. Positive scores indicated that individuals had higher levels of physiological arousal (i.e., recovered less) than their baseline and reactivity suggested. Negative scores indicated that individuals recovered more than expected. Thus, this approach asked whether a member of one group was expected to change more than a member of other groups, given that they had the same initial values. For each dependent variable, we removed outliers that had z-scores higher than 3.29 (Field et al., 2012). Based on this criterion, we removed ten participants for respiratory rate and fingertip temperature analysis, seven participants for SBP, DBP, HR, and SCL, and five for CO and TPR. Analyses were performed with SPSS 21.0 (IBM, USA).

2.2. Results

2.2.1. Manipulation check

Participants responded to the speech preparation stressor with large responses in SBP, DBP, HR, CO, SCL (Table 2). They also responded with moderate increases in respiratory rate and skin temperature and decreases in TPR.

2.2.2. Effects of effect on physiological recovery from anticipated threat

We found that elicited affect influenced levels of SBP and DBP in the recovery phase (Table 3; Fig. 2). A Tukey's HSD post hoc test revealed that individuals produced stronger DBP recovery in response to both high-approach and low-approach positive affects compared to the neutral conditions. For SBP, individuals in the low-approach positive affect group recovered more than individuals in neutral conditions. Yet, there were no statistically significant differences between the high-approach and low-approach positive affect group in their influence on the SBP recovery. No other significant effects occurred for HR and for the exploratory dependent variables.

2.3. Discussion

This study is the first to test differences between the impact of high-approach positive affect vs. low-approach positive affect on several responses in peripheral physiology (cardiovascular, electrodermal, and respiratory). Building upon previous research (Harmon-Jones et al., 2008), we tested whether approach motivation influences the efficiency

Table 1
Discrete emotions produced by the affective photos.

	M (SD)			F	p	Post hoc
	(A) High-approach PA	(B) Low-approach PA	(C) Neutral			
Curiosity	6.36 (1.92)	5.58 (2.00)	5.19 (2.29)	4.67	.011	A > C
Tenderness	3.29 (2.21)	5.35 (2.07)	2.83 (2.11)	22.29	< .001	A > B, B > C
Enthusiasm	6.80 (1.91)	5.58 (2.11)	3.04 (1.80)	53.59	< .001	A > B, A > C, B > C
Love	3.49 (2.40)	4.44 (2.51)	2.21 (1.63)	13.81	< .001	A > C, B > C
Excitement	6.22 (2.08)	3.79 (2.00)	3.11 (1.96)	37.54	< .001	A > B, A > C
Desire	4.93 (2.99)	2.42 (1.79)	1.32 (0.70)	44.46	< .001	A > B, A > C, B > C
Amusement	4.08 (2.44)	6.21 (2.21)	3.04 (2.35)	26.58	< .001	A < B, B > C
Sadness	1.49 (1.24)	1.72 (1.25)	4.13 (2.56)	37.49	< .001	A < C, B < C
Calmness	6.41 (1.84)	6.04 (1.92)	5.36 (2.18)	4.00	.02	A > C
Fear	1.86 (1.50)	1.79 (1.61)	2.98 (2.27)	7.39	.001	A < C, B < C
Happiness	5.98 (2.33)	5.47 (2.07)	3.00 (2.04)	30.05	< .001	A > C, B > C
Disgust	1.41 (1.12)	2.40 (2.16)	2.98 (2.24)	9.99	< .001	A < B, A < C
Awe	6.73 (1.80)	4.21 (2.14)	2.74 (2.06)	57.39	< .001	A > B, A > C, B > C
Content	6.75 (1.97)	5.86 (1.94)	3.21 (2.14)	45.88	< .001	A > C, B > C
Interest	7.22 (1.68)	6.14 (1.74)	5.68 (2.12)	10.39	< .001	A > B, A > C
Surprise	3.80 (2.27)	4.00 (2.28)	3.91 (2.51)	0.11	.879	–
Anger	1.24 (0.88)	1.25 (0.81)	2.06 (1.78)	8.16	< .001	A < C, B < C

Post-hoc testes = Tukey's HSD; > and < indicate significant differences between groups at $p < .05$.

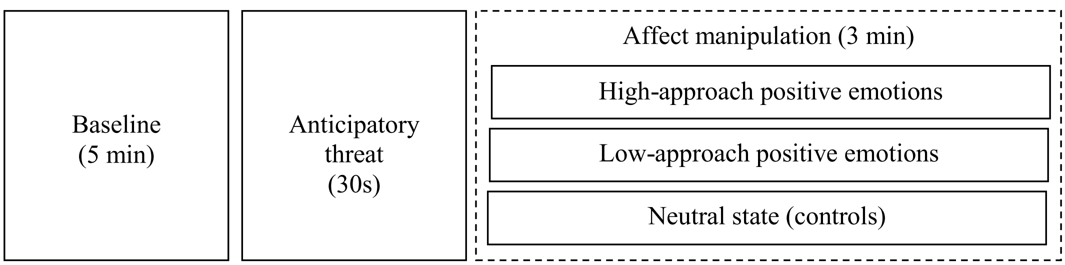

Fig. 1. Study 1 procedure.

of physiological recovery from anticipated threat. We replicated and extended previous findings that have shown the effects of positive emotions on stronger cardiovascular recovery (Fredrickson and Levenson, 1998; Fredrickson et al., 2000). We observed that individuals had lower-than-expected levels of DBP in response to both types of positive stimuli compared to neutral conditions. These effects were independent of motivation intensity of elicited affect. Furthermore, we found lower levels of SBP in response to low-approach positive emotions. The effects for high-approach positive affect and SBP were less consistent.

SBP and DBP are robust predictors of cardiovascular disease risk and longevity (Prospective Studies Collaboration, 2002). Thus, these findings corroborate previous theories and empirical evidence that positive emotions are health-protective (Pressman and Cohen, 2005). Notably, our research corresponds with previous studies indicating that positive affect buffers the effects of negative affect in its influence on daily SBP and DBP (Ong and Allaire, 2005). Furthermore, we found no effects of positive affect on HR. This appears to contradict the undoing hypothesis, but it replicates what has been found in some previous studies (Hannesdóttir, 2007; Steptoe et al., 2007). Likewise, we observed no undoing effects for respiration and fingertip temperature, again in line with previous studies (Purdum, 2010). We were the first to present findings for CO and TPR in the context of undoing effects (c.f. Cavanagh and Larkin, 2018). However, we observed no effects of positive affect on these parameters. CO and TPR, along with HR, are related to motivated performance and increased cardiac efficiency (Jamieson et al., 2012). This might indicate that individuals in the recovery phase, regardless of elicited affect, maintained comparable levels of resources mobilized in preparation to cope with the anticipated speech stressor. Decreases in SBP and DBP with little responses from other systems have

Table 2
Physiological reactivity to stress in Study 1.

	Baseline		Stress		F	df	p	η^2
	M	SD	M	SD				
SBP [mm Hg]	118.54	14.19	131.70	14.32	480.96	1, 150	< .001	0.76
DBP [mm Hg]	69.09	9.25	76.91	9.94	516.97	1, 151	< .001	0.77
HR [beats/min]	82.22	11.80	92.96	13.40	303.23	1, 152	< .001	0.67
CO [l/min]	6.55	1.42	7.70	1.68	391.96	1, 153	< .001	0.71
TPR [mmHg· min/l]	0.85	0.18	0.81	0.19	27.99	1, 153	< .001	0.15
Resp. rate [b/min]	16.94	3.79	18.91	4.06	42.49	1, 149	< .001	0.22
SCL [μS]	1.72	2.91	3.61	3.57	195.89	1, 148	< .001	0.57
Fingertip temp. [°C]	33.15	2.75	33.18	2.72	9.86	1, 150	.001	0.06

Note. SBP = systolic blood pressure, DBP = diastolic blood pressure, CO = cardiac output, TPR = total peripheral resistance, HR = heart rate, SCL = skin conductance level.

Table 3
The effects of high-approach and low-approach positive affect on recovery from anticipated threat (Study 1).

	Neutral (A)		Low-approach PA (B)		High-approach PA (C)		F	df	p [p-corr.]	η^2	Post hoc
	M	SD	M	SD	M	SD					
Expected:											
SBP [mm Hg]	4.93	13.60	−3.49	15.84	−1.23	14.05	4.38	2, 152	.014 [.02]	0.06	A < B
DBP [mm Hg]	3.28	7.94	−1.67	8.80	−1.52	8.86	5.22	2, 152	.006 [.02]	0.06	A < B, A < C
HR [beats/min]	−1.06	9.87	1.10	10.90	0.11	12.70	0.46	2, 152	.634 [.63]	0.01	–
Explorative:											
CO [l/min]	0.14	1.29	−0.12	1.50	0.03	1.27	0.48	2, 149	.620	0.01	–
TPR [mmHg·min/l]	0.01	0.17	0.01	0.15	−0.02	0.15	0.52	2, 149	.594	0.01	–
Resp. rate [b/min]	0.07	3.56	0.09	3.33	−0.22	3.38	0.14	2, 154	.866	< 0.01	–
SCL [μS]	0.21	2.31	−0.25	2.34	0.12	2.67	0.51	2, 152	.601	0.01	–
Fingertip temp. [°C]	−0.24	2.96	0.35	2.51	−0.13	2.70	0.14	2, 154	.503	< 0.01	–

Note. SBP = systolic blood pressure, DBP = diastolic blood pressure, CO = cardiac output, TPR = total peripheral resistance, HR = heart rate, SCL = skin conductance level. Residual change scores controlled for differences in baseline and reactivity. Post hoc tests = Tukey's HSD. p-Values for the hypothesized outcomes corrected for False Discovery Rate and reported in brackets.

been attributed to contentment (Kreibig, 2010). This might suggest that the physiological responses in the recovery were driven by affective rather than cognitive goal-oriented processes.

In sum, Study 1 extends previous findings suggesting that high-approach and low-approach positive affect have an equal influence on physiological recovery. It also indicates the benefits of using the multilayer approach rather than averaging several biosignals. These findings are the first to show the predictive limitations of the Motivational Dimensional Model of Affect. We observed that motivational intensity of affect had little influence on physiological responding. With significant previous findings regarding brain activity and cognitive processes (Harmon-Jones et al., 2008), this is the first

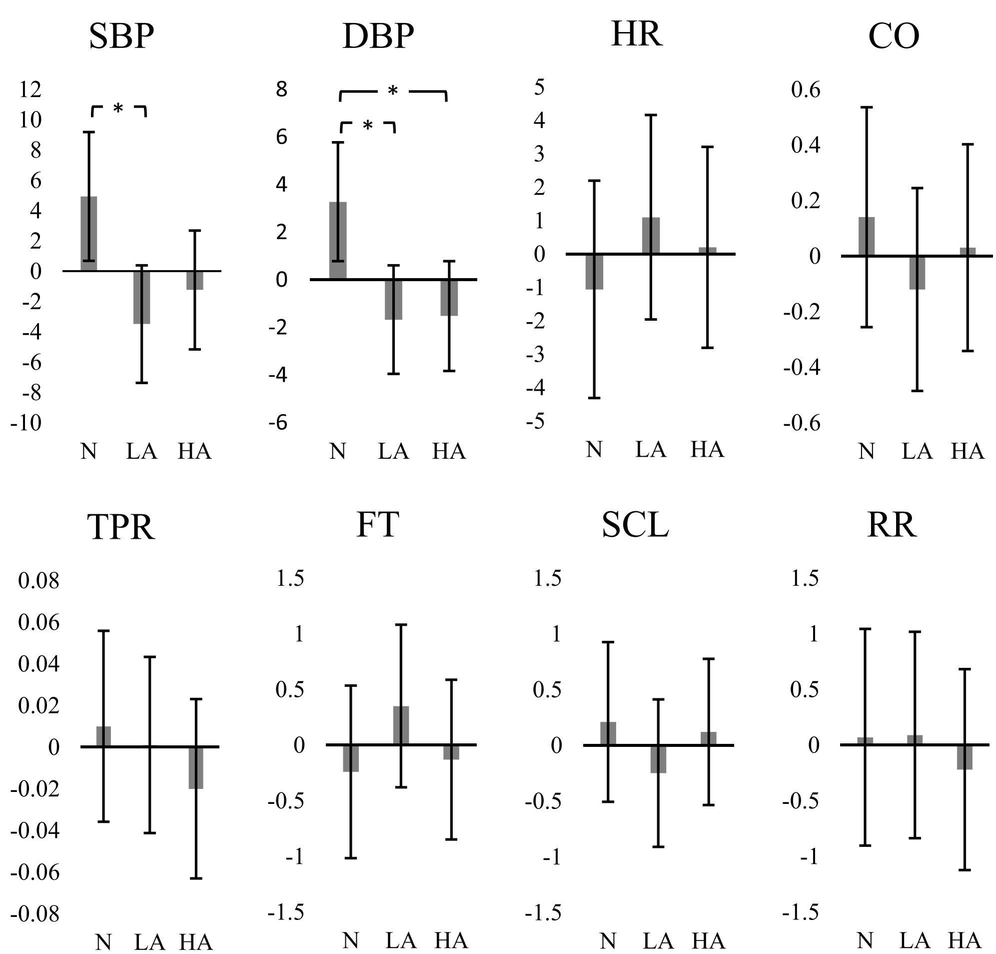

Fig. 2. The effects of high-approach positive affect (HA), low-approach positive affect (LA) and neutral conditions (N) on physiological recovery from anticipated threat.
*$p < .05$.
Note. Residual change scores controlled for baseline and reactivity. SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate, CO = cardiac output, TPR = total peripheral resistance, SCL = skin conductance level, FT = fingertip temperature, RR = respiration rate. Post hoc testes = Tukey's HSD. Error bars = 95% CIs.

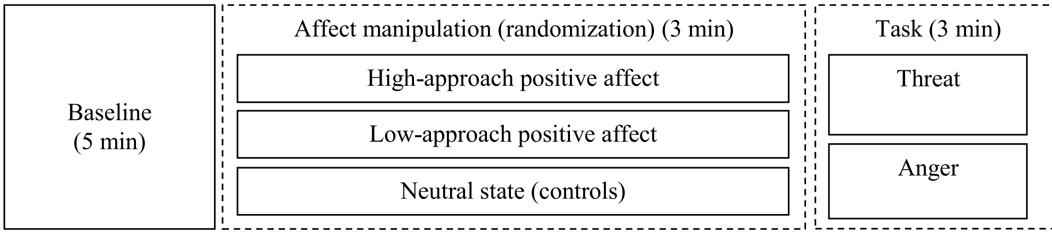

Fig. 3. Study 2 procedure.

evidence that motivational intensity may have little influence on the peripheral physiology.

3. Study 2

In Study 2, we examined how high-approach and low-approach positive emotions influence reactivity to stress. We aimed to present the affective photos before the task and to examine whether elicited affect would influence the way individuals react to stress. An abundance of research has indicated how daily-life positive affect and elicited positive emotions that precede stress improve stress responding (Monfort et al., 2015; Ong et al., 2006; Pressman and Cohen, 2005). However, little is known about whether high-approach positive emotions differ from low-approach positive emotions in how effectively they buffer stress responses. Based on previous research, we expected that high-approach motivation would lead to stronger reactivity as it produces more conflicted motivation with avoidance-related stress. As in Study 1, we expected the differences to occur for SBP, DBP, and HR. However, we also aimed to explore whether similar down-regulation occurs for other cardiovascular and electrodermal parameters.

We also examined whether reactivity to anger (a high-approach negative emotion) vs. threat would interact with high-approach positive affect. Anger is related to the challenge rather than threat response (Herrald and Tomaka, 2002; Jamieson et al., 2013). Thus, the physiological patterns for anger are hypothesized to resemble activation observed in positive emotions (i.e., increased HR, CO and decreased TPR), in contrast to a threat, where TPR is more likely to increase (Jamieson et al., 2013; Mendes et al., 2008). We expected that conflicted motivation between high-approach positive emotions and high-avoid threat would produce stronger physiological responses when compared to high-approach positive emotions followed by a high-approach anger response. Anger and threat have seldom been studied together, despite the unique motivational load that characterizes anger (Harmon-Jones and Allen, 1998; Mendes et al., 2008).

3.1. Method

3.1.1. Participants

This study involved 220 volunteers (49.5% female) between the ages of 18 and 31 years old ($M = 21.84$, $SD = 2.26$). Upon conducting power analyses with G*Power 3.1 (Faul et al., 2009), for ANOVA with six groups, a sample size of 216 was deemed appropriate to detect effects of size $f = 0.25$ with α 0.05 and power of 0.80. Each participant received a cinema ticket for their involvement. Ten participants were excluded due to BMI > 30, and the resulting BMI range was 15.16–29.76 ($M = 22.60$, $SD = 2.85$). Other exclusion criteria were the same as in Study 1. The study was approved by the Institutional Ethics Committee.

3.1.2. Measures

We used the same measures and instruments for the electrocardiography and skin conductance as in Study 1. For hemodynamic parameters, we used the Finometer NOVA apparatus (Finapres Medical Systems, Netherlands), which uses an arm cuff to calibrate blood pressure measurements recorded at the finger level. Consequently, finger measurements with Finometer NOVA are closer estimates of blood pressure measured at the brachial artery. Due to equipment malfunction, we did not account for respiration and fingertip temperature in Study 2.

3.1.3. Threat and anger elicitation

We used the same method as in Study 1 for threat, with 3 min for the speech preparation. To elicit anger, we used an anger/threat recall task (Neumann et al., 2004; Waldstein et al., 2000; Why and Johnston, 2008). Participants were asked to prepare a speech on the topic "What makes you angry/threatened?" Participants were given 3 min to prepare the speech. After 3 min, they were informed that they were selected not do deliver the speech. Depending on the randomization, participants were assigned to develop the threat or the anger speech.

3.1.4. Procedure

This experiment began with a 5-min baseline, followed by 3 min of watching affective pictures (high-approach positive affect, low-approach positive affect, or neutral depending on randomization), and 3 min of speech preparation (social threat or anger depending on randomization) (Fig. 3).

3.1.5. Analytic strategy

We conducted 3 × 2 Analyses of Variance (ANOVA) with Affect (high-approach positive affect, low-approach positive affect, and neutral) and Task (threat vs. anger) as the factors and physiological responses as the depended variables. As in Study 1, an FDR correction was applied for the hypothesized effects, and post hoc comparisons were conducted with Tukey's HSD. For each dependent variable, we calculated residualized change scores by regressing reactivity on the baseline and saving residuals. Positive scores indicated that individuals responded with higher reactivity than could be expected based solely on their baseline levels. We removed outliers above z-scores higher than 3.29. We removed thirteen participants for DBP analysis, nine for SCL, seven for HR and TPR, and six for SBP and CO. Analyses were performed with SPSS 21.0 (IBM, USA).

3.2. Results

3.2.1. Manipulation check

Participants responded to the speech preparation stressor with large responses in SBP, DBP, HR, CO, SCL, respiratory rate, and a medium response in fingertip temperature (Table 4).

3.2.2. Effects of high- and low-approach positive affect on threat and anger reactivity

We found that Affect had a significant effect on the DBP and HR reactivity (Table 5; Fig. 4). Post hoc comparisons indicated that low-approach positive affect produced lower DBP reactivity than the neutral conditions. For high-approach positive affect, the results were less coherent: high-approach positive affect did not differ from low-approach positive affect in DBP reactivity, nor were there differences when compared with the neutral conditions. HR reactivity was lower for high-

Table 4
Physiological reactivity to stress in Study 2.

	Baseline		Stress		*F*	*df*	*p*	η²
	M	*SD*	*M*	*SD*				
SBP [mm Hg]	119.13	14.94	130.29	18.69	269.86	1, 203	< .001	0.57
DBP [mm Hg]	77.35	10.68	82.22	12.13	107.53	1, 196	< .001	0.35
HR [beats/min]	77.57	11.07	83.01	12.45	240.86	1, 202	< .001	0.47
CO [l/min]	5.51	1.25	6.14	1.49	133.98	1, 203	< .001	0.40
TPR [mmHg· min/l]	0.91	0.22	0.89	0.22	4.41	1, 202	.037	0.02
SCL [μS]	0.09	0.09	0.15	0.11	326.08	1, 200	< .001	0.62

Note. SBP = systolic blood pressure, DBP = diastolic blood pressure, CO = cardiac output, TPR = total peripheral resistance, HR = heart rate, SCL = skin conductance level.

approach positive affect and low-approach positive affect compared to the neutral conditions. There were no differences in HR between the high-approach and low-approach affect. Additionally, we observed similar responses to anger and threat (Table 6). We found no other main effects and interactions for the physiological responses, all *ps* > .05.

3.3. Discussion

Study 2 provided a further examination of differences between high-approach and low-approach positive affect in their effect on physiological stress responses. We found that low-approach positive emotions produced lower DBP and HR reactivity compared to neutral conditions. We also found that high-approach positive affect produced lower HR reactivity, but the findings for DBP reactivity here were less conclusive. Finally, we found no support for the hypothesis that anger interacts with motivational intensity in its effects on physiological reactivity.

As in Study 1, we provided new evidence for the health protective effects of positive affect (Pressman et al., 2019). Participants that focused on low-approach positive stimuli before stress were more likely to exhibit a less intense physiological response once the stress phase started. Increased levels of DBP, suggestive of α-adrenergic contraction of blood vessels, have been previously related to responses to adverse social situations (Brown et al., 1998). This might suggest that amusing pictures might have influenced the participants to perceive their situation as more positive. This finding is important because levels of DBP above 75 mm Hg represent a cardiac risk factor in adults (Prospective Studies Collaboration, 2002). Given that participants in our study increased their DBP up to 82 mm Hg on the average during the task, the response caused by low-approach positive emotions might have been health-protective.

We found no effects for CO and TPR, but low-approach and high-approach positive affect buffered HR reactivity. We might interpret these findings using these measures as cardiovascular markers of motivation and stress appraisal (Seery, 2011). This pattern might suggest that individuals in the positive affect groups were less action-oriented compared to those in the control group, but the groups did not differ in their challenge/threat-related responses. Given that CO and TPR are predictive of successful outcomes and this effect is not moderated by HR levels (Behnke and Kaczmarek, 2018), this might suggest that individuals in each group mobilized sufficient physiological coping resources to cope with the upcoming task. However, this pattern could also be interpreted from the affective standpoint. Decreased HR with no changes in CO and TPR is characteristic of contentment (Kreibig, 2010). Thus, these physiological responses might indicate that individuals may have derived more contentment form the affective presentations and that this physiological pattern buffered their stress response.

4. General discussion

Overall, this project examined the effects of valence (positive vs. neutral) and approach-motivation intensity (high-approach vs. low-approach) on physiological responses to stress. With several previous studies focused on the approach motivation intensity and the brain (Harmon-Jones et al., 2008; Li et al., 2018), these are the first studies that focused on the effects of motivational intensity for peripheral physiology. Complementing brain studies, we accounted for the target responses in the human body (e.g., smooth muscles and glands) and observed how the autonomous nervous system regulates critical bodily functions in response to aversive and propulsive affective provocations. Our findings showed that the effects of high-approach and low-approach affect were mostly similar. The results regarding high-approach positive affect were less consistent. First, we were able to document that high-approach positive affect did not differ from low-approach positive affect (e.g., DBP recovery, HR reactivity). Second, in some cases, the high-approach positive affect produced intermediate effects, i.e., high-approach positive affect did not differ from the neutral conditions as well as the low-approach positive affect (e.g., SBP recovery, DBP reactivity).

In this research, we replicated previous findings regarding the soothing function of low-approach positive affect (e.g., amusement) and

Table 5
The effects of high-approach and low-approach positive affect on reactivity (Study 2).

	Neutral (A)		Low-approach PA (B)		High-approach PA (C)		*F*	*df*	*p* [*p*-corr.]	η²	Post hoc
	M	*SD*	*M*	*SD*	*M*	*SD*					
Expected:											
SBP [mm Hg]	−0.07	10.48	−0.25	7.15	0.32	10.96	0.05	2, 198	0.948 [0.95]	< 0.01	–
DBP [mm Hg]	1.88	7.76	−1.32	5.56	−0.58	5.86	4.32	2, 191	0.015 [0.02]	0.04	A > B
HR [beats/min]	1.83	6.68	−1.25	4.28	−0.64	5.89	5.59	2, 197	0.004 [0.01]	0.05	A > B, A > C
Explorative:											
CO [l/min]	0.11	0.81	−0.06	0.52	−0.05	0.95	0.05	1, 198	0.386	< 0.01	–
TPR [mmHg· min/l]	−0.01	0.09	−0.01	0.08	0.01	0.09	1.41	2, 197	0.245	0.01	–
SCL [μS]	0.003	0.052	−0.005	0.044	0.002	0.050	0.53	2, 195	0.589	0.01	–

Note. SBP = systolic blood pressure, DBP = diastolic blood pressure, CO = cardiac output, TPR = total peripheral resistance, HR = heart rate, SCL = skin conductance level. Residual change scores controlling for differences in baseline and reactivity. Post hoc testes = Tukey's HSD. *p*-values for the hypothesized outcomes corrected for False Discovery Rate and reported in brackets.

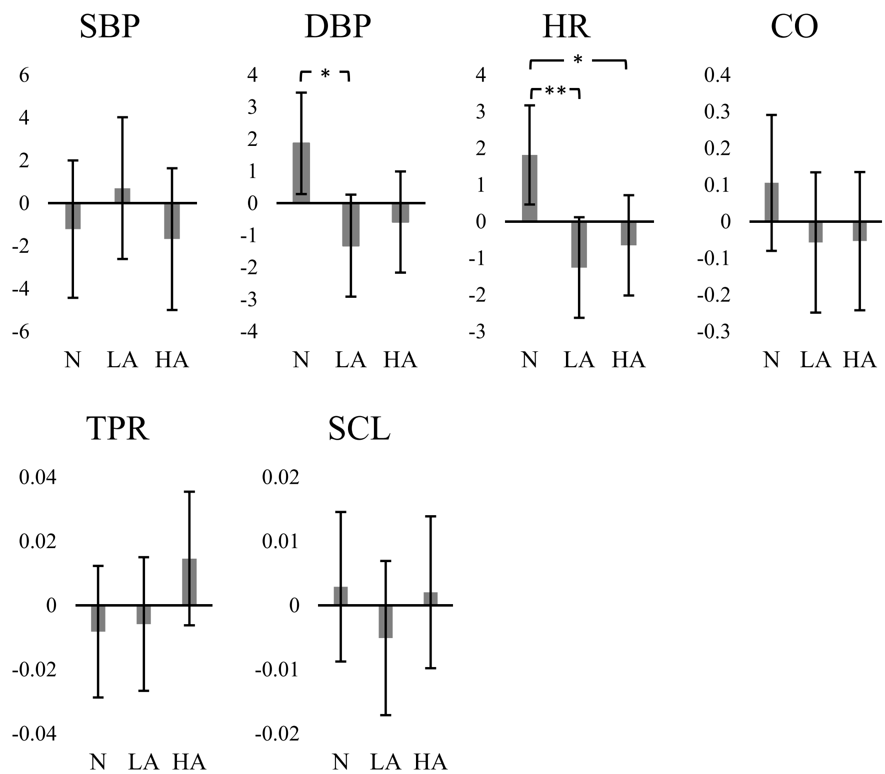

Fig. 4. The effects of high-approach positive affect (HA), low-approach positive affect (LA) and neutral conditions (N) on physiological reactivity to stress.
*p < .05, **p < .01.
Note. Residual change scores controlled for baseline. SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate, CO = cardiac output, TPR = total peripheral resistance, SCL = skin conductance level. Post hoc testes = Tukey's HSD. Error bars = 95% CIs.

Table 6
Differences in reactivity to threat and anger (Study 2).

	Threat		Anger		*F*	*df*	*p* [*p*-corr.]	η^2
	M	*SD*	*M*	*SD*				
Expected:								
SBP [mm Hg]	−0.74	11.22	0.73	7.80	1.16	1, 198	.284 [.42]	< 0.01
DBP [mm Hg]	−0.39	5.69	0.37	7.34	0.65	1, 191	.423[.42]	< 0.01
HR [beats/min]	−0.90	5.69	0.87	5.89	4.90	1, 197	.028 [.08]	0.02
Explorative:								
CO [l/min]	−0.04	0.93	0.04	0.61	0.49	1, 198	.483	< 0.01
TPR [mmHg· min/l]	0.01	0.09	−0.01	0.08	1.01	1, 197	.315	0.01
SCL [μS]	−0.003	0.045	0.003	0.052	0.63	1, 195	.430	< 0.01

Note. SBP = systolic blood pressure, DBP = diastolic blood pressure, CO = cardiac output, TPR = total peripheral resistance, HR = heart rate, SCL = skin conductance level. Residual change scores controlling for differences in baseline and reactivity. *p*-values for the hypothesized outcomes corrected for False Discovery Rate and reported in brackets.

extended the evidence to high-approach positive affect (e.g., desire) (Levenson, 1999). This might indicate that valence rather than the approach motivation intensity is the active ingredient of affect in its soothing effect on physiological stress responding (Fredrickson et al., 2000). Using high-approach positive affect is likely to produce outcomes that work in the same direction, yet tend to be less pronounced. Notably, we had sufficient power to detect effects at least moderate in size. Although moderate to large effects were observed for the down-regulation effects of positive emotions (Fredrickson and Levenson, 1998; Monfort et al., 2015) and cognitive effects of motivational intensity (Gable and Harmon-Jones, 2008), it is likely that we were unable to reveal significance of differences that might occur between the effects of high-approach vs. low-approach positive affect with more statistical power. We also extended the soothing effects from the recovery to the reactivity, which has been studied less frequently. Positive affect buffered cardiac reactivity and did not affect hemodynamic processes that mobilize resources crucial for efficient action. Employing a multilayer approach to the measurement, we were able to indicate that these responses to positive affect influenced blood pressure and HR but did not affect other hemodynamic responses that have been associated with the challenge and threat response such as CO or TPR.

Results in this study are relevant to inform the development of the structural and functional theories of positive emotions (Fredrickson, 2001; Harmon-Jones, 2018; Shiota et al., 2017; Siegel et al., 2018). We present an instance when the Motivational Dimensional Model of Affect fails to provide meaningful physiological differences in responses to stress. We also found no evidence of different reactivity to anger and threat, and no interaction involving task type (anger vs. threat) in the influence of motivational intensity on stress reactivity. These results support the broaden-and-build theory of positive emotions with more uniform view on the function of positive emotions (Fredrickson, 2001). However, we extend the empirical evidence for the broaden-and-build model. While most previous studies on the broaden-and-build model have used low-approach positive affect (e.g., amusement), our findings indicated that high-approach positive emotions (a mix of desire, excitement, and enthusiasm) produce effects similar to low-approach emotions (amusement). Whereas most recent theorizing calls for a stronger differentiation (Shiota et al., 2017; Harmon-Jones, 2018;

Siegel et al., 2018), we found that it is also worthwhile to account for situations where some affective influences may be less pronounced in some aspects of human functioning. A balanced theoretical and empirical differentiation and generalization is needed to increase the predictive strength of theories.

Our studies have limitations. First, the physiological influences of affect that we observed were of small magnitude both in absolute terms (the proportion of explained variance in the dependent variable) and in relative terms (in comparison to the pervasive physiological effects of the stress tasks). However, as the relationship between cardiovascular reactivity and cardiovascular disease risk is linear (Prospective Studies Collaboration, 2002), even effects of a smaller magnitude have cumulative long-term effects on health. As indicated in a comprehensive meta-analysis, cardiovascular responses observed in laboratory settings are positively related to long-term risk for cardiovascular problems (Chida and Steptoe, 2010). Thus, the effects that we presented might reflect how individuals respond to stress and affective stimuli in daily life. Second, we used only one approach to elicit positive emotions and stress. Although using standardized pictures has been endorsed by theorists (Harmon-Jones and Gable, 2018) and used successfully in other studies (Li et al., 2018), more diverse and direct methods with stronger effects are needed to corroborate and extend these findings (e.g., Angus and Harmon-Jones, 2018). Moreover, we did not account for individual differences in personality that might moderate the influence of affect and stress on physiological reactivity (Lü et al., 2018). Finally, despite relatively large samples, we had sufficient statistical power to detect at least moderate effect sizes. Thus, further studies with stronger designs (e.g., within-individual comparisons) might provide more information on whether a more nuanced effect of motivational intensity on peripheral physiology exists.

Our studies have some practical implications for health psychology as well as for the study of emotions and psychophysiological responses to stress. First, our findings suggest that a broader class of positive emotions (high-approach such as enthusiasm or desire) can be used to mitigate prolonged physiological arousal or buffer reactivity. This finding is relevant to health promotion, prevention, and stress management programs (Pressman et al., 2019). Second, our studies provided and replicated evidence for the validity of the pictures that we used. Presenting pictures that differ on the approach-avoid motivation but do not differ on valence and arousal appears to be a viable method of approach intensity manipulation. These findings also correspond with similar methods used recently in another study on high-approach and low-approach intensity motivations (Li et al., 2018). Finally, previous literature on the undoing hypothesis has focused on several physiological signals. We provided evidence that accounting for several biosignals provides a more comprehensive interpretative framework for the context in which the hypothesized phenomenon exists. Introducing CO and TPR into the undoing hypothesis literature, we suggest further studies that might corroborate the notion that undoing effects are mostly due to affective or experiential processes rather than goal-oriented or motivational ones. Finally, this approach supplements studies where several physiological responses were analyzed as a compound (Fredrickson and Levenson, 1998; Yuan et al., 2010).

The strength of this study is that we provided the first examination of functional differences between high-approach and low-approach positive affect in their influence on several interrelated systems in human physiology. Moreover, we were able to present how high-approach and low-approach positive affect both influence several outcomes: namely, recovery and reactivity to fear and anger. We found no meaningful differences between the effects of high-approach vs. low-approach positive affect in their effect on peripheral physiology. However, we supported and extended previous findings regarding the soothing function of positive affect (Levenson, 1999) suggesting that high-approach positive affect is an equivalent to low-approach positive affect regarding down-regulation of physiological arousal.

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