Motiv Emot (2016) 40:862–877
DOI 10.1007/s11031-016-9579-1

ORIGINAL PAPER

The effects of implicit and explicit affiliation motives on vagal activity in motive-relevant situations

Elisabeth Prestele[1] · Friederike X. R. Gerstenberg[2] · Birk Hagemeyer[3] · Fay C. M. Geisler[4]

Published online: 14 September 2016

Abstract We investigated the independent and interactive effects of the implicit need for affiliation (nAFF) and the explicit self-attributed need for affiliation (sanAFF) on parasympathetic vagal activity (indexed via heart rate variability) in three motive-relevant situations: in a socioevaluative stress situation (N = 49), in a socially ambiguous situation (N = 50), and during socially supported recovery from stress (both subsamples). Vagal activity has been linked with self-regulation and social engagement. Vagal withdrawal has been found to accompany stress responses, whereas vagal advance has been found to accompany attenuated stress and affiliative behavior. Response surface analyses in the current study revealed additive but opposite effects on vagal activity for nAFF (vagal advance) and sanAFF (vagal withdrawal) during the socioevaluative stress situation, high nAFF and low sanAFF incongruence predicted vagal withdrawal in the socially ambiguous situation, and sanAFF predicted vagal advance during socially supported recovery from stress. We suggest that assessing reactions to motive-relevant stress situations represents a profitable approach for investigating the differential effects of implicit and explicit motives.

✉ Elisabeth Prestele
prestele@uni-landau.de

[1] University of Koblenz-Landau, Fortstraße 7, 76829 Landau, Germany

[2] Technische Universität München, Munich, Germany

[3] Friedrich-Schiller-Universität Jena, Jena, Germany

[4] University of Greifswald, Greifswald, Germany

Keywords Implicit need for affiliation · Explicit need for affiliation · Heart rate variability · Response · Surface analysis · Polyvagal theory

Introduction

Humans are social beings with an inherent need to have contact and interact with other people (e.g., Baumeister and Leary 1995; Deci and Ryan 1985; Maslow, 1958). However, there are individual differences in the need for affiliation. This affiliation motive energizes and orients everyday experiences and behavior and is defined as the need for social interactions and a desire ''to establish and/or maintain warm and friendly interpersonal relations'' (French and Chadwick 1956, p. 296). The central goal of the affiliation motive is to be in the company of and to have friendly exchanges with other people to avoid loneliness (McClelland, 1987; Weinberger et al. 2010). Accordingly, situations that are relevant for the affiliation motive are (at least potentially) social situations.

Theory and research on motives call for the differentiation of two independent motive systems reflecting *implicit needs* and *explicit self-attributed needs* (e.g., Köllner and Schultheiss 2014; McClelland et al. 1989). The two systems are differentiated by their accessibility to introspection, the stimuli that activate them, and the resulting behavior. Implicit needs are affective preferences for certain stimuli and behaviors that are associated with positively valued activities. This preference is not necessarily accessible to introspection. Relevant cues almost automatically initiate and guide a person's spontaneous behavior. Explicit needs, by contrast, are defined by the goals and values that a person attributes to him- or herself. They are part of the self-concept and are thus accessible to conscious awareness (McClelland et al., 1989). These self-attributed needs are associated with controlled behavior and decisions in structured situations that contain cues related to future goal states. The assumption of two independent motive systems is empirically supported by low intercorrelations between implicit and explicit motives that refer to the same motivational domain (i.e., affiliation, power, achievement; for a recent meta-analysis, see Köllner and Schultheiss 2014) and their differential effects in predicting diverse outcomes (e.g., Dufner et al. 2015; Schultheiss, 2008). In addition, the relative independence of the two motives implies that people can be differentiated not only by the strength of their implicit and explicit needs but also by the specific constellations of the two systems. Motive incongruence, that is, when one's implicit needs are not validly translated into planned motive-satisfying behavior (low explicit/high implicit) or when one's explicit needs are not supported by the internal energy of implicit needs (high explicit/low implicit; Brunstein et al. 1998; Elliot et al. 2006), is considered a "hidden stressor" (Baumann et al. 2005, p. 783) that "can certainly lead to trouble" (McClelland et al., 1989, p. 700).

In the present study, we aimed to investigate the effects of the implicit need for affiliation (nAFF) and the explicit self-attributed need for affiliation (sanAFF) in motive-relevant situations. Thereby we pursued three aims. First, we investigated the differential effects of nAFF and sanAFF on physiological responses during a socioevaluative stress situation. By doing so, we aimed to close a gap in research by simultaneously considering nAFF and sanAFF in a motive-relevant stress situation. In addition, we aimed to extend existing research by focusing on parasympathetic vagal activity (i.e., vagal advance and vagal withdrawal), a part of the physiological stress response that is considered to be directly involved in social engagement behavior (Porges, 2001, 2007; Porges and Furman 2011), the central theme of the affiliation motive. It is important to note that we predicted opposite effects of nAFF and sanAFF on vagal activity. Second, we investigated the effects of incongruence between nAFF and sanAFF as a source of stress. That is, we predicted an association between incongruence between nAFF and sanAFF and vagal activity during a socially ambiguous situation. Third, we investigated whether both nAFF and sanAFF as dispositional propensities would benefit from social support for stress recovery. Cardiovascular recovery from stress is associated with increased vagal activity (Mezzacappa et al. 2001). Thus, we predicted that nAFF and sanAFF would be associated with vagal activity during socially supported recovery from stress.

Differential effects of nAFF and sanAFF on the physiological stress response

Personal values and goals determine how a person appraises a given situation (e.g., Lazarus, 2006). If a personal goal is at stake or blocked in a given situation, the person appraises the situation as threatening, thus resulting in an enhanced physiological and affective stress response (e.g., Penley and a., & Tomaka, J. 2002; Shewchuk et al. 1999; Tong, 2010; for basic need dissatisfaction: Lundqvist and Raglin 2014; Quested et al., 2011). As individual differences in sanAFF reflect differences in explicit values and goals concerning social contact, it can be reasoned that sanAFF is associated with increased stress as a result of blocked social goals. There are only a few studies on the association of sanAFF-related constructs and stress responses to social situations. Santiago-Rivera and Bernstein (1996), for example, found that a greater self-reported importance of affiliation was associated with an increase in harm appraisals of negative interpersonal events. In another study, Yang et al. (2014) reported that the self-attributed need for social approval was positively correlated with an increase in heart rate during a socioevaluative stress situation.

By contrast, studies on the effects of nAFF on physiological stress responses indicate that nAFF can buffer the negative effects of motive-relevant stress situations. Wegner et al. (2014), for example, found that high nAFF predicted a reduced cortisol stress response in a socioevaluative stress situation. They concluded that their results could be accounted for by the stress-buffering effects of stable social bonds that people high in nAFF are particularly likely to have been motivated to establish throughout their lives. In another study, Wirth and Schultheiss (2006) found that high nAFF was associated with a reduced cortisol response and an enhanced progesterone response following a film that induced a fear of rejection. Progesterone dampens stress responses and promotes "affiliation-seeking in response to withdrawal of affiliation" (Wirth and Schultheiss 2006, p. 793).

Many studies on stress responses assess sympathetic stress responses by measuring salivary cortisol concentrations (e.g., Het et al. 2009; Kirschbaum et al. 1993). On the basis of the Polyvagal Theory (Porges and Furman 2011; Porges, 2001, 2007), we focused on parasympathetic vagal activity as part of the physiological stress response in the present study. The Polyvagal Theory represents a neurophysiological model that links cardiac vagal activity to self-regulation and social engagement. Porges (2001) outlined a social engagement system consisting of the anatomical and neurophysiological link between neural regulation of the heart and the striated muscles of the face, head, and neck. This "face–heart connection" promotes social interactions and social bonds. According to the Polyvagal Theory (Porges, 2001, 2007), dynamic changes in vagal innervation in response to situational demands result in the regulation of arousal to support adaptive behavior: The influence of the vagus is reduced to support the metabolic requirements of mobilization (e.g., fight/flight behaviors, stress) or increased to support social engagement behaviors. Therefore, vagal activity is related to behavioral and psychological processes along a continuum ranging from stress-related behaviors (vagal withdrawal) to prosocial–affiliative interactions (vagal advance). Accordingly, Schwerdtfeger and Schlagert (2011) found that the perception of available support was accompanied by enhanced vagal innervation of the heart in the context of a laboratory stressor.

Taken together, we hypothesized that sanAFF would predict vagal withdrawal in a socioevaluative stress situation (indicating stress). By contrast, we hypothesized that nAFF would predict vagal advance in a socioevaluative stress situation (indicating attenuated stress and social engagement).

Incongruence between nAFF and sanAFF as a source of stress

Theory and research on motive (in)congruence focuses on the effects of interindividual differences in the intrapersonal constellation of implicit and explicit needs (McClelland et al., 1989). Motive congruence occurs when implicit and explicit needs are in harmony and are thus able to energize and orient behavior toward one preferred goal state. Motive incongruence occurs when one's self-attributed need does not converge with one's implicit need. Positive effects of motive congruence and negative effects of incongruence on emotional and physical well-being are well documented for affiliative motives (Brunstein et al., 1998; Hagemeyer et al. 2013; Hofer and Busch 2011; Hofer et al. 2006; Schüler et al. 2008; . 2009). Some of these studies, however, have demonstrated two important limitations. The first limitation involves the common operationalization of motive incongruence as the absolute difference between measures of explicit and implicit motives. An absolute difference score does not allow for investigations of differential effects of the two forms of incongruence (low/high vs. high/low) or for curvilinear effects of incongruence. To address this limitation, we implemented a response surface analysis (see the Method section for a detailed description) to explore linear and curvilinear main effects of nAFF and sanAFF as well as their congruence and incongruence. Second, most studies on the (in)congruence between nAFF and sanAFF have investigated effects on subjective well-being assessed with retrospective ratings of the last few weeks or in general. The question of whether dispositional motive (in)congruence has a similar influence on physiological responses to a concrete situation has remained largely unexplored. To address this limitation, we investigated the effects of the (in)congruence between sanAFF and nAFF on vagal activity in a socially ambiguous situation.

Ambiguous situations, that is, situations that are subject to conflicting interpretations (McLain, 1993), have the potential to be experienced as threatening and stressful (Grenier et al. 2005). Personality drives the interpretation of ambiguous situations, and these interpretations can reduce the initial ambiguity (Meyer and Dalal 2009). In a situation containing cues that might be interpreted as indicating a social situation but also its exact opposite, a person with a congruent constellation of nAFF and sanAFF should benefit from a straightforward interpretational tendency that reduces stressful ambiguity. A person suffering from incongruence between nAFF and sanAFF, however, is disadvantaged by his or her intrapersonally conflicting needs, resulting in an inability to reduce ambiguity by applying a straightforward interpretation. Thus, we hypothesized that incongruence between sanAFF and nAFF would predict vagal withdrawal (indicating stress) in a socially ambiguous situation.

Benefitting from social support for stress recovery

A surge in vagal activity at the offset of psychological stress is a distinct feature of the parasympathetic stress recovery process (Mezzacappa et al., 2001). Physiological stress recovery represents a critical component of an adequate reaction to stress. Specifically, delayed cardiovascular recovery from stress predicts adverse health outcomes (Crowley et al., 2011; Stewart et al. 2006) probably because a longer duration of cardiac response has a damaging effect on the circulatory system and can lead to the development of hypertension and coronary artery disease. Thus, vagal advance following a stressful experience provides adaptive recovery from stress. In general, social support has the potential to foster recovery from stress (Meuwly et al., 2012). This should be especially true for individuals with an affective preference for social stimuli (i.e., those high in nAFF) as well as for individuals with the explicit goal of establishing friendly interpersonal exchanges (i.e., those high in sanAFF). Accordingly, research has shown that high nAFF (e.g., Dufner et al. 2015; McAdams and Powers 1981) and high sanAFF (e.g., Brewer and Klein 2006; Mehrabian and Ksionzky 1974) are associated with more positive affective, physiological, and behavioral responses to positive social interactions. To our knowledge, no study has investigated whether these positive responses also extend to positive social interactions during recovery from stress. We therefore tested the hypothesis that both sanAFF and nAFF would predict vagal advance during supportive social contact after stress.

Methods

Participants

A sample of $N = 99$ students (96 nonpsychology; 3 psychology; $M_{age} = 22.3$, $SD_{age} = 3.7$; 56 % female) from three universities in Munich (Germany) participated in the study in exchange for course credit or monetary compensation.

Procedure

Participants were tested individually. About two weeks before the laboratory session, participants completed a questionnaire on their explicit motives (see description below). Upon arrival at the laboratory, participants were greeted briefly by the female investigator. The chest strap for the HRV measurement was then attached to them, and participants were asked to sit still and rest by themselves without any task for 5 min. Following this resting phase, participants completed a measure of nAFF (see description below) and were then randomly assigned to and accordingly completed a social stress test (socioevaluative situation; $N = 49$) or a placebo stress test (socially ambiguous situation; $N = 50$). Afterwards, participants returned to the investigator. The investigator was friendly, asked some standardized questions about participants' perceptions of the experimental stress induction, and responded in a supportive fashion to participants' reports (stress recovery). The investigator was instructed and trained to listen actively (e.g., rephrase the participants reports, ask for more detailed descriptions) but to abstain from any evaluation of the participants' reports (be it supportive or contradictory) or of the experimental situation.

We implemented the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) and the Placebo TSST (Het et al., 2009) as the socioevaluative stress situation and the socially ambiguous situation, respectively. The TSST consists of preparation (5 min), a simulated job interview (5 min), and a highly demanding arithmetic task (5 min) in front of an emotionally nonresponsive and overly critical two-person committee, a video camera, and a microphone. During the job interview, the committee predominantly observes and takes notes on the participants' behavior. During the arithmetic task, they also provide instant feedback on each mistake. The two confederates constituting the committee were trained intensively to strictly adhere to the protocol, including the emotionally unresponsive and critical expression toward the participants. The presence of and the interaction with the committee are social stimuli that are relevant for the affiliation motive. Thereby, the central theme of the affiliation motive (i.e., the desire for warm and friendly interpersonal contact) is permanently frustrated by the TSST.

The Placebo TSST consists of preparation (5 min), a discussion about a recent leisure experience (5 min), and a simple arithmetic task (5 min). The participant is left alone in the experimental room and her or his voice is recorded via microphone. The participants are told that the experimenter will listen to the recordings after the experiment. The situation represents a socially ambiguous situation that might be interpreted as being more (voice recording that is listened to by the experimenter) or less (alone in the room) social.

Measures

Vagal activity

Heart rate variability (HRV) was used as a proxy measure for vagal activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). HRV refers to the interval between heartbeats, which varies from beat to beat. Vagal advance results in increased HRV, and vagal withdrawal results in decreased HRV. Heart rate was measured with the heart rate monitoring system Polar RS800CX (Polar Electro Oy, Kempele, Finland, 2008). HRV indices were based on the middle 2 min of the resting time at the beginning of the experimental session (baseline), the last 2 min of the (Placebo) TSST (stress reactivity), and the middle 2 min of the socially supported stress recovery (stress recovery). We chose the last 2 min of the (Placebo) TSST to capture the cumulative effect of the socioevaluative stress situation. The sequential interbeat intervals of the three intervals were corrected for artifacts with the Polar Precision Performance™ Software and subsequent visual inspection. As an index of HRV, we utilized the root mean square of successive differences (RMSSD, [ms^2]). Higher RMSSD values indicate higher HRV, and lower RMSSD values indicate lower HRV. This time-domain measure is highly correlated with frequency domain measures of the high frequency component of the respiratory frequency range and is thus considered to reflect vagal influence (Denson et al. 2011). The RMSSD was computed with the HRV analysis program (Niskanen et al. 2004). Missing RMMSD data (11.8 %) could be attributed to nonsystematic technical malfunctions. The RMSSD scores showed skewness and kurtosis values greater than 1 and were therefore reported as natural logarithms (ln_RMSSD).

In order to control for baseline differences in HRV, we first regressed HRV during the (Placebo) TSST on HRV at baseline and used residual change scores as the dependent variable in all further analyses. Thus, we received a value for vagal withdrawal (low HRV/low ln_RMSSD) or vagal advance (high HRV/high ln_RMSSD) during the (Placebo) TSST that was independent of vagal tone (Obradovic et al. 2011). We applied the same procedure to control for HRV during the (Placebo) TSST when predicting HRV during stress recovery. Thus, we received a value for vagal withdrawal (low HRV) or vagal advance (high HRV) during recovery from stress that was independent of vagal activity during the (Placebo) TSST.

Implicit and explicit affiliation motives

The *explicit affiliation motive* (*san*AFF) was assessed with the 10-item *Hope for Affiliation* scale from the Unified Motive Scales (UMS; Schönbrodt and Gerstenberg 2012) 2 weeks before the laboratory session. Based on an item response theory analysis, the UMS combines selected items of several established motive scales and some newly developed items. Some items are formulated as statements that require an agreement rating that ranges from 1 (*strongly disagree*) to 6 (*strongly agree*; sample item "Encounters with other people make me happy"). Other items are formulated as goals that require an importance rating that ranges from 1 (*not important*) to 6 (*very important*; sample item: "I engage in a lot of activities with other people"). Previous research has demonstrated their incremental validity beyond other scales (Schönbrodt and Gerstenberg 2012). The individual items were *z*-standardized before the mean scale scores were computed. Cronbach's alpha was good ($\alpha = 0.90$).

The *implicit affiliation motive* (nAFF) was assessed with the Picture Story Exercise (PSE; e.g., Schultheiss and Pang 2007). For this procedure, participants were asked to write fictional stories in response to four picture cues that were presented in a fixed order. Following Schultheiss and Pang's (2007) recommendations, we chose the four picture cues so that they would be comparable to the TSST condition in that each picture showed one person performing and one or more persons observing. Two trained coders later independently coded the contents of all stories for imagery indicative of nAFF. According to the applied scoring manual (Winter, 1994), the indicative contents comprise feelings, cognitions, and activities that express concerns about establishing, maintaining, or restoring positive and friendly interactions and relationships with other people. Both coders achieved at least 85 % agreement with expert scorings of PSE answers during the coder training. The intercoder agreement for nAFF in the current data was $r = 0.91$. Raw motive scores were generated by summing the scores across the four picture stories within each coder and subsequently averaging between coders. As the raw motive scores were significantly correlated with the sum of the written words ($r = 0.50$, $p < 0.001$), we regressed the motive scores on the sum of the words and used the residual scores in all further analyses.

Statistical analyses

We conducted two sets of analyses. First, we tested whether the (Placebo) TSST and the socially supported recovery from stress impacted HRV by computing a repeated-measures ANOVA with time of measurement as a within-subjects factor and experimental condition as a between-subjects factor. We used the R package ez to compute this analysis (Lawrence, 2013).

Second, to test our hypotheses, we implemented a set of response surface analyses (RSAs; Edwards, 2002) in the TSST and Placebo conditions separately. RSA extends multiple linear regression to polynomial regression by including the quadratic and multiplicative terms of two predictor variables (X = sanAFF; Y = nAFF) besides their linear main effects to predict an outcome (Z = HRV).

$$Z = b_0 + b_1X + b_2Y + b_3X^2 + b_4XY + b_5Y^2 + e. \quad (1)$$

Our predictor variables were centered on their sample means prior to the analyses. The polynomial regression coefficients (b_1–b_5) in Eq. 1 were converted into a set of surface parameters (a_1–a_5; see Eqs. 2–5). Surface parameters directly describe the linear and quadratic effects of congruence and incongruence between two independent variables in predicting one dependent variable.

$$a_1 = b_1 + b_2 \quad (2)$$

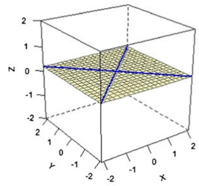
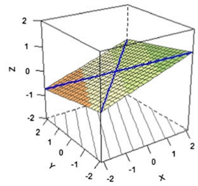
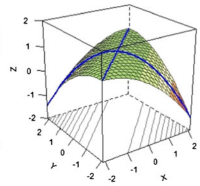
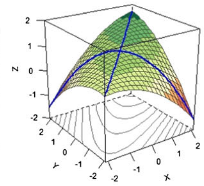
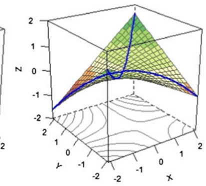
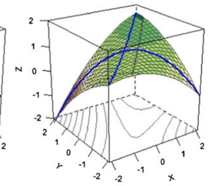
$$a_2 = b_3 + b_4 + b_5 \quad (3)$$

$$a_3 = b_1 - b_2 \quad (4)$$

$$a_4 = b_3 - b_4 + b_5 \quad (5)$$

Finally, to ease the interpretation of results, the surface parameters can be transferred to a 3D plot and a two-dimensional contour plot. Table 1 summarizes six models that differ in the regression and surface parameters that are freely estimated or restricted to be equal or zero. In the 3D plots in Table 1, the linear effect of congruence is represented by the slope (a_1), and the quadratic effect of congruence is represented by the curvature (a_2) of the line of congruence (LOC). The LOC directly connects the front to the back corner. When applied to our research question, a positive a_1 surface parameter would indicate that congruently high sanAFF/nAFF was associated with higher HRV

Table 1 Summary of competing RSA models: estimated regression and surface parameters and resulting 3D Plots

	Null model	Additive model	Squared difference model (SQD)	Rising ridge model (RR)	Interaction Model (IA)	Full model
k	0	2	1	2	3	0
Regression parameters		b_1, b_2	b_3, b_4, b_5 $b_3 = b_5$; $b_4 = 2*b_3$	b_1, b_2, b_3, b_4, b_5 $b_1 = b_2$; $b_3 = b_5$	b_1, b_2, b_4	b_1, b_2, b_3, b_4, b_5
Surface parameters		a_1, a_3	a_4	a_1, a_4	a_1, a_2, a_3, a_4 $a_2 = -a_4$	a_1, a_2, a_3, a_4
3D plot						

k Number of free parameters. The line of congruence (LOC) connects the front and back corners; the line of incongruence (LOIC) connects the left and right corners

rather than congruently low sanAFF/nAFF (see additive, Rising Ridge(RR), Interaction (IA), and full models in Table 1). A positive a_2 parameter would indicate that congruent and more extreme sanAFF/nAFF was associated with higher HRV than congruent but rather average sanAFF/nAFF (see IA and full models in Table 1).

The linear and quadratic effects of incongruence are represented by the slope (a_3) and curvature (a_4) of the line of incongruence (LOIC). The LOIC is orthogonal to the LOC. A general negative effect of incongruence between sanAFF and nAFF on HRV (sanAFF exceeds nAFF or vice versa) would be indicated by a negative curvature along the LOIC (negative a_4; see Squared difference [SQD], RR, IA, and full models in Table 1). An asymmetric effect of incongruence, however, would be indicated by a significant linear slope along the LOIC (a_3; see additive, IA, and full models in Table 1).

In addition to testing all regression and surface parameters for significance, it was possible to compare the fit of specific competing models. Thus, we were able to directly test whether the *additive* linear effect model in the TSST condition significantly fit our data better than any model that included general effects of (in)congruence (*IA*, *RR*, *or SQD*) and whether a model including (in)congruent effects in the Placebo condition had a better fit than the additive model (see Table 1 for specifications of the competing models). To select the best fitting and most parsimonious model, we compared the competing models according to their relative Akaike Information Criterion (lowest AIC indicates the most accurate and at the same time most parsimonious model) and their model weight (see Schönbrodt, 2007). A difference in the AIC (ΔAIC) of less than 2 indicates that two competing models have equal goodness of fit, and the model weight is interpreted as the probability that the given model fits the data best out of all competing models (Burnham and Anderson 2002). In addition, we computed χ^2-Likelihood Ratio (LR) tests to ensure that the selected model fit the data significantly better than the null model and equally as well as the full polynomial model. All of these analyses were implemented in the R package RSA (Schönbrodt 2016). For each analysis, we applied the listwise deletion of missing values, which resulted in reduced sample sizes for the ANOVAs ($N = 80$) and RSAs (stress reactivity: $N_{\text{Placebo}} = 39$, $N_{\text{TSST}} = 42$; stress recovery: $N_{\text{Placebo}} = 42$, $N_{\text{TSST}} = 43$).

Results

Descriptive statistics for the sanAFF, nAFF, and the three HRV indices and the zero-order correlations between the variables are presented in Table 2 for the TSST and Placebo conditions separately. Two HRV outliers ($|z| > 3.29$; $p < 0.001$) were excluded from further analyses. There were no significant gender differences with respect to nAFF, $t(97) \leq -0.24$, $p = 0.813$, baseline HRV, $t(83) = 0.81$, $p = 0.420$, HRV during the (Placebo) TSST, $t(86) = 0.17$, $p = 0.867$, and HRV during stress recovery, $t(83) \leq 0.23$, $p = 0.818$. Women ($M = -0.12$) tended to score higher than men ($M = 0.09$) on sanAFF, $t(97) = -1.48$, $p = 0.143$ (cf. Schultheiss and Brunstein 2002).

ANOVA

The results of the repeated-measures ANOVA confirmed the differential effects of the TSST versus the Placebo TSST on HRV across all participants. The time course of HRV in the two experimental conditions across the three times of

Table 2 Descriptive statistics and correlations

Variable	(1)	(2)	(3)	(4)	(5)	*M*	SD
(1) Explicit affiliation motive (*san*AFF)	_	−0.13	0.01	0.24	0.29*	−0.09	0.76
(2) Implicit affiliation motive (*n*AFF)	0.18	_	0.05	−0.05	0.09	−0.09	1.19
(3) HRV baseline	0.30*	0.10	_	0.66***	0.73***	3.57	0.60
(4) HRV stress reactivity	−0.09	0.24*	0.44**	_	0.67**	3.27	0.52
(5) HRV stress recovery	0.18	0.29*	0.59***	0.72***	_	3.84	0.48
M	0.09	0.09	3.56	2.94	3.61	_	_
SD	0.69	1.32	0.55	0.61	0.46	_	_

Sample sizes differ due to nonsystematic technical malfunctions in the HRV assessment. TSST: $N = 49$ for sanAFF and nAFF, $N = 43$ for HRV baseline and stress recovery, $N = 45$ for HRV stress reactivity; Placebo: $N = 42$ for HRV baseline and stress recovery, $N = 43$ for HRV stress reactivity

HRV heart rate variability (natural logarithm of RMSSD), *TSST* condition below the diagonal, Placebo condition above the diagonal

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$ (derived from 10,000 bootstrapped replications)

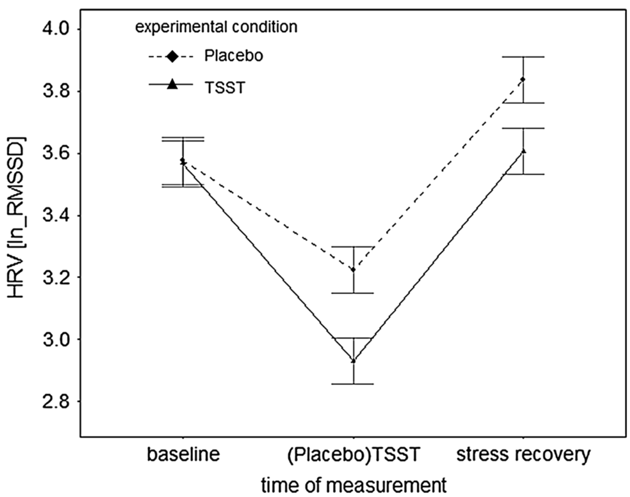


Fig. 1 Heart rate variability (natural logarithm of RMSSD) as a function of time of measurement and experimental condition. *Error bars* are Fisher's least significant difference

measurement is illustrated in Fig. 1. Along with the significant main effects of experimental condition, $F(1, 78) = 2.86$, $p = 0.095$, $\eta^2 = 0.03$, and time, $F(2, 156) = 80.29$ (Greenhouse-Geisser corrected $p < 0.001$, $\eta^2 = 0.21$), the two-way interaction involving experimental condition and time was significant, $F(2, 156) = 3.97$ (Greenhouse-Geisser corrected $p = 0.027$, $\eta^2 = .01$). Post hoc analyses revealed that the interaction between condition and time was significant for the change in HRV from baseline to stress reactivity, $F(1, 78) = 5.21$, $p = 0.025$, $\eta^2 = 0.02$, but not for the change in HRV from stress reactivity to stress recovery, $F(1, 78) = 0.53$, $p = 0.470$, $\eta^2 = 0.00$. As expected, the decrease in HRV from baseline (indicating stress), $F(1, 78) = 62.74$, $p < 0.001$, $\eta^2 = 0.16$, was significantly stronger in the TSST than in the Placebo TSST condition. The increase in HRV from stress reactivity to stress recovery, $F(1, 78) = 202.28$, $p < 0.001$, $\eta^2 = 0.29$, was comparable between the two conditions. In sum, the results of the repeated-measures ANOVA confirmed that the decrease in HRV from baseline to stress reactivity (indicating a stress response in both groups) was significantly stronger in the TSST condition than in the Placebo condition and that the increase in HRV from (Placebo) TSST to stress recovery (indicating recovery from stress in both groups) was comparable in the two groups.

RSA for HRV during socioevaluative stress and stress recovery (TSST condition)

Inspecting the fit indices to compare the additive model with the three models representing (in)congruence (IA, RR, and SQD) in the upper part of Table 3, the additive model had the best fit for predicting HRV during *socioevaluative stress* from sanAFF and nAFF. The additive model had the lowest AICc with a model weight of 0.54. All models with fewer free parameters (more parsimonious models, $k < 4$) had a $CFI < 0.87$. Furthermore, the χ^2-LR tests indicated that the additive model was significantly better than the null model, $\Delta\chi^2(2) = 9.384$, $p = 0.009$, and that it was not significantly worse than the full polynomial model, $\Delta\chi^2(3) = 0.65$, $p = .885$. The regression coefficients and derived surface parameters of the final additive model are summarized in the upper part of Table 4. The table additionally reports robust standard errors and percentile-bootstrapped CIs and *p*-values. The resulting regression coefficients indicated a significant negative linear effect of sanAFF and a significant positive linear effect of nAFF on HRV with moderate effect sizes (respective $\Delta R^2s = 0.09/0.08$). Jointly, these effects resulted in a significant negative linear slope along the line of incongruence LOIC (*a3*). For better interpretation, the results are plotted as a 3D plot and a contour plot in Fig. 2A1, A2, respectively. Interpreting only the regions of the surface that were in the

Table 3 Model comparison for HRV stress reactivity and stress recovery in the TSST condition

Model	*K*	AICc	ΔAICc	Model weight	Evidence ratio	χ^2 (df)	CFI	R^2	p_{model}	R^2_{adj}
	HRV stress reactivity									
Additive	2	666.82	0.00	0.54		0.65 (3)	1.00	0.145	0.048	0.101
Null	0	669.07	2.25	0.18	3.08	9.28 (5)	0.00	0.000		0.000
IA	3	669.08	2.26	0.18	3.10	0.51 (2)	1.00	0.146	0.109	0.078
SQD	1	671.12	4.29	0.06	8.54	7.87 (4)	0.00	0.001	0.811	-.024
RR	2	673.10	6.28	0.02	23.13	8.31 (3)	0.00	0.007	0.880	-.044
Full	5	673.65	6.83	0.02	30.49	– (–)	1.00	0.155	0.277	0.038
	HRV stress recovery									
Additive	2	622.91	0.00	0.48		2.71 (3)	1.00	0.150	0.039	0.107
IA	3	624.76	1.85	0.19	2.52	2.61 (2)	1.00	0.159	0.077	0.094
Null	0	625.59	2.68	0.13	3.83	13.19 (5)	0.00	0.000		0.000
RR	2	625.72	2.81	0.12	4.08	6.45 (3)	0.58	0.092	0.144	0.047
SQD	1	627.22	4.31	0.06	8.62	10.57 (4)	0.00	0.011	0.505	-0.013
Full	5	628.46	5.54	0.03	16.00	– (–)	1.00	0.184	0.167	0.074

k number of free parameters, *AICc* corrected akaike information criterion, *Evidence ratio* Ratio of model weights for the best model compared with each other model, *CFI* comparative fit index R^2 variance explained by the model, p_{model} *p* value for variance explained by the model, R^2_{adj} adjusted R^2,$N_{\text{stress reactivity}} = 42$, $N_{\text{stress recovery}} = 43$, *RR* rising ridge model *SQD* squared difference model, *additive* two linear main effects, *IA* interaction model, *null* intercept-only model

Table 4 Regression coefficients b1 to b3 and surface parameters for the additive models predicting HRV stress reactivity and stress recovery in the TSST Condition

	Estimate	Robust *SE*	95 % CI (lower)	95 % CI (upper)	β	*p*
HRV stress reactivity						
*san*AFF	−0.258	0.114	−0.500	−0.015	−0.313	0.038
*n*AFF	0.118	0.046	0.019	0.285	0.284	0.028
a1	−0.140	0.115	-0.403	0.161	–	0.358
a3	−0.377	0.129	-0.658	−0.110	–	0.009
HRV stress recovery						
*san*AFF	0.180	0.060	0.071	0.341	0.363	0.002
*n*AFF	0.020	0.026	−0.045	0.118	0.081	0.480
a1	0.200	0.063	0.065	0.384	–	0.010
a3	0.161	0.068	0.035	0.337	–	0.011

Additive two linear main effects. Confidence intervals and *p* values were derived from a percentile bootstrap with 10,000 replications; *Estimate* unstandardized regression coefficients; β standardized regression coefficients; $N_{\text{stress reactivity}} = 42$; $N_{\text{stress recovery}} = 43$

range of the original data (points on the contour plot), it could be seen that at each value of the explicit affiliation motive, there was a positive slope for predicting HRV with the implicit affiliation motive and vice versa. As a result, the main effects added up so that the highest HRV values (reduced stress) were predicted for people with high nAFF and low sanAFF, and the lowest HRV values (increased stress) were predicted for people with low nAFF and high sanAFF.

For predicting HRV *stress recovery* following the TSST condition from sanAFF and nAFF, the additive model offered the best fit to the data (lower part of Table 3) with a model weight of 0.48. The null model had a significantly worse fit than the additive model, $\Delta\chi^2(2) = 10.315$, $p = 0.006$, and the additive model was not significantly worse than the full polynomial model, $\Delta\chi^2(3) = 2.710$, $p = 0.438$. The resulting regression coefficients and surface parameters are summarized in the lower part of Table 4. Applying the additive model, there was a significant moderate to large positive regression coefficient for sanAFF in predicting HRV stress recovery but no significant effect of nAFF (respective $\Delta R^2 s = 0.13/0.01$). Transforming these regression parameters into surface parameters, there were significant positive slopes along the LOC (*a1*) and the LOIC (*a3*). These results are depicted in Fig. 2B1, B2: The higher a person's sanAFF, the higher her

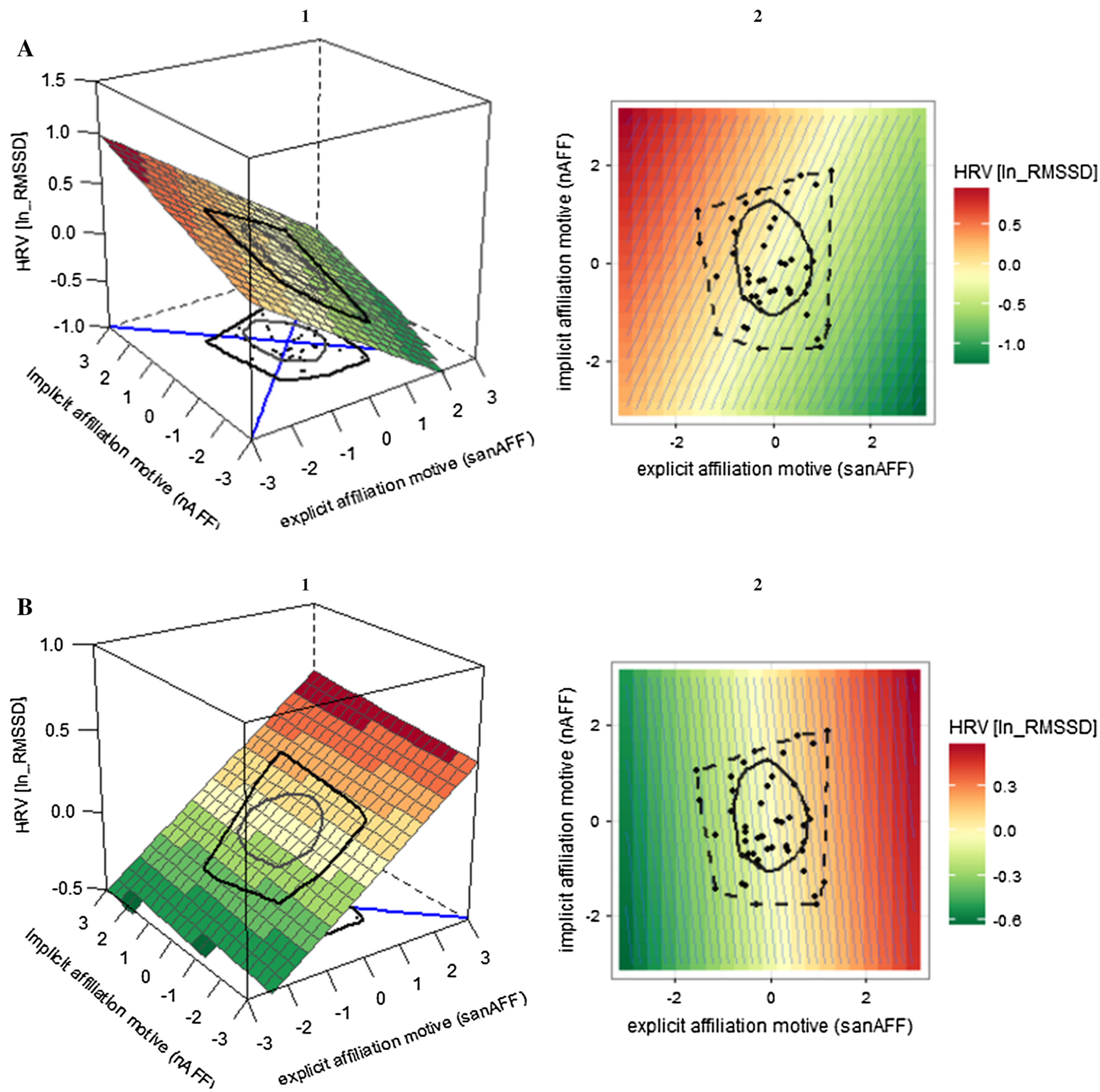


Fig. 2 3D (*1*) and contour (*2*) plots of the response surfaces for heart rate variability (natural logarithm of RMSSD, residual change scores) during stress reactivity (**A**) and stress recovery (**B**) in the TSST condition. The response surface colors indicate high (*red*) versus low (*green*) predicted values for heart rate variability. Black points indicate the range of empirical data (Color figure online)

or his HRV (reduced stress) following the TSST. nAFF, however, had no effect on HRV stress recovery when the effect of HRV during the TSST was controlled for.

RSA for HRV in a socially ambiguous situation and stress recovery (Placebo TSST condition)

The fit indices for the competing RSA models in predicting HRV during the Placebo TSST are summarized in the upper part of Table 5. The IA model had the lowest AICc with a model weight of 0.47. The χ^2-LR tests indicated that the IA model was significantly better than the null model, $\Delta\chi^2(3) = 13.00$, $p = 0.005$, and that it was not significantly worse than the full polynomial model, $\Delta\chi^2(2) = 3.78$, $p = .151$. After the full polynomial model, the adjusted R^2 value was highest for the IA model. The regression coefficients and derived surface parameters for the final IA model are summarized in the upper part of Table 6. The regression coefficients indicated a significant and moderate positive effect of sanAFF and a

Table 5 Model comparison for the HRV stress reactivity and stress recovery in the placebo condition

Model	k	AICc	ΔAICc	Model weight	Evidence ratio	χ^2 (df)	CFI	R^2	p_{model}	R^2_{adj}
	HRV stress reactivity									
IA	3	475.24	0.00	0.47		3.78 (2)	0.87	0.241	0.021	0.175
Additive	2	476.36	1.12	0.27	1.75	8.32 (3)	0.59	0.170	0.035	0.124
Full	5	477.25	2.00	0.17	2.72	–(–)	1.00	0.299	0.032	0.193
Null	0	479.29	4.04	0.06	7.55	16.77 (5)	0.00	0.000		0.000
SQD	1	481.39	6.15	0.02	21.64	22.49 (4)	0.00	0.000	0.961	−0.027
RR	2	483.62	8.37	0.01	65.79	39.72 (3)	0.00	0.000	0.998	−0.055
	HRV stress recovery									
RR	2	556.13	0.00	0.29		0.42 (3)	1.00	0.099	0.132	0.052
Null	0	556.18	0.05	0.28	1.02	4.63 (5)	1.00	0.000		0.000
SQD	1	556.65	0.52	0.22	1.30	3.28 (4)	1.00	0.038	0.217	0.014
Additive	2	557.54	1.42	0.14	2.03	1.67 (3)	1.00	0.068	0.255	0.020
IA	3	559.67	3.54	0.05	5.87	3.83 (2)	1.00	0.072	0.411	−0.001
Full	5	562.98	6.85	0.00	30.78	– (–)	1.00	0.109	0.502	−0.014

$N_{\text{reactivity}} = 39$, $N_{\text{recovery}} = 42$, *k* Number of free parameters; *AICc* corrected Akaike Information Criterion, *Evidence ratio* Ratio of model weights for the best model compared with each other model, *CFI* Comparative fit index, R^2 variance explained by the model; p_{model} *p* value for variance explained by the model; R^2_{adj} = adjusted R^2, $N_{\text{stress reactivity}} = 39$, $N_{\text{stress recovery}} = 42$. Model abbreviations: *RR* Rising ridge model, *SQD* Squared difference model, Additive = two linear main effects, *IA* Interaction model, *null* Intercept-only model

Table 6 Regression coefficients b1 to b5 and derived surface parameters for the selected models predicting HRV stress reactivity and stress recovery in the placebo condition

Model	Estimate	Robust *SE*	95 % CI (lower)	95 % CI (upper)	β	*p*
HRV stress reactivity (IA)						
*san*AFF	0.207	0.087	0.009	0.380	0.432	0.039
*n*AFF	−0.102	0.057	−0.204	0.034	−0.291	0.161
*san*AFF X *n*AFF	0.184	0.117	−0.087	0.404	0.317	0.210
a1	0.106	0.096	−0.129	0.298	–	0.326
a2	0.184	0.117	−0.087	0.404	–	0.210
a3	0.309	0.112	0.055	0.514	–	0.012
a4	−0.184	0.117	−0.404	0.087	–	0.210
HRV stress recovery (RR)						
*san*AFF	0.074	0.042	−0.009	0.170	0.161	0.088
*n*AFF	0.074	0.042	−0.009	0.170	0.225	0.088
*san*AFF^2	0.028	0.028	−0.034	0.089	0.067	0.392
*san*AFF X *n*AFF	−0.057	0.057	−0.177	0.067	−0.100	0.392
*n*AFF^2	0.028	0.028	−0.034	0.089	0.124	0.392
a1	0.147	0.083	−0.018	0.341	–	0.088
a4	0.113	0.114	−0.134	0.354	–	0.392

IA Interaction model, *RR* Rising ridge model. Confidence intervals and *p* values were derived from a percentile bootstrap with 10,000 replications, *Estimate* unstandardized regression coefficients; *β* standardized regression coefficients; $N_{\text{stress reactivity}} = 39$; $N_{\text{stress recovery}} = 42$

nonsignificant small negative effect of nAFF (respective $\Delta R^2s = 0.09/0.03$). Beyond these main effects, the interaction of sanAFF and nAFF showed a small to moderate but nonsignificant effect in predicting HRV during the Placebo TSST ($\Delta R^2 = 0.07$). The critical test for the expected general negative effect of incongruence between sanAFF and nAFF on HRV during the Placebo TSST is the surface parameter describing the curvature of the LOIC (*a4*). This parameter was not significant. What we found, however, was a significant linear slope on the LOIC (*a3*), indicating that the direction of incongruence was important and not the general degree of incongruence. As can be seen

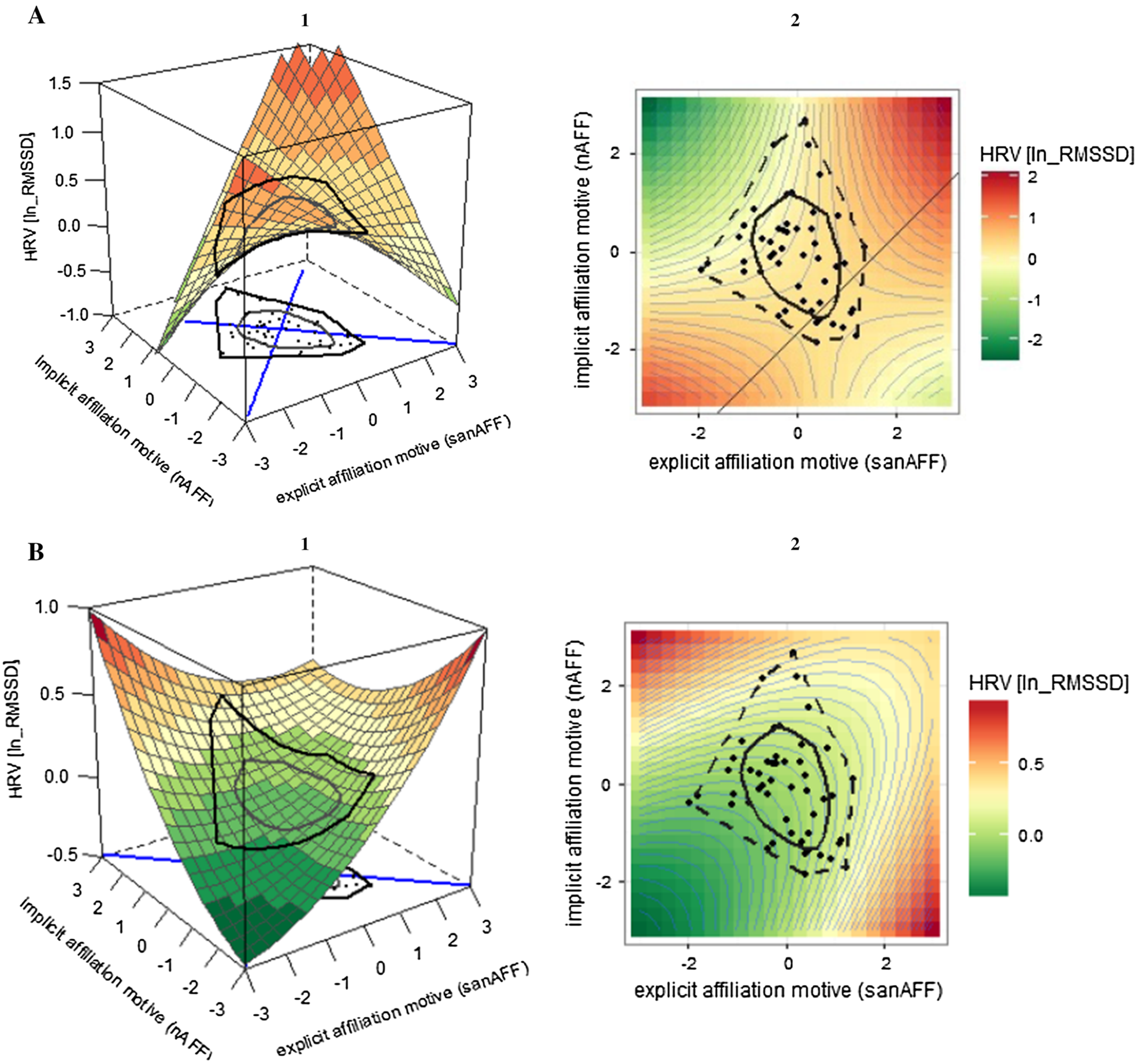


Fig. 3 3D (*1*) and contour (*2*) plots of the response surfaces for heart rate variability (natural logarithm of RMSSD, residual change scores) during stress reactivity (**A**) and stress recovery (**B**) in the Placebo condition. The response surface colors indicate high (*red*) versus low (*green*) predicted values for heart rate variability. Black points indicate the range of empirical data (Color figure online)

in Fig. 3A1, A2, the significant slope of the LOIC indicates that HRV was significantly lower for the incongruent case in which high nAFF was accompanied by low sanAFF than when they were congruent or when the incongruence was in the other direction (low nAFF and high sanAFF). That is, during the socially ambiguous situation, the lowest HRV (indicating stress) was found for persons who had a high nAFF that was not supported by an equally high sanAFF in contrast to persons with congruent values and persons whose high sanAFF was not supported by an equally high nAFF.

The results of the model comparison for the prediction of HRV *stress recovery* following the Placebo TSST are summarized in the lower part of Table 5. According to the AICc, the RR model had the best fit to the data, although it explained approximately only 10 % of the variance in HRV stress recovery ($p = 0.132$). The χ^2-LR tests indicated that the RR model was not significantly worse than the full polynomial model, $\Delta\chi^2(3) = 0.42$, $p = .937$, but also that it was only marginally better than the null model, $\Delta\chi^2(2) = 5.45$, $p = 0.066$. Furthermore, the null model was one of the most plausible models ($\Delta\text{AICc} < 2$), and even the full polynomial model's R^2 was not significantly different from zero. Thus, the results of the RR model for predicting stress recovery following the Placebo TSST can be regarded only descriptively. Unrestricted regression coefficients and surface parameters from the RR model are summarized in the lower part of Table 6, and the resulting surface is plotted as a 3D plot and a contour plot in Fig. 3B1, B2, respectively. The regression coefficients indicated nonsignificant and small positive effects of sanAFF and nAFF (respective $\Delta Rs^2 = 0.03/0.02$). Beyond these main effects, the restricted interaction of sanAFF and nAFF and the two quadratic terms, sanAFF^2 and nAFF^2, offered only a small increase in the prediction of HRV stress recovery following the Placebo TSST ($\Delta R^2 = 0.03$). Again, the surface parameters did not indicate a curvature in the LOIC (*a4*) but a marginal linear slope along the LOC (*a1*) resulting from the joint main effects of sanAFF and nAFF. This means that there was a tendency for higher values in both sanAFF and nAFF to be associated with a higher HRV, indicating reduced stress following the Placebo TSST. There was no effect of (in)congruency.

Discussion

The aim of our study was to investigate the independent and interactive effects of nAFF and sanAFF on parasympathetic vagal activity (HRV) in three motive-relevant situations: in a socioevaluative stress situation, in a socially ambiguous situation, and during socially supported recovery from stress. Vagal activity is especially suitable for indicating the physiological responses associated with satisfied versus frustrated affiliation motives as it is related to processes that can be arranged along a continuum from stress-related behaviors to prosocial–affiliative interactions (Porges, 2001, 2007; Porges and Furman 2011). An additional strength of the present study is that we evaluated situated effects of both affiliation motive systems (nAFF and sanAFF) simultaneously. In addition, we implemented RSAs (Edwards, 2002) to investigate the linear and curvilinear effects of congruence and incongruence in both motive systems and to directly compare competing models for additive main versus interaction effects.

First, the well-documented effectiveness of the TSST in eliciting substantial physiological stress responses (Dickerson and Kemeny 2004) was confirmed. Our analyses revealed that the decrease in vagal activity from baseline to stress reactivity (indicating stress) was significantly stronger in the TSST condition compared with the Placebo TSST condition.

In predicting individual differences in response to socioevaluative stress (TSST), we expected a stress-enhancing effect of sanAFF and a stress-buffering effect of nAFF. The parameters of the best-fitting additive model supported these hypotheses on additive but opposite effects of sanAFF and nAFF. Higher sanAFF predicted vagal withdrawal (indicating stress), and higher nAFF predicted vagal advance. Concerning sanAFF, these results replicate and expand prior findings on positive associations of sanAFF-related constructs with cognitive and physiological stress responses in actual experimental and retrospectively assessed social stress situations (Santiago-Rivera and Bernstein 1996; Yang et al., 2014). With respect to nAFF, we replicated prior findings on negative associations between nAFF and physiological stress responses (cortisol, progesterone) to announced socioevaluative stress situations (Wegner et al., 2014) and following a frustrating film sequence (Wirth Wirth and Schultheiss 2006).

The enhancing effect of nAFF on vagal activity can be interpreted as part of the neurophysiological social engagement system postulated by the Polyvagal Theory (Porges, 2001, 2007; Porges and Furman 2011). Specifically, the assumption is that cardiac vagal activity promotes social interactions and social bonds in response to situational demands with the purpose of regulating arousal in order to support adaptive behavior. A person high in nAFF is probably actively engaged in dealing with stimuli that indicate possible social interactions, instead of getting stressed if the effort is not immediately externally rewarded. This assumption is based on the idea that persons with high nAFF respond with more positive and less negative physiological reactions to social situations (McClelland et al. 1987; Sokolowski, 1986), invest a lot of effort in behaviors that are deemed to support friendly interactions such as socializing behavior (Dufner et al. 2015; Exline, 1963; McAdams and Constantian 1983; McAdams et al. 1984; McClelland et al., 1989), and are more confident that their efforts are suitable for enhancing the probability of positive interactions in a social situation than persons with low nAFF are (e.g., Sokolowski, 1992). Accordingly, studies have shown that persons high in the implicit need for achievement engage intensively in tasks in which their high need for achievement is frustrated by achievement feedback that did not satisfy their need (e.g., Brunstein and Hoyer 2002). A similar effect could be assumed for nAFF in promoting "affiliation-seeking in response to withdrawal of affiliation" (Wirth Wirth and Schultheiss 2006, p. 793) as well as more positive and less negative physiological responses to social situations (McClelland et al., 1987; Sokolowski, 1986).

Our findings on the positive outcome (i.e., lower stress response) for people high in nAFF in a socioevaluative stress situation (i.e., when social needs are unmet) may seem to be at odds with findings that show that a lack of satisfaction of implicit needs is associated with reduced well-being and negative affect (Brunstein et al., 1998; Kordik et al. 2012; McClelland, 1987; Winter, 1996).

However, in the present study, we did not look at the affective side of stress; we instead looked at a physiological indicator of the stress response that is associated with social engagement (i.e., vagal activity). It is interesting that newer models of control highlight the involvement of negative affect in recruiting control (Inzlicht et al. 2015; Inzlicht and Legault 2014). Thus, not only might our findings on the association of nAFF and vagal activity when social needs are unsatisfied fail to contradict findings on the association of nAFF and negative affect, but these two sets of findings might actually complement each other. However, this claim deserves further investigation.

In predicting the response to a socially ambiguous situation (Placebo TSST), we expected a stress-enhancing effect of nAFF–sanAFF incongruence. The Placebo TSST has no strong cues that clearly indicate the frustration of the affiliation motive. However, an ambiguous social cue may produce stress in people with incongruent nAFF and sanAFF. In line with others, we expected incongruence (i.e., high nAFF and low sanAFF or vice versa) to act as a "hidden stressor" (Baumann et al., 2005, p. 783), independent of the direction of incongruence (McClelland et al., 1989). The parameters of the best-fitting moderated regression model (IA) did not support this hypothesis on symmetrical effects of motive incongruence but rather supported a directional linear effect: In response to a socially ambiguous situation, the highest stress response (vagal withdrawal) was found for persons who had high nAFF and low sanAFF in contrast to persons with congruent values and persons with low nAFF and high sanAFF. High nAFF/low sanAFF-incongruence bears the intrapersonal conflict that the aroused implicit need is not suitably supported by the initiation and guidance of behavior through the explicit motive (e.g., Elliot et al., 2006). There are two possible explanations for this asymmetric effect of motive incongruence. First, it might be the case that the other type of incongruence (low nAFF/high sanAFF) is less relevant in a situation in which there is no real partner to interact with. Thus, there are no direct obstacles (e.g., an unresponsive interaction partner) blocking the desired goal that would have to be overcome by a supporting implicit need (e.g., McClelland et al., 1989). Another possible explanation lies in the picture cues that we used to assess nAFF. They depict situations in which one person is being evaluated by one or more other persons. We consciously chose our pictures to fit the TSST condition with which we wanted to assess the effects of nAFF on our dependent variable (see Schultheiss and Pang 2007). However, as they depict only one kind of social (evaluative) situation, these cues might be able to reflect only limited variance in overall nAFF. Although these variations in nAFF are the ones that are important predictors of variations in HRV in the TSST condition, the overall variation in more general nAFF might allow for more general conclusions about general (in)congruence effects in the ambiguous placebo condition. Future studies should investigate whether a broader range of affiliation picture cues, which would provide a more general measure of nAFF, might reveal a more symmetric effect of motive incongruence as suggested by the results of studies that have applied absolute difference scores (e.g., Schüler et al., 2009) or if the asymmetric incongruence is characteristic of the ambiguous placebo condition.

In predicting the response to supportive social contact after stress, we expected that nAFF and sanAFF would support an attenuation of the stress response. Overall, a significant increase in vagal activity from socioevaluative stress (TSST) and the socially ambiguous situation (Placebo TSST) to the positive social contact afterwards indicated a fading stress response. As expected, sanAFF was associated with an attenuated stress response (i.e., vagal advance) during socially supported stress recovery after socioevaluative stress. However, we found no effect of nAFF on vagal activity during socially supported stress recovery after the socioevaluative stress situation. Taking the already existing increasing effect of nAFF on vagal activity during the socioevaluative stress situation into account, it is not surprising that we did not find a continuously increasing effect of nAFF on vagal activity after that situation. We did not find a significant effect of nAFF and sanAFF on vagal activity during socially supported stress recovery after the socially ambiguous situation. There was only a tendency for both nAFF and sanAFF to be associated with an attenuated stress response (i.e., vagal advance). These effects were small and can be interpreted only descriptively at this point. In sum, our analysis revealed that talking to a friendly person about a stressful experience was especially beneficial for participants high in sanAFF. Note that according to the Polyvagal Theory (Porges, 2001, 2007; Porges and Furman 2011), vagal advance is the physiological side of a reaction characterized by both reduced stress and prosocial-affiliative behavior. However, as we did not include a control condition in the stress recovery phase, it is unclear whether the buffering effect of sanAFF is specific to the socially supportive situation or if it would also occur during recovery without social support. Thus, the degree of social support during stressful recovery should be experimentally manipulated in future studies to allow for a direct test of the interaction between motives and support.

In general, the correlations between HRV at baseline and HRV during the (Placebo) TSST as well as between HRV during the (Placebo) TSST and HRV during stress recovery indicate that a substantial proportion of the variance in HRV during stress reactivity can be explained by individual differences in vagal tone (baseline), and a substantial proportion of variance in HRV during stress recovery can be explained by individual differences in vagal activity during the (Placebo) TSST (see Egizio et al., 2008). The remaining proportion of variance (variance in the residualized values) is therefore smaller than the variance in the unresidualized values and might thereby restrict the size of possible covariances. However, the variation in the residualized values is a valid indicator of individual differences in vagal withdrawal and advance as it provides meaningful information about whether a participant's vagal activity is relatively higher or lower than would be expected from his or her vagal activity at the previous measurement occasion (Obradović et al., 2011).

Finally, it has to be acknowledged that our findings are based on modest sample sizes and that this is a limitation of the present study. Thus, further research is necessary to replicate our findings in larger samples. Besides providing an additional validation of our results, larger samples may also allow for the investigation of cognitive processes that may mediate the effects of the affiliation motives on HRV, for example, assessing the participants' reappraisal of the stress situation (Denson et al., 2011) and implementing variations in motive-relevant demands and in the social support that is given.

In addition, a logical follow-up question is whether the influence on stress reactivity and recovery in motive-relevant situations generalizes to other motives. More precisely, do the achievement motives influence stress reactivity and recovery in situations in which standards of excellence prevail, and do the power motives influence stress reactivity and recovery in situations in which status and prestige are at stake? When examining motive-specific stress responses in motive-related situations, it is advisable to consider the possibility that affiliation-, power-, and achievement-related stress responses may primarily involve different physiological systems. Although the neural circuitry and peripheral neuroendocrine pathways that comprise the human stress response systems have a shared species-typical structure, there is great variation between individuals in the calibration of these systems in response to external stressors (Ellis et al. 2006), and this variation may be associated with motives. The present study demonstrated associations between affiliation motives and the vagal stress response in social situations. Stress that is related to power motivation, for example, may be most evident in adrenal steroid cortisol (Schultheiss, 2007).

Conclusions

We investigated the effects of nAFF and sanAFF in motive-relevant situations on a physiological feature of the stress response involved in social engagement: parasympathetic vagal activity (HRV; Porges, 2001, 2007; Porges and Furman 2011). We applied RSAs to investigate independent and interactive effects of the implicit and explicit motive systems in the domain of affiliation as a tool that can be used to test hypotheses on additive main effects and (a)symmetric effects of (in)congruence between the systems as well as to directly compare such competing models. sanAFF predicted (a) a greater stress response to socioevaluative stress and (b) an attenuated stress response (social engagement) during affiliation after socioevaluative stress. nAFF predicted a reduced stress response (or social engagement, respectively) in response to socioevaluative stress. The incongruent combination of high nAFF and low sanAFF predicted a greater stress response to a socially ambiguous situation. We suggest that the investigation of the influence of motives on stress reactivity and recovery in motive-relevant situations represents a theoretically sound approach that can be used to plot a meaningful person-situation interaction in the domain of implicit and explicit motives.

Acknowledgments We would like to thank Christine Altstötter-Gleich and Anette Hiemisch for valuable comments on an earlier version of this article.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in the current study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

Baumann, N., Kaschel, R., & Kuhl, J. (2005). Striving for unwanted goals: stress-dependent discrepancies between explicit and implicit achievement motives reduce subjective well-being and increase psychosomatic symptoms. *Journal of Personality and Social Psychology, 89*(5), 781–799. doi:10.1037/0022-3514.89.5.781.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497–529.

Brewer, S., & Klein, J. D. (2006). Type of positive interdependence and affiliation motive in an asynchronous, collaborative learning environment. *Educational Technology Research and Development, 54*(4), 331–354. doi:10.1007/s11423-006-9603-3.

Brunstein, J. C., & Hoyer, S. (2002). Implizites versus explizites Leistungsstreben: Befunde zur unabhängigkeit zweier motivationssysteme [Implicit versus explicit achievement strivings: Empirical evidence of the independence of two motivational systems]. *Zeitschrift Für Pädagogische Psychologie, 16*(1), 51–62. doi:10.1024//1010-0652.16.1.51.

Brunstein, J. C., Schultheiss, O. C., & Grässman, R. (1998). Personal goals and emotional well-being: The moderating role of motive dispositions. *Journal of Personality and Social Psychology, 75*(2), 494–508.

Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multimodel inference: A practical information-theoretic approach*. Berlin: Springer Science & Business Media.

Crowley, O. V., McKinley, P. S., Burg, M. M., Schwartz, J. E., Ryff, C. D., Weinstein, M., et al. (2011). The interactive effect of change in perceived stress and trait anxiety on vagal recovery from cognitive challenge. *International Journal of Psychophysiology, 82*(3), 225–232. doi:10.1016/j.ijpsycho.2011.09.002.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

Denson, T. F., Grisham, J. R., & Moulds, M. L. (2011). Cognitive reappraisal increases heart rate variability in response to an anger provocation. *Motivation and Emotion, 35*(1), 14–22. doi:10.1007/s11031-011-9201-5.

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355–391. doi:10.1037/0033-2909.130.3.355.

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

Edwards, J. R. (2002). Alternatives to difference scores: Polynomial regression analysis and response surface methodology. In F. Drasgow & N. Schmitt (Eds.), *Measuring and analyzing behavior in organizations: Advances in measurement and data analysis* (pp. 350–400). San Francisco, CA: Jossey-Bass.

Egizio, V. B., Jennings, J. R., Christie, I. C., Sheu, L. K., Matthews, K. A., & Gianaros, P. J. (2008). Cardiac vagal activity during psychological stress varies with social functioning in older women. *Psychophysiology, 45*(6), 1046–1054. doi:10.1111/j.1469-8986.2008.00698.x.

Elliot, A. J., Gable, S. L., & Mapes, R. R. (2006). Approach and avoidance motivation in the social domain. *Personality and Social Psychology Bulletin, 32*(3), 378–391. doi:10.1177/0146167205282153.

Ellis, B., Jackson, J., & Boyce, W. (2006). The stress response systems: Universality and adaptive individual differences. *Developmental Review, 26*(2), 175–212. doi:10.1016/j.dr.2006.02.004.

Exline, R. V. (1963). Explorations in the process of person perception: Visual interaction in relation to competition, sex, and need for affiliation. *Journal of Personality, 31*(1), 1–20. doi:10.1111/j.1467-6494.1963.tb01836.x.

French, E. G., & Chadwick, I. (1956). Some characteristics in affiliation motivation. *The Journal of Abnormal and Social Psychology, 53*(3), 296–300.

Grenier, S., Barrette, A. M., & Ladouceur, R. (2005). Intolerance of uncertainty and intolerance of ambiguity: Similarities and differences. *Personality and Individual Differences, 39*(3), 593–600. doi:10.1016/j.paid.2005.02.014.

Hagemeyer, B., Neberich, W., Asendorpf, J. B., & Neyer, F. J. (2013). Congruence of implicit and explicit communal motives predicts the quality and stability of couple relationships. *Journal of Personality, 81*(4), 390–402. doi:10.1111/jopy.12016.

Het, S., Rohleder, N., Schoofs, D., Kirschbaum, C., & Wolf, O. T. (2009). Neuroendocrine and psychometric evaluation of a placebo version of the "Trier social stress test". *Psychoneuroendocrinology, 34*(7), 1075–1086. doi:10.1016/j.psyneuen.2009.02.008.

Hofer, J., & Busch, H. (2011). Satisfying one's needs for competence and relatedness: consequent domain-specific well-being depends on strength of implicit motives. *Personality and Social Psychology Bulletin, 37*(9), 1147–1158. doi:10.1177/0146167211408329.

Hofer, J., Chasiotis, A., & Campos, D. (2006). Congruence between social values and implicit motives: effects on life satisfaction across three cultures. *European Journal of Personality, 20*(4), 305–324. doi:10.1002/per.590.

Inzlicht, M., Bartholow, B. D., & Hirsh, J. B. (2015). Emotional foundations of cognitive control. *Trends in Cognitive Sciences, 19*(3), 126–132. doi:10.1016/j.tics.2015.01.004.

Inzlicht, M., & Legault, L. (2014). How distress underlies effective self-control (and unites diverse social psychological phenomena). In J. P. Forgas & E. Harmon-Jones (Eds.), *Motivation and its regulation: The control within* (pp. 115–132). New York: Psychology Press.

Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. H. (1993). The "Trier social stress test" - a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*(1–2), 76–81. doi:10.1159/000119004.

Köllner, M. G., & Schultheiss, O. C. (2014). Meta-analytic evidence of low convergence between implicit and explicit measures of the needs for achievement, affiliation, and power. *Frontiers in Psychology, 5*, 826. doi:10.3389/fpsyg.2014.00826.

Kordik, A., Eska, K., & Schultheiss, O. C. (2012). Implicit need for affiliation is associated with increased corrugator activity in a non-positive, but not in a positive social interaction. *Journal of Research in Personality, 46*(5), 604–608. doi:10.1016/j.jrp.2012.05.006.

Lawrence, M. A. (2013). ez: Easy analysis and visualization of factorial experiments (R package version 4.2-2). Retrieved from http://cran.r-project.org/package=ez.

Lazarus, R. S. (2006). *Stress and emotion: A new synthesis*. New York: Springer Publishing Company.

Lundqvist, C., & Raglin, J. S. (2014). The relationship of basic need satisfaction, motivational climate and personality to well-being and stress patterns among elite athletes: An explorative study. *Motivation and Emotion, 39*(2), 237–246. doi:10.1007/s11031-014-9444-z.

Maslow, A. H. (1958). A dynamic theory of human motivation. In M. Stacey & C. L. DeMartino (Eds.), *Understanding human motivation* (pp. 26–47). Cleveland, OH: H. Allen Publishers.

McAdams, D. P., & Constantian, C. A. (1983). Intimacy and affiliation motives in daily living: An experience sampling analysis. *Journal of Personality and Social Psychology, 45*(4), 851–861.

McAdams, D. P., Jackson, R. J., & Kirshnit, C. (1984). Looking, laughing, and smiling in dyads as a function of intimacy motivation and reciprocity. *Journal of Personality, 52*(3), 261–273. doi:10.1111/j.1467-6494.1984.tb00881.x.

McAdams, D. P., & Powers, J. (1981). Themes of intimacy in behavior and thought. *Journal of Personality and Social Psychology, 40*(3), 573–587. doi:10.1037/0022-3514.40.3.573.

McClelland, D. C. (1987). *Human motivation*. New York, NY: Cambridge University Press.

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

McClelland, D. C., Patel, V., Stier, D., & Brown, D. (1987). The relationship of affiliative arousal to dopamine release. *Motivation and Emotion, 11*(1), 51–66. doi:10.1007/BF00992213.

McLain, D. L. (1993). The MSTAT-I: A new measure of an individual's tolerance for ambiguity. *Educational and psychological measurement, 53*, 183–189. doi:10.1177/0013164493053001020.

Mehrabian, A., & Ksionzky, S. (1974). *A theory of affiliation*. Lexington, Mass.: Heath.

Meuwly, N., Bodenmann, G., Germann, J., Bradbury, T. N., Ditzen, B., & Heinrichs, M. (2012). Dyadic coping, insecure attachment, and cortisol stress recovery following experimentally induced stress. *Journal of Family Psychology : JFP, 26*(6), 937–947. doi:10.1037/a0030356.

Meyer, R. D., & Dalal, R. S. (2009). Situational strength as a means of conceptualizing context. *Industrial and Organizational Psychology, 2*, 99–102.

Mezzacappa, E. S., Kelsey, R. M., Katkin, E. S., & Sloan, R. P. (2001). Vagal rebound and recovery from psychological stress. *Psychosomatic Medicine, 63*(4), 650–657.

Niskanen, J. P., Tarvainen, M. P., Ranta-Aho, P. O., & Karjalainen, P. A. (2004). Software for advanced HRV analysis. *Computer Methods and Programs in Biomedicine, 76*(1), 73–81. doi:10.1016/j.cmpb.2004.03.004.

Obradović, J., Bush, N. R., & Boyce, W. T. (2011). The interactive effect of marital conflict and stress reactivity on externalizing and internalizing symptoms: The role of laboratory stressors. *Development and Psychopathology, 23*(1), 101–114. doi:10.1017/S0954579410000672.

Penley, J., & Tomaka, J. (2002). Associations among the big five, emotional responses, and coping with acute stress. *Personality and Individual Differences, 32*(7), 1215–1228. doi:10.1016/S0191-8869(01)00087-3.

Porges, S. W. (2001). The polyvagal theory: Phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology, 42*(2), 123–146. doi:10.1016/S0167-8760(01)00162-3.

Porges, S. W. (2007). The polyvagal perspective. *Biological Psychology, 74*(2), 116–143. doi:10.1016/j.biopsycho.2006.06.009.

Porges, S. W., & Furman, S. A. (2011). The early development of the autonomic nervous system provides a neural platform for social behaviour: A polyvagal perspective. *Infant and Child Development, 20*, 106–118. doi:10.1002/icd.688.

Quested, E., Bosch, J. A., Burns, V. E., Cumming, J., Ntoumanis, N., & Duda, J. L. (2011). Basic psychological need satisfaction, stress-related appraisals, and dancers' cortisol and anxiety responses. *Journal of Sport & Exercise Psychology, 33*(6), 828–846.

Santiago-Rivera, A. L., & Bernstein, B. L. (1996). Affiliation, achievement and life events: Contributors to stress appraisals in college men and women. *Personality and Individual Differences, 21*(3), 411–419. doi:10.1016/0191-8869(96)00076-1.

Schönbrodt, F. (2007). *Testing fit patterns with polynomial regression models*. Germany: Munich.

Schönbrodt, F. D. (2016). RSA: An R package for response surface analysis (version 0.9.10). Retrieved from http://cran.r-project.org/web/packages/RSA/index.html.

Schönbrodt, F. D., & Gerstenberg, F. X. R. (2012). An IRT analysis of motive questionnaires: The unified motive scales. *Journal of Research in Personality, 46*(6), 725–742. doi:10.1016/j.jrp.2012.08.010.

Schüler, J., Job, V., Fröhlich, S. M., & Brandstätter, V. (2008). A high implicit affiliation motive does not always make you happy: A corresponding explicit motive and corresponding behavior are further needed. *Motivation and Emotion, 32*(3), 231–242. doi:10.1007/s11031-008-9096-y.

Schüler, J., Job, V., Frölich, S. M., & Brandstätter, V. (2009). Dealing with a "hidden stressor": Emotional disclosure as a coping strategy to overcome the negative effects of motive incongruence on health. *Stress and Health, 25*(3), 221–233. doi:10.1002/smi.1241.

Schultheiss, O. C. (2007). A biobehavioral model of implicit power motivation arousal, reward, and frustration. In E. Harmon-Jones & P. Winkielman (Eds.), *Social neuroscience: Integrating biological and psychological explanations of social behavior* (pp. 176–196). New York: Guilford Press.

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

Schultheiss, O. C., & Brunstein, J. C. (2002). Inhibited power motivation and persuasive communication: A lens model analysis. *Journal of Personality, 70*(4), 553–582. doi:10.1111/1467-6494.05014.

Schultheiss, O. C., & Pang, J. S. (2007). Measuring implicit motives. In R. W. Robins, R. C. Fraley, & R. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 322–344). New York: Guilford.

Schwerdtfeger, A. R., & Schlagert, H. (2011). The conjoined effect of naturalistic perceived available support and enacted support on cardiovascular reactivity during a laboratory stressor. *Annals of Behavioral Medicine, 42*(1), 64–78. doi:10.1007/s12160-011-9272-2.

Shewchuk, R. M., Elliott, T. R., MacNair-Semands, R. R., & Harkins, S. (1999). Trait influences on stress appraisal and coping: An evaluation of alternative frameworks. *Journal of Applied Social Psychology, 29*(4), 685–704. doi:10.1111/j.1559-1816.1999.tb02019.x.

Sokolowski, K. (1986). *Kognitionen und emotionen in anschlussthematischen situationen [Cognition and emotion in affiliative situations]*. Wuppertal: Bergische Universität (Unpublished dissertation).

Sokolowski, K. (1992). Entwicklung eines verfahrens zur messung des anschlussmotivs [The development of a measure for the motive to affiliate]. *Diagnostica, 38*, 1–17.

Stewart, J. C., Janicki, D. L., & Kamarck, T. W. (2006). Cardiovascular reactivity to and recovery from psychological challenge as predictors of 3-year change in blood pressure. *Health Psychology, 25*(1), 111–118. doi:10.1037/0278-6133.25.1.111.

Task force of the european society of cardiology and the North American society of pacing and electrophysiology. (1996). Heart rate variability: Standards of measurement, physiology interpretation, and clinical use. *Circulation, 93*, 1043–1065. doi:10.1161/01.CIR.93.5.1043.

Tong, E. M. W. (2010). Personality influences in appraisal-emotion relationships: The role of neuroticism. *Journal of Personality, 78*(2), 393–417. doi:10.1111/j.1467-6494.2010.00620.x.

Wegner, M., Schüler, J., & Budde, H. (2014). The implicit affiliation motive moderates cortisol responses to acute psychosocial stress in high school students. *Psychoneuroendocrinology, 48*, 162–168. doi:10.1016/j.psyneuen.2014.06.013.

Weinberger, J., Cotler, T., & Fishman, D. (2010). The duality of affiliative motivation. In O. Schultheiss & J. Brunstein (Eds.), *Implicit motives* (pp. 71–88). New York, NY: Oxford University Press.

Winter, D. G. (1994). *Manual for scoring motive imagery in running text* (4th ed.). Ann Arbor, MI: University of Michigan.

Winter, D. G. (1996). *Personality: Analysis and interpretation of lives*. New York, NY: McGraw-Hill.

Wirth, M. M., & Schultheiss, O. C. (2006). Effects of affiliation arousal (hope of closeness) and affiliation stress (fear of rejection) on progesterone and cortisol. *Hormones and Behavior, 50*(5), 786–795. doi:10.1016/j.yhbeh.2006.08.003.

Yang, J., Yang, Y., Li, H., Hou, Y., Qi, M., Guan, L., et al. (2014). Correlation between self-esteem and stress response in Chinese college students: The mediating role of the need for social approval. *Personality and Individual Differences, 70*, 212–217. doi:10.1016/j.paid.2014.06.049.