Comprehensive Psychoneuroendocrinology 8 (2021) 100091

Contents lists available at ScienceDirect

Comprehensive Psychoneuroendocrinology

journal homepage: www.sciencedirect.com/journal/comprehensive-psychoneuroendocrinology

Self-soothing touch and being hugged reduce cortisol responses to stress: A randomized controlled trial on stress, physical touch, and social identity

Aljoscha Dreisoerner [a,*], Nina M. Junker [a], Wolff Schlotz [a,b], Julia Heimrich [a], Svenja Bloemeke [c], Beate Ditzen [d], Rolf van Dick [a]

[a] Institute of Psychology, Goethe University, Germany
[b] Labs & Methods, Max-Planck-Institute for Empirical Aestetics, Germany
[c] Institute of Language Studies, RWTH Aachen, Germany
[d] Institute for Medical Psychology, University Hospital Heidelberg, Germany

ARTICLE INFO

This article is dedicated to the memory of Wolff Schlotz.

Keywords:
Tactile stimulation
Self-touch
Social support
Social identity
Self-compassion
Stress

ABSTRACT

Background: Being touched by others improves stress coping. However, when touch from others is unavailable, feels uncomfortable, or is not considered to be safe (as in the COVID-19 pandemic), self-touch gestures, like placing a hand on the heart, may provide an alternative way to experience less strain.
Methods and materials: In this study, 159 healthy participants (96 women, 62 men, and 1 non-binary person), aged 18–35 years, were exposed to a standardized psychosocial stressor (Trier Social Stress Test) to investigate whether self-soothing touch or receiving a hug from others has a buffering effect on their stress responses. In addition, the study explored whether the effectiveness of these interventions is moderated by participants' assignment to a "personal" or "social" identity condition. Participants provided salivary cortisol samples, wore an ECG to record their heart rate, and completed self-report measures on stress-related subjective-emotional states during the study.
Results: For cortisol, mixed-effects regression models with Touch and Identity as between-subject factors and Time as the within-subject factor yielded a significant main effect for touch and a significant interaction of Touch x Time indicating that cortisol levels differed between the experimental touch interventions. Post-hoc contrast tests showed that participants in both touch conditions had lower cortisol levels after the stressor than those in the control conditions. Heart rates and self-reported measures of stress neither differed across touch nor identity conditions. The three-way interaction for Touch x Identity x Time was non-significant for either outcome measure.
Discussion: These results are in line with previous work indicating that physical touch has protective effects on physiological stress responses but not necessarily on self-reported stress and suggest that self-soothing touch and receiving hugs are simple and yet potentially powerful means for buffering individuals' resilience against stress.

1. Introduction

Exposure to psychosocial stressors, such as social conflict or being judged by others, leads to increased activity of the sympathetic nervous system and the hypothalamic–pituitary–adrenal (HPA) axis, resulting in increased fear inducing responses from the amygdala, higher cortisol levels, as well as impaired cognitive abilities including working memory function [1,2]. Some level of stress is considered helpful for optimal development and functioning [1] but strategies for coping with too much stress are clearly necessary.

Skin-to-skin contact and other forms of tactile stimulation improve stress coping in animals and humans [3–6]. In healthy adults, receiving massages has been associated with lower blood pressure, heart rate, cortisol levels, and decreased anxiety [7–9]. Likewise, receiving frequent hugs relates to lower blood pressure and heart rate [10,11] as well as to faster recovery times after being infected with a common cold virus [12]. One study showed that hugging a human-shaped cushion can reduce cortisol levels [13], however no experimental studies, to the best

* Corresponding author. Zeißelstrasse 16a, 60318, Frankfurt am Main, Germany.
E-mail addresses: dreisoerner@psych.uni-frankfurt.de (A. Dreisoerner), junker@psych.uni-frankfurt.de (N.M. Junker), heimrich@psych.uni-frankfurt.de (J. Heimrich), svenja.bloemeke@rwth-aachen.de (S. Bloemeke), beate.ditzen@med.uni-heidelberg.de (B. Ditzen), van.dick@psych.uni-frankfurt.de (R. van Dick).

https://doi.org/10.1016/j.cpnec.2021.100091
Received 1 October 2021; Accepted 5 October 2021
Available online 8 October 2021

of our knowledge, have so far directly looked at the effects of receiving hugs on physiological and subjective-emotional responses to psychosocial stress.

Touch improves stress coping through several physiological mechanisms [4,14]. As touch from others (e.g., grooming) or consoling touch (e.g., stroking, hand-holding, or hugging) communicates proximity, positive affiliation, and might be perceived as a signal of safety [15], positive effects are likely mediated by increased secretion of the neuropeptide oxytocin [6,16–19]. Furthermore, receiving tactile stimulation relates to increased vagus nerve activity in a pressure-based process, which causes decreased physiological responses such as lower HPA activity, lower autonomic nervous system activity, and lower overall arousal [4,20].

Since receiving touch from others is not always available or may be unwelcome (as in the current COVID-19 pandemic), soothing self-touch gestures such as placing a hand on body parts like the heart, face, or belly, may be an alternative way to improve stress responses [21]. Although the benefits of receiving touch from others are well documented, self-touch as a deliberate intervention to soothe stress responses has received little attention so far. Anthropologists and psychologists describe self-touching like caressing, rubbing, or scratching in primates and humans as a subconscious and rarely intentional response to high levels of negative affect or overall arousal as an attempt to reduce bodily or emotional tension [22,23]. Yet, self-soothing touch is also an expression of self-compassion [24], which can be summarized as a kind and caring attitude towards the self in times of suffering that has been found to improve stress coping [25]. If humans use self-touch as a subconscious mechanism to regulate their emotions, we propose that self-touch can also be used deliberately as a coping strategy against stress. Mechanisms from self-touching on stress coping could work via the same tactility as other-produced touching or via self-induced signals of safety [26].

We further propose social identification as a potential moderator for improved stress coping through touch. According to social identity theory, our identity not only stems from individual but also from social characteristics, namely group memberships [27]. The more groups individuals belong to and the more they feel as a part of these groups, the better their health and stress coping (e.g., Refs. [28,29]). There is both a theoretical foundation and some early empirical evidence as to why social identity should moderate stress-reducing effects from receiving touch from others. Affiliative touch like hand-holding or hugging can be perceived as a form of social support [12,14]. Häusser et al. proposed that individual identification with a group alters the perception of social support as more benevolent [30]. Therefore, if individuals more strongly identify with the sender of touch, they will be more likely to perceive the sender's intention as benevolent and without a hidden agenda [31]. Frisch et al. provide experimental evidence for this proposition [32]. In their study, participants were manipulated to either perceive a personal identity or a shared identity with two confederates, who would later form the committee in the Trier Social Stress Test (TSST). During the mock interview and the arithmetic phase of the TSST, the committee then either displayed supportive (e.g., nodding, smiling) or unsupportive behaviors (e.g., frowning, shaking heads). The supportive behavior of the committee only buffered the cortisol response to the stressor when participants shared a social identity with the committee. In our study, social support is given in the form of a hug.

On this basis, we propose that, compared to a placebo control group, self-soothing touch (*Hypothesis 1*) as well as receiving a hug (*Hypothesis 2*) reduces cortisol levels, heart rate, and subjective-emotional responsiveness towards a stressor. In addition, we propose that social identification moderates the strain-relieving function of the two touch conditions (*Hypothesis 3*). To provide a multi-dimensional measurement of stress, we measured salivary free cortisol, heart rate, and subjective-emotional stress evaluations, thus contributing to the literature on the multi-modality of the stress response. Such a multi-model approach is particularly important as subjective stress evaluations and cortisol level responsiveness during the TSST have been found to vary, indicating that two different processes might take place [33,34]. We tested our hypotheses in a lab experiment with Touch (being hugged versus self-soothing touch versus a control condition), and Identity (personal versus social) as between-subject factors. We repeatedly measured salivary free cortisol, heart rate, and subjective-emotional stress evaluations with Time as the within-subject factor before, during, and after the TSST.[1]

2. Method

2.1. Participants

To detect a medium effect size with 80% power, we aimed for 30 participants for each of the six conditions and 180 participants in total [35]. Exclusion criteria for participation were regular smoking (more than 5 cigarettes/week), substance abuse, use of hormonal medication (e.g., L-Thyroxine), or current symptoms of mental or physical illness [36]. In addition, women who used any form of oral contraception (birth control pill, hormone patch, etc.) were not allowed to enter the study [37]. Furthermore, participants had to be between 18 and 35 years old and abstain from food or coffee 1 h prior to the lab experiment.

Participants were recruited on the campus of a German university and via social media networks and told that they would participate in a study on assessment centers. All sessions lasted 90 min and took place between 12.30 p.m. and 5.00 p.m. to control for diurnal changes in cortisol secretion [38]. Participants were informed about the general study procedures and provided written consent to their participation. The true aims of the study were explained after the experiment. After completing the study, participants either received 13€ or course credit for their participation. The study was approved by the ethics committee of the authors' university (2018-01) and followed the protocols laid out by the Declaration of Helsinki.

Between May 2018 and December 2018, a total of $N = 162$ individuals participated in the study. Since the participants were recruited from a limited pool, finding the last 18 participants turned out to be unreasonably difficult, which is why we settled for 162. Two participants reported being in therapy for a current mental disorder and were therefore excluded. One participant did not complete the experiment and was excluded because of language difficulties following the study protocols, leaving a final sample of $N = 159$ participants for data analysis. These 159 were, on average, 21.78 years old ($SD = 3.38$) with 96 women, 62 men, and 1 person of non-binary gender.

2.2. Procedure

Before coming to the lab, the participants completed an online questionnaire providing information on demographics (e.g., age, gender, course of study, study subject), health data (e.g., previous illnesses, medication for chronic diseases, drug abuse), and several personality measures.[2] One participant and three confederates were then invited to each session. Participants provided written consent, were informed about the study procedure, and filled out another questionnaire measuring a number of cortisol-related variables (e.g., nicotine consumption, allergies, time awake, last food, and caffeine-intake, acute

[1] The pre-registration document to the study used in this article can be found at https://osf.io/9xdum/.

[2] Data from a number of demographical, personality and well-being measures was collected but not used in the present analysis. These include recent food intake, recent physical activity, the Primary Appraisal Secondary Appraisal (PASA) questionnaire, the Ten Item Personality Measure (TIPI), the WHO-5 Well-being Index, the Satisfaction with Life Scale (SWLS), 1-item collective self-efficacy, 1-item social support, and 1-item dispositional identification. We report all other measures, manipulations, and exclusions in the study.

physical symptoms of illness, and acute medication intake).

The participants were then randomized using block randomization to one of six study conditions (hug versus self-soothing touch versus control and personal versus social identity) with potential sizes of 30 for each study condition. Participants and confederates were blind to randomization, experimenters were not. We then manipulated participants' social identity similar to Ref. [28]. In the *personal identity condition*, participants sat on individual tables, wore a shirt in a unique color, and wrote their name on their name tag. They were instructed to think about what differentiated them from the other participants. Finally, they were told to think of ways to improve the quality of life in their hometown and that their performance would be scored individually. At the end of this priming phase, individual photos were taken.

In the *social identity condition*, participants and confederates sat on a group table, wore same-colored shirts, and came up and wrote a group name on their name tags. They were asked to think about what made them similar to the other participants and how they, as a group, could improve the quality of life in their hometown. The confederates were also asked to behave in a congenial way (smile more, tell jokes, and interact) with the actual participant to build rapport. In the social identity condition, group pictures were taken. After the social identity manipulation, fake lots were drawn to determine roles during the TSST, where the actual participant always drew the role of the interviewee.

Psychosocial stress was induced using the Trier Social Stress Test (TSST, [39]). In the TSST, participants were told that they would be interviewed for their dream job and that they would have to complete two tasks, an individual speech about themselves and a mental arithmetic task. Then, they received 5 min alone in the room to prepare before presenting their speech in front of a committee formed from two of the three confederates and a fake video camera. After the interview, participants had to count backward in steps of 17, starting from 2043, and had to start over whenever they made a mistake. The confederates were instructed to only provide neutral non-verbal responses and to encourage the presenters to go on whenever they stopped. Studies indicate that the TSST enables a naturalistic exposure to a socio-evaluative stressful situation, with two-to three-fold increases in HPA axis and cardiovascular responses [34,39]. Deviating from the standard TSST and to manipulate touch, the experimenter re-entered the room after the preparation time for the interview was over and told the participants that they would receive a support measure determined by drawing manipulated lots that read "hug," "self-soothing touch," or "paper plane".

Participants in the *hug condition* received a standardized hug from one of five female heterosexual student assistants (with one confederate hugging 41 participants and the other four confederates hugging one to five participants in the hug-condition). The experimenter explained that the confederate and the participant would hug for 20 s (duration based on Ref. [10]). They were asked to concentrate on their breathing and notice the warmth of the embrace. As an option, they could close their eyes. The hug was always initiated by the confederate, first making eye contact, then embracing front-to-front with the right arm reaching over and the left arm reaching under, hands placing flat on the lower back and shoulder blade. To avoid any sexual connotations of the hug, the confederate wore loose clothes and no make-up or perfume.

Participants in the *self-soothing touch condition* were instructed to give themselves 20 s of self-soothing touch to calm themselves. The duration was the same as for participants who received a hug to make the two touch conditions comparable. Neff and Germer suggest that what works for one person may not work for other people [21]. Because of this, the experimenter demonstrated and mirrored various options, such as placing one or two hands on the heart or belly or stroking the upper arms or cheeks. Participants were encouraged to choose a way to touch that felt comfortable for them and were then instructed to take two to three deep breaths and concentrate on the warmth, the pressure of the hands, and their breathing. Virtually all participants chose to place the right hand on the left side of the chest (above the heart) and the left hand on the abdomen.

Participants in the *control group* built a paper plane.

To evaluate how long the effects of the touch and identity manipulations lasted and to evaluate their effects on the speed of recovery from the stressor, participants stayed in the lab for another 40 min after the TSST ended, providing saliva samples, and filling out evaluations of subjective-emotional responses to stress. We gave them magazines to read during that time.

2.3. Measures

Fig. 1 shows the times when measurements of stress-response indicators were taken. The measures are described in the following.

2.3.1. Subjective-emotional stress responses

The German version of the Subjective-Emotional Response Scale (SERS; Schlotz and Kumsta, unpublished manuscript) was used as the main dependent variable to record subjective emotional stress responses during the experiment. Participants answered the SERS seven times during the study (see Fig. 1). The SERS comprises 15 items asking for the intensity of current feelings and moods (e.g., calm, nervous, guilty, satisfied) on a 4-point response scale (0 = *not at all* to 3 = *very much so*) and comprises three subscales, namely tense arousal ($\alpha = 0.80$, averaged over seven measurement points), self-conscious affect ($\alpha = 0.78$), and anxiety ($\alpha = 0.68$). Three participants failed to complete any of the SERS items, leaving a sample of $n = 156$. Item responses relevant for the peak analysis were missing from another two participants (for tense arousal and self-conscious affect) and four participants (for anxiety), respectively. Due to one missing gender indicator and four missing start time records, the final sample size for analysis was $n = 147$ for anxiety, and $n = 149$ for tense arousal and self-conscious affect.

2.3.2. Salivary cortisol

Several studies indicate that salivary cortisol is a reliable and valid measure of HPA activity and the physiological stress response [36]. Cortisol was collected six times (see Fig. 1) using a commercially available tool for sampling saliva (Salivette Cortisol, Sarstedt, Germany). The samples were stored at −20 °C until analysis at the Stress-biomarkers Lab at the Institute of Medical Psychology, Heidelberg University Hospital, Germany. To obtain 0.5–1.0 ml clear saliva with low viscosity, the samples were thawed, and then centrifuged at 1000 rpm for 2 min. A commercially available enzyme immunoassay was used to analyze the free cortisol concentration in saliva (ELISA; Demeditec, Kiel, Germany). Free saliva inter- and intra-assay coefficients of variation were 12.50% and 4.12%, respectively [40]. The reliable range of the assays used to determine free saliva concentration was 0.024–30 ng/ml. No values were below this range; however, 13 values exceeded the range and were therefore excluded from the data. Valid measures for all 6 assessments were available for 110 participants, no valid cortisol measures were available for 5 participants, and 39 participants had between 1 and 5 missing measures (mostly due to insufficient amounts of saliva in the Salivette). Due to one missing gender indicator and one missing start time record, the final sample size for cortisol analysis was $n = 152$. Cortisol missingness was independent of treatment (Fisher's exact $p = .27$). Cortisol measures were transformed to nmol/L before analysis. The distribution of cortisol measures in this sample showed a typical positive skewness. However, as sensitivity analyses using Box-Cox transformation of cortisol measures [41] to approximate a normal distribution yielded very similar results, we report results from modeling cortisol measures on the nmol/L scale.

2.3.3. Heart rate

Heart rate was used as an indicator for stress-related autonomic nervous system responses. Participants wore an unobtrusive and silent transportable mini-ECG device with two electrodes, one on the right side of the body in the middle below the clavicle and the second electrode on

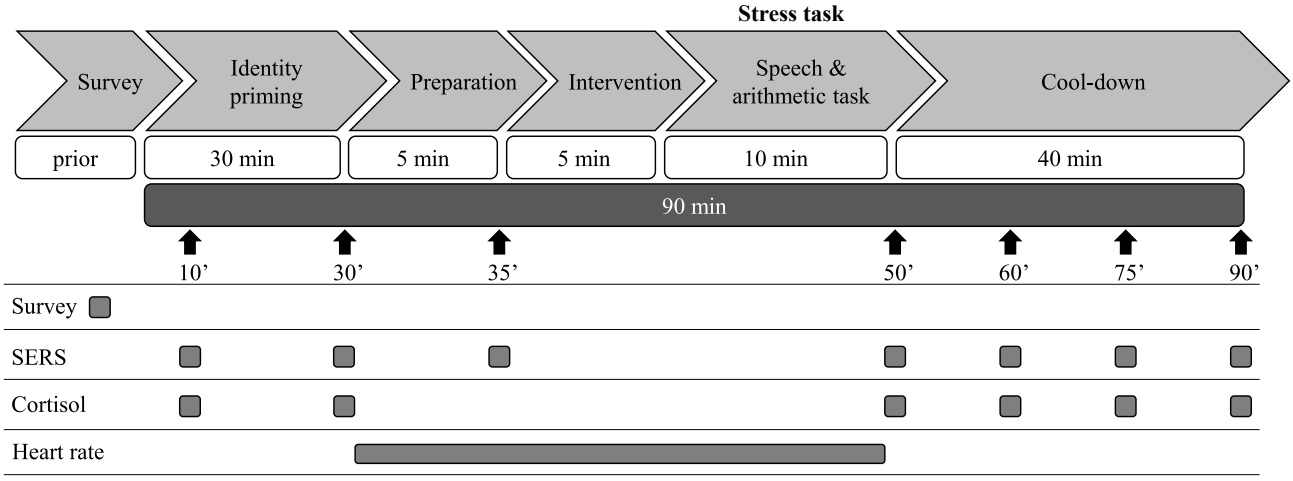

Fig. 1. Study procedure and measurement timings.

the left side below the heart (eMotion Faros 360°; Mega Electronics Ltd, Kupio, Finnland). All heart rate data sets were extracted and prepared for data analysis using HRV Scanner professional software (BioSign GmbH, Ottenhofen, Germany). Heart rate (beats per minute) was recorded from the beginning of the preparation phase until the end of the arithmetic task phase of the TSST (Fig. 1). Measurements were then divided and averaged for the three phases of the TSST (5 min at the beginning, two times 5 min for the TSST). The measurement during the intervention that followed the preparation phase of the TSST was edited out of the data because participants had to move, which influences heart rate measurements. Complete heart rate data were available for 119 participants, with 35 participants whose data were incomplete due to technical issues and 5 participants with partly missing data resulting in a sample of $n = 124$ for the heart rate analysis. Heart rate missingness was independent of treatment (Fisher's exact $p = .61$).

2.3.4. Additional measures

To rule out potentially confounding factors after randomization, several additional measures were included in the study. Dispositional stress reactivity was measured using the Perceived-Stress Reactivity Scale (PSRS, different answers formats ranging from 0 to 2, $\alpha = 0.80$, [42]). The Chronic Stress Screening Scale (CSSS; 1 = *never* to 5 = *very often*, $\alpha = 0.88$) from the Trier Inventory for Chronic Stress (TICS; [43]) was used to assess chronic stress. Dispositional self-compassion was measured using the German short form of the Self-Compassion Scale (SCS-D; $\alpha = 0.82$, 1 = *never* to 5 = *always*, [44]). Furthermore, we added two manipulation checks. To measure liking of the support measure (self-soothing touch, receiving hug, building paper plane), we used 8 adjectives (e.g., comfortable, nice, pleasant) on a scale from 1 (*do not agree at all*) to 6 (*very much agree*, $\alpha = 0.83$). Finally, we measured how participants in the hug condition evaluated the confederate who provided the hug using 8 items (e.g., likable, warm, cold [reverse-coded]) on a scale from 1 (*do not agree at all*) to 6 (*very much agree*, $\alpha = 0.94$).

2.4. Data analysis

Data were analyzed with Stata/SE (Version 15.1).

As cortisol levels are associated with time of day due to circadian rhythmicity [38], and stress-related cortisol levels typically differ between men and women [45], all models for hypothesis testing were adjusted for gender and TSST start time. As similar associations were also observed between gender and start time as well as heart rate and subjective-emotional responses, those models were adjusted in the same way [37].

We had pre-registered that we would analyze the data using area under the curve (AUC) values and ANOVA. However, since we encountered more missing values for cortisol levels and heart rate than anticipated, we decided to conduct our main analyses using mixed-effects regression models with maximum likelihood estimation because these models were both a better fit to the data and better equipped to handle missingness in the data set [46]. We included a first-order autoregressive covariance matrix of residuals in these analyses to account for attenuation of correlations between more distal measures. Likelihood ratio tests confirmed a superior fit of the models including the autoregressive residual parameter over models with compound symmetry residual structure for both cortisol, $\Delta\chi^2(1) = 255.61$, $p < .001$, and heart rate, $\Delta\chi^2(1) = 5.02$, $p = .025$.

We tested our hypotheses for cortisol and heart rate as outcomes using models with three fully crossed categorical predictor variables: fixed measurement Time (6 for cortisol, 3 for heart rate), Identity (social versus personal identity), and Touch (self-soothing touch versus receiving a hug versus control). Full model follow-up contrasts tested for all fixed effects, with the three-way interaction Identity x Touch x Time testing our main hypothesis. Since a sample of $N = 159$ in the context of testing fixed effects is still considered small and because study condition sizes were not perfectly balanced (see Table 1), degrees of freedom used for hypothesis tests for the fixed effects were based on small-sample approximation using the Kenward-Roger method [47].

For the subjective-emotional measures as outcomes, the mixed-effects regression model fit was poor. As an alternative data analysis approach with better model fit, we calculated individual peak responses by subtracting the maximum of the measures just before and just after the TSST from the initial measure and used ANOVA models with the individual peak response as outcome and two fully crossed categorical predictor variables: Identity salience and touch conditions. The two-way interaction Identity x Touch tested our main hypothesis for these outcomes.

To calculate standardized effect sizes, we conducted repeated-measures ANOVA for cortisol and heart rate data for calculation of standardized effect size estimates (see Tables A.1 and A.2 in the appendix). Local effect size indicators f^2 [35] were calculated based on these ANOVA results. Following Ref. [35], f^2 close to 0.02 indicates small effects, f^2 close to 0.15 medium sized effects, and f^2 close to 0.35 large effects. In addition, we present mean differences as estimators of unstandardized effect sizes for statistically significant effects (cf. [48]).

We used G*Power [49] to conduct a sensitivity power analysis based on data from our statistical models. The analysis for cortisol as outcome had 80% power to detect a within-between interaction effect of size $f^2 = 0.031$, assuming a sample size of 152 participants, 6 groups, 6 measurements, $\alpha = 0.05$, ICC = 0.56, and $\varepsilon = 0.39$. The analysis for heart rate as outcome had 80% power to detect a within-between interaction effect of size $f^2 = 0.023$, assuming a sample size of 119 participants, 6 groups,

Table 1
Mean scores (SE), and frequency of gender, for samples by experimental conditions, and results of difference tests.

	Personal identity (*n*)			Social identity (*n*)			Effects (*p*)		
	Self-touch (28)	Hug (27)	Control (27)	Self-touch (25)	Hug (26)	Control (26)	Identity	Touch	Identity x Touch
Gender female	19 (68%)	18 (67%)	14 (52%)	20 (80%)	12 (46%)	13 (54%)	.91	.066	.21
Age	22.1 (0.74)	21.8 (0.74)	22.8 (0.84)	21.6 (0.58)	21.4 (0.44)	21.3 (0.75)	.15	.79	.68
SC	3.2 (0.14)	3.1 (0.11)	3.4 (0.13)	3.3 (0.14)	3.3 (0.10)	3.2 (0.16)	.93	.55	.26
PSRS	22.9 (1.76)	21.6 (1.54)	22.2 (1.55)	22.3 (1.83)	21.2 (1.35)	19.9 (1.73)	.40	.63	.80
CSSS	22.0 (1.68)	18.7 (1.81)	17.9 (1.76)	18.7 (1.52)	19.5 (1.92)	17.4 (1.83)	.51	.32	.49
Start time[a]	14.6 (0.25)	14.2 (0.20)	14.5 (0.27)	14.6 (0.21)	14.2 (0.26)	14.1 (0.26)	.55	.16	.62

Note. SC = Self Compassion Scale Short Form; PSRS = Perceived Stress Reactivity Scale; CSSS = Chronic Stress Screening Scale.
[a] Hours since midnight.

3 measurements, α = 0.05, ICC = 0.71, and ε = 0.89. The analysis for subjective-emotional responses as outcomes had 80% power to detect an interaction effect for the interaction of 2 between-subjects factors of size $f^2 = 0.067$, assuming a sample size of 147 participants, 6 groups, $df_{num} = 2$, and α = 0.05 (sample size varied per outcome because missingness was not evenly distributed across all outcomes as described in the measures section).

The distributions of residuals showed that all models adequately represented the data. Sensitivity analyses excluding potentially influential outliers (standardized residuals with $M \pm 3$ *SD*) or using only participants with complete data did not substantially change the results. Therefore, we report the results from models including all available data.

3. Results

3.1. Descriptive statistics, manipulation and randomization checks

Table 1 shows the descriptive statistics and the results for the difference tests on relevant background variables by condition. We found an overrepresentation of women in the self-soothing touch condition (logistic regression with Touch as predictor: $OR_{self\text{-}touch} = 2.48$, $p = .031$). Similarly, the exact time of day when the experimental procedure was started for a participant was on average slightly, although not statistically significant, later in the self-soothing touch conditions.

Before proceeding with hypotheses testing, we checked how participants perceived the touch manipulations and how participants in the hug condition hug evaluated the confederates who provided the hug.

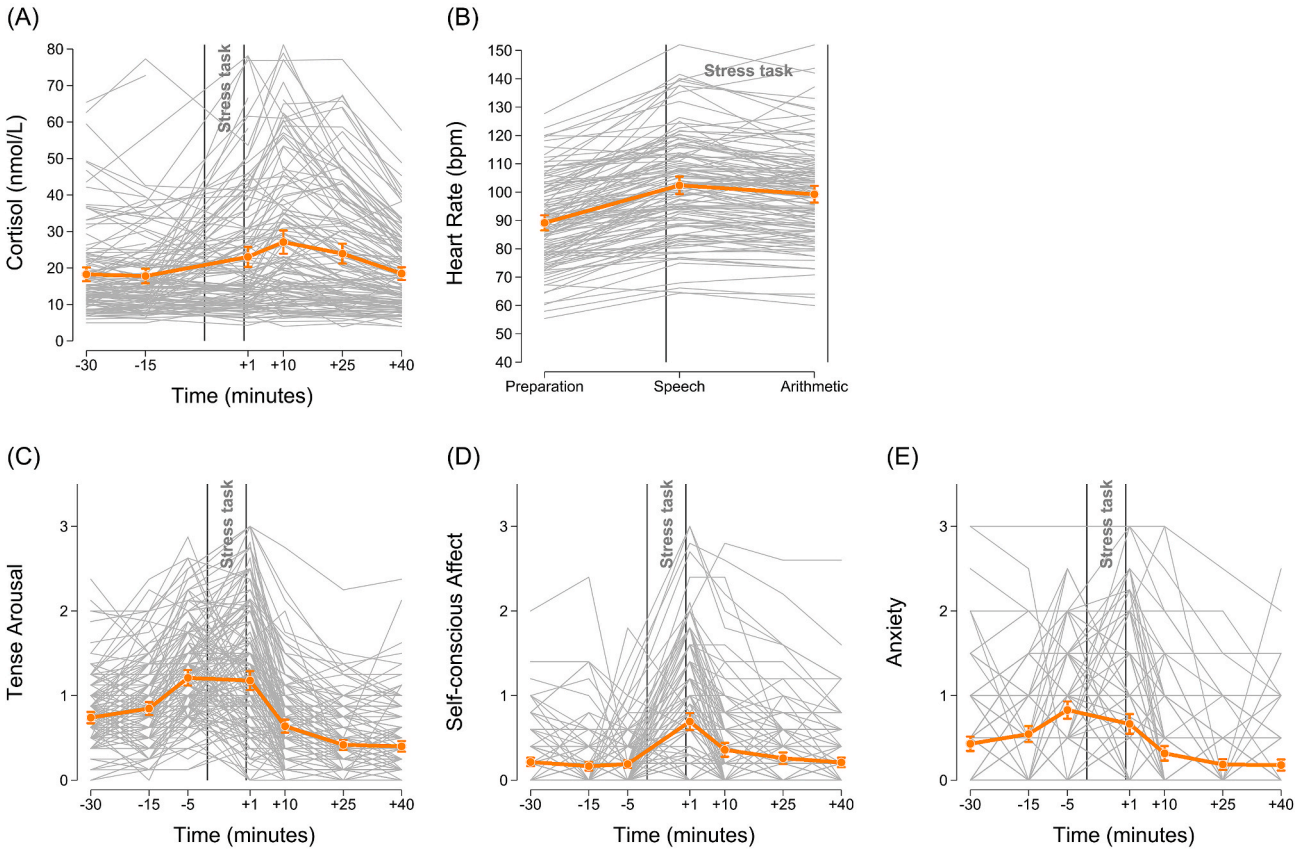

Fig. 2. Average trajectories of (A) cortisol, (B) heart rate, and subjective-emotional states, namely (C) tense arousal, (D) self-conscious affect, and (E) anxiety. Footnote: *Note*. Thick orange lines and dots (±95% CIs) indicate average trajectories. Thin gray lines indicate individual trajectories. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Results of contrast tests for main effects and interactions of experimental conditions for cortisol and heart rate from mixed-effects regression models adjusted for sex and start time.

	Cortisol			Heart rate		
	F (*df*, *ddf*)	p	f^2	*F* (*df*, *ddf*)	p	f^2
Identity	1.39 (1, 156.9)	.67	0.008	1.52 (1, 111.3)	.22	0.013
Touch	3.15 (2, 156.4)	.046	0.025	0.22 (2, 111.4)	.80	0.004
Identity x Touch	0.05 (2, 156.5)	.61	0.006	0.68 (2, 111.3)	.51	0.011
Time	32.12 (5, 514.0)	<.001	0.227	132.39 (2, 149.6)	<.001	1.177
Identity x Time	0.55 (5, 514.0)	.55	0.004	2.64 (2, 149.6)	.075	0.028
Touch x Time	3.65 (10, 554.0)	<.001	0.055	1.42 (4, 166.7)	.23	0.026
Identity x Touch x Time	0.20 (10, 554.0)	.99	0.002	1.48 (4, 166.7)	.21	0.022

Note. *ddf* = denominator degrees of freedom (Kenward-Roger adjusted); Standardized effect size indicator f^2 based on repeated measures ANOVA (see appendix Table A.2 and Tables A.4 for details).

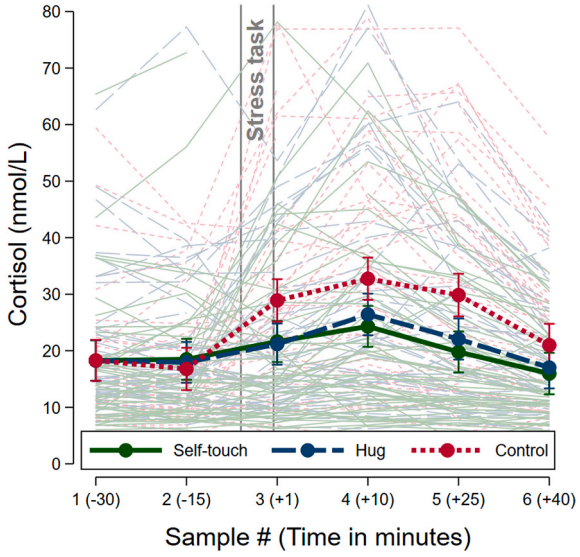

Fig. 3. Cortisol trajectories by touch condition. Footnote: *Note*. Thick lines and dots indicate averages for each condition (±95% CIs). Thin lines indicate individual trajectories.

Results from a one-way ANOVA show that there was a significant effect of Touch on support liking, $F(2, 149) = 10.38$, $p < .001$. Participants in the two touch conditions evaluated support as more pleasant than those in the control conditions (Self-touch: $M = 4.56$, $SD = 0.88$; Hug: $M = 4.07$, $SD = 0.77$; Control: $M = 3.84$, $SD = 0.75$) with significant differences between self-soothing touch versus hug ($p = .01$) and self-soothing touch versus control ($p < .001$), but no significant difference between hug and control condition ($p = .40$). Inversely, this implies that participants who were hugged liked their support measure at least as much as those who built a paper plane—an indication that receiving a hug was not perceived as uncomfortable. Furthermore, the five confederates who provided the hug were extremely well liked with $M = 5.1$, $SD = 0.88$ with no significant differences among them, $F(4, 46) = 1.37$, $p = .26$.

3.2. Results for of hypothesis testing

Fig. 2A–E shows the average and the individual trajectories for cortisol, heart rate, and the three subjective-emotional measures, Tables A3, A4, and A5 in the online appendix summarize the exact observed cell means. The Figures show substantial increases in response to the TSST in all measures. Tense arousal and anxiety further showed an increase in anticipation of the stress test (from t_1 to t_2).

3.2.1. Results for the cortisol responses

Table 2 shows the results of the fixed effects contrast tests for cortisol. The TSST induced an increase in cortisol across all experimental conditions ($p < .001$). The average cortisol levels among the three touch conditions across time differed significantly ($p = .046$). In particular, they were lower in the self-touch condition (mean difference = −4.86 nmol/L, 95% CI [−9.00, −0.72], $F(1, 155.9) = 5.38$, $p = .022$) as well as the hug condition (mean difference = −4.13 nmol/L, 95% CI [−8.21, −0.05], $F(1, 158.2) = 3.99$, $p = .047$) compared to the control condition. The experimental touch manipulations also had a significant effect on cortisol levels over time in response to the experimental stressor, as evidenced by the Touch x Time interaction ($p < .001$).

Table 3
Contrasts of cortisol levels between Touch conditions and the control condition by time.

Contrast	Mean difference (nmol/L)	95% CI		*F*	*df*	*ddf*	*p*
		LL	UL				
Self-touch versus Control							
Time 1	−0.02	−5.16	5.11	<0.01	1	323.25	.99
Time 2	1.71	−3.54	6.97	0.41	1	351.04	.52
Time 3	−7.26	−12.54	−1.99	7.33	1	351.58	.007
Time 4	−8.46	−13.71	−3.21	10.03	1	339.47	.002
Time 5	−10.09	−15.37	−4.81	14.13	1	338.42	<.001
Time 6	−5.04	−10.36	0.28	3.47	1	337.66	.063
Hug versus Control							
Time 1	−0.05	−5.19	5.09	<0.01	1	336.30	.99
Time 2	1.15	−4.05	6.36	0.19	1	356.98	.66
Time 3	−7.75	−12.99	−2.51	8.46	1	361.15	.004
Time 4	−6.34	−11.59	−1.10	5.65	1	355.64	.018
Time 5	−7.81	−13.06	−2.57	8.58	1	347.10	.004
Time 6	−3.98	−9.27	1.31	2.19	1	346.80	.14

Note. CI = confidence interval; *LL* = lower limit; *UL* = upper limit; ddf = denominator degrees of freedom (Kenward-Roger adjusted).

Fig. 3 shows the average cortisol trajectories by Touch conditions and Table 3 shows the contrasts between conditions within measurement occasions. Cortisol levels in both touch conditions were significantly lower in comparison to the control condition for three out of four measurement occasions following the stress test. At the last measurement occasion (i.e., 40 min after the stressor ended), cortisol responses had largely reached pre-stress levels, and—similar to pre-stress cortisol levels—no significant differences between conditions were observed.

Contrary to our expectation, the three-way interaction Identity x Touch x Time was not different from zero, indicating that the cortisol responses were not influenced by the two experimental factors in the way we hypothesized ($p = .99$). In addition, the identity manipulation did not have an effect on cortisol trajectories (Identity x Time interaction, $p = .55$) and on average cortisol levels (main effect of Identity $p = .67$).

The standardized effect-size indicator for the interaction effect Touch x Time was $f^2 = 0.055$, indicating a small effect. However, the unstandardized effect sizes, as indicated by the mean differences shown in

Table 3, are substantial and well beyond a level that has been found to separate responders from non-responders to stress [50]. In sum, for cortisol, these results fully support both Hypothesis 1 and Hypothesis 2. Hypothesis 3 was not supported.

As an exploratory analysis, we conducted a logistic regression to see if participants who showed a decline in cortisol levels from t_2 to t_3 (as an indicator of stress levels in the anticipation phase of the TSST) were over-represented in the touch conditions. The logistic regression revealed that CortDecliners were indeed over-represented in both touch conditions, $OR_{Touch} = 0.59$, $z = 2.32$, $p = .02$, with significant differences for self-soothing touch versus control and insignificant differences between hug versus control, $OR_{Self\text{-}touch} = 2.96$, $z = 2.36$, $p = .02$, $OR_{Hug} = 2.40$, $z = 1.87$, $p = .06$.

Fig. 3 also shows that all conditions reached their peak cortisol levels at t_4. To explore if recovery started earlier in the touch conditions, we calculated a linear regression to predict cortisol levels at t_5 based on cortisol levels at t_4 and a dummy variable for each touch condition (self-soothing touch = 1, 0; hug = 0, 1; control = 0, 0). A significant regression equation was found, $F(3, 126) = 165.45$, $p < .001$, with an $R^2 = 0.80$. The self-soothing touch condition dummy predicted changes in cortisol levels, implying that recovery started earlier in the self-soothing touch condition than in the control condition, $b = -4.32$, $SE = 1.64$, $t(46) = -2{,}63$, $p = .01$. The hug condition dummy did not predict changes in cortisol levels, $b = -2.52$, $SE = 1.63$, $t(43) = -1.55$, $p = .13$), so no inference can be made that recovery started sooner in the hug condition compared to the control condition even though the effect pointed in the expected direction.

3.2.2. Results for the heart rate responses

The results of the fixed effects contrast tests for the heart rate responses are shown in Table 2. The significant effect of Time indicates that the TSST induced substantial changes in heart rate across conditions ($p < .001$). Hypothesis 1 and 2 received no support as the heart rate trajectories over time did not differ between touch conditions (Touch x Time interaction, $p = .23$). In addition, contrary to Hypothesis 3, the three-way interaction Identity x Touch x Time was not statistically significant ($p = .21$). In sum, for heart rate, Hypotheses 1, 2, and 3 were not supported by the data.

3.2.3. Results for the subjective-emotional responses

Although the participants responded with an increase in stress-related subjective-emotional states to the stress situation over seven measurements (cf., Fig. 2C–E), neither experimental touch, identity manipulation, nor their interaction had a significant effect on tense arousal (Touch: $p = .82$, Identity: $p = .23$, Identity x Touch: $p = .11$), self-conscious affect (Touch: $p = .83$, Identity: $p = .57$, Identity x Touch: $p = .89$), or anxiety (Touch: $p = .95$, Identity: $p = .83$, Identity x Touch: $p = .25$), providing no support for Hypotheses 1, 2, and 3.

4. Discussion

The negative consequences of too much stress are pervasive, and humans require strategies to cope with them [1]. In this randomized controlled study, we investigated the effectiveness of self-soothing touch and receiving hugs from another person on stress responses and whether the benefits from these would be moderated by social identity. We found that, compared to a control group, participants providing self-soothing touch and receiving hugs had reduced cortisol secretion responses to socio-evaluative stress with lower average cortisol values on three out of four measurement points after the stressor. Furthermore, the self-soothing touch condition showed faster recovery of cortisol levels to near-baseline after the stressor than the control group. Heart rate and self-reported psychological stress increased due to the stressor, but these changes were not modulated by touch conditions. In addition, sharing a social identity did not moderate the effectiveness of the touch interventions.

The effectiveness of receiving hugs is supported by our study as we found significant differences between participants who received hugs and the control group in cortisol levels, but we did not find these differences for heart rates and subjective-emotional stress evaluations. Other studies found beneficial effects for affiliative touch like hugging or hand-holding on outcomes such as blood pressure and recovery times after a virus infection (e.g., Refs. [11,12]), so our study extends the literature on the benefits of receiving hugs. However, the magnitude of the effects of receiving a hug in our study was lower than those in other studies. This may be because even though we manipulated closeness between participants and confederates, participants were still hugged by a confederate and not a real friend or family member. Triscoli et al. found that being stroked by a romantic partner was rated as more pleasant than self-stroking [51]. In contrast, participants in our study rated the self-touch as more pleasant than receiving a hug potentially because being touched by the romantic partner is perceived differently and has different effects than being hugged by a relative stranger. Nevertheless, both touch conditions were liked well (and more than the neutral control condition). Future research could invite friends or significant others to the lab and ask them to provide the hug, which might increase the effectiveness of this intervention (cf. [8]).

The results further suggest that self-soothing touch buffers cortisol responses to stress as average cortisol levels in the self-soothing touch condition were lower than those of the control conditions following the stressor. Participants in the self-soothing touch condition were also over-represented among those who displayed a reduction in cortisol values from t_2 to t_3 (as an indication of stress during the anticipation phase). In addition, our exploratory analyses showed that cortisol values recovered to baseline faster in the self-soothing touch condition than in the control condition. Since, unlike touch from others, self-touch by definition cannot communicate social support, this finding seems particularly important for individuals who are temporarily or permanently isolated from others. Self-soothing touch is a risk-free and easily administered method of expressing self-compassion [21]. As Gilbert argued, humans not only have the need to acquire new things and to protect themselves from harm, they also need to feel content and safe—a need that self-soothing touch can ease [52]. Thus, self-soothing touch could serve as a reliable and predictable signal for self-induced safety [15,26] and give a sense of being loved and cared for in moments of distress. Future research is needed to investigate this preliminary conclusion further.

We did not find a significant interaction effect of social identity and touch on any stress indicator, suggesting that the stress-reducing effect of touch was not moderated by social identity. These findings are in line with our assumptions for self-soothing touch. Self-soothing touch was self-administered with no observers other than the experimenter, which makes self-soothing touch mostly independent from other people. However, for receiving hugs, we expected that sharing a social identity would increase the effectiveness of the hug, which was not the case. Social identity theory suggests that humans derive large parts of their identity from group memberships [27] and several studies have found positive effects of shared social identities for cortisol levels after a stressor (e.g., Refs. [28,32]). We used the same manipulation to prime personal and social identities as these studies, yet our study did not support a stress-buffering effect of social identities. In the social identity condition, the committee members formed an in-group with the participant. Since participants identified with the confederates in the first part of the experiment, making them the interviewers later could have made socio-evaluative stress worse as their judgment may have suddenly mattered more when participants wanted to be liked or be seen as competent, which may have offset any positive effects derived from forming a social identity in the first part of the study. Alternatively, participants in the personal identity condition may have developed indifference towards the confederates and their judgment, thus receiving an unintended stress-buffering effect that may have masked the benefits from shared social identities. Despite these potential explanations, our finding that receiving hugs from people is effective

irrespective of sharing a social identity with them is in line with the benefits of massage therapy [4,5] and animal studies (e.g., Ref. [6]).

It is interesting to note that subjective stress evaluations after touch were unaffected in this study. It appears that while cortisol responses to touch were present and persistent, this effect may not have reached consciousness. In fact, a discrepancy between psychological and physiological responses to stress has been found in several previous studies (e.g., Refs. [8,28,32,53]), however issues of social desirability or self-presentation may also have contributed to this missing correlation. The lack of findings for subjective-emotional stress responses might also be due to faster changes in these states, whereas changes in psychophysiological outcomes are slower. Covariance between stress response systems can only be detected when these specific dynamics are considered [54]. The absence of statistically significant effects of our experimental interventions on stress-related subjective-emotional states might well be due to insufficiently dense sampling at the relevant period.

Both touch interventions had buffering effects on cortisol responses to the stressor. We suggested two broad mechanisms that could explain these effects (tactile stimulation and activation of self-related psychological constructs). First, stress-buffering effects may be due to tactile stimulation of C-fiber receptors that then stimulate vagal and parasympathetic activity that helps regulate stress responses [4,20]. Self-soothing touch and receiving hugs share this mechanism. Second, receiving hugs also features non-tactile aspects and activation of psychological constructs such as social support, proximity, positive affiliation, or belonging, whereas self-soothing touch may invoke feelings of self-induced safety [15,26], intentionality, and mindfulness. For self-soothing touch and receiving hugs, the psychological mechanism likely also involves increased secretion of the neuropeptide oxytocin. Future research could test these suggested mechanisms for effects on stress coping from touch directly.

The findings for self-soothing touch and receiving hugs are encouraging. However, the present study is not without limitations, and further research is needed. First, most of the participants were Psychology students, and the majority were women and between 20 and 25 years old. This limits the generalizability of our findings to a broader population. Second, some participants in our study had relatively high cortisol values with basal values exceeding 30 nmol/l and peaks exceeding 80 nmol/l, suggestive of higher baseline stress levels/cortisol responses in these individuals. Third, in addition to tactile stimulation, self-touching and being hugged may share other aspects such as positive affect, increased attention, or heightened arousal. A comparison with the control condition does not allow to rule out these alternative explanations for the effects obtained in the present study.

Fourth, there was some data loss in all variables, and our models had to account for this missingness in their estimations, which likely introduced small biases in our results. To obtain reliable measurements for cortisol, we controlled for various variables such as gender, physical activity, time of day, smoking, drug abuse, use of oral contraceptives, and various medical conditions [36,37]. However, menstrual cycle phases or other third variables may have influenced cortisol levels. We adjusted our models for most potentially confounding variables and did sensitivity analyses testing the influence of outlying observations and are therefore confident that our findings are not due to confounding variables. Yet, future replication attempts are certainly needed.

Several questions remain open after the current research on self-soothing touch and touch in general. For instance, we looked at self-soothing touch between the anticipation phase and the mock interview of the TSST. As such, self-soothing touch had both a calming function (stress from the anticipation phase) *and* a protective function towards future stress (stress from the upcoming interview). One interesting avenue for future research could be to first stress participants, then use self-soothing touch after the stressor and see if they feel better or if their recovery time to baseline cortisol levels can be shortened (exclusive focus on the calming function). Furthermore, we used self-soothing touch in healthy humans in the context of socio-evaluative stress. A natural extension of the research would be to look at clinical populations, such as patients with anxiety or depression, or to other challenging situations, including acute and chronic pain.

5. Conclusion

As humans, we need to be touched from the moment we are born to fulfill our need to feel content and safe [52,55]. Life holds many challenges threatening this need. When touch from others is unavailable or does not feel comfortable, self-soothing touch provides an alternative way to re-activate memories of support and compassion in the face of stress. This seems all the more relevant at the time of writing this paper (i.e., during the COVID-19 pandemic). Governments all around the world have asked their citizens to keep physical distance from each other, sometimes issuing shelter-in-place orders (such as in Italy in March and April 2020). Thus, when we are prevented from meeting (and being touched and hugged by other people), self-soothing touch may not only be an effective option to reduce the effects of the stress resulting from the pandemic—for many, it may be the only option.

Open practices

Pre-registration and data for the experiment are available at https://osf.io/9xdum/.

CRediT authorship contribution statement

Aljoscha Dreisoerner: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – Original draft, Visualization, Project administration, Funding acquisition. Nina Junker: Conceptualization, Writing – Review & editing, Supervision. Wolff Schlotz: Conceptualization, Methodology, Formal analysis, Writing – Original draft, Writing – Review & Editing, Visualization. Julia Heimrich: Data curation, Writing – Original draft, Project administration. Svenja Bloemeke: Data curation, Methodology, Project administration. Beate Ditzen: Conceptualization, Methodology, Resources, Writing – Review & Editing, Funding acquisition. Rolf van Dick: Conceptualization, Methodology, Resources, Writing – Review & Editing, Funding acquisition, Supervision.

Funding

The work was supported by the Social Psychology department at Goethe University, the Institute of Medical Psychology at Heidelberg University, a grant from the Association of the Friends and Supporters of the Goethe-University Frankfurt and a doctoral grant provided by the Friedrich-Naumann Foundation for Freedom to Aljoscha Dreisoerner.

Declarations of competing interest

None.

Acknowledgements

We thank the many study participants who contributed their data to the project and acknowledge the contribution and assistance of Anna

Lisa Aydin, Isabel Grünenwald, Leon Hoche, Larissa Klein, Laura Durner, Pauline Raesch, and Robson Dodd for supporting the execution of the study, Dieter Zapf and Marcel Kern for providing a lab to conduct the study, Martin Stoffel, Brigitte Seib, and Stefanie Rahn for assaying the saliva samples, Sheena Lita Aperocho for proofreading the manuscript, Markus Hofer and Reinhard Beise from Biosign GmbH for providing a discount to the HRV Scanner software, Susanne Richter and Rita Friedrich for general assistance, and Kristin Neff for her invaluable feedback on earlier versions of the manuscript and general support.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cpnec.2021.100091.

References

[1] A.F. Arnsten, Stress signaling pathways that impair prefrontal cortex structure and function, Nat. Rev. Neurosci. 10 (2009) 410–422, https://doi.org/10.1038/nn.4087.
[2] R.M. Sapolsky, L.M. Romero, A.U. Munck, How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions, Endocr. Rev. 21 (2000) 55–89, https://doi.org/10.1210/edrv.21.1.0389.
[3] R.I.M. Dunbar, The social role of touch in humans and primates: behavioural function and neurobiological mechanisms, Neurosci. Biobehav. Rev. 34 (2010) 260–268, https://doi.org/10.1016/j.neubiorev.2008.07.001.
[4] T.M. Field, Massage therapy effects, Am. Psychol. 53 (1998) 1270–1281, https://doi.org/10.1037/0003-066X.53.12.1270.
[5] C.A. Moyer, J. Rounds, J.W. Hannum, A meta-analysis of massage therapy research, Psychol. Bull. 13 (2004) 3–18, https://doi.org/10.1037/0033-2909.130.1.3.
[6] Y. Tang, D. Benusiglio, A. Lefevre, L. Hilfiger, F. Althammer, A. Bludau, V. Grinevich, Social touch promotes interfemale communication via activation of parvocellular oxytocin neurons, Nat. Neurosci. 23 (2020) 1125–1137, https://doi.org/10.1038/s41593-020-0674-y.
[7] S.H. Cady, G.E. Jones, Massage therapy as a workplace intervention for reduction of stress, Percept. Mot. Skills 84 (1997) 157–158. https://doi/10.2466/pms.1997.84.1.157.
[8] B. Ditzen, I.D. Neumann, G. Bodenmann, B. von Dawans, R.A. Turner, U. Ehlert, M. Heinrichs, Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women, Psychoneuroendocrinology 32 (2007) 565–574, https://doi.org/10.1016/j.psyneuen.2007.03.011.
[9] T.M. Field, M.A. Diego, M. Hernandez-Reif, S. Schanberg, C. Kuhn, Massage therapy effects on depressed pregnant women, J. Psychosom. Obstet. Gynecol. 25 (2004) 115–122, https://doi.org/10.1080/01674820412331282231.
[10] K.M. Grewen, B.J. Anderson, S.S. Girdler, K.C. Light, Warm partner contact is related to lower cardiovascular reactivity, Behav. Med. 29 (2003) 123–130, https://doi.org/10.1080/08964280309596065.
[11] K.C. Light, K.M. Grewen, J.A. Amico, More frequent partner hugs and higher oxytocin levels are linked to lower blood pressure and heart rate in premenopausal women, Biol. Psychol. 69 (2005) 5–21, https://doi.org/10.1016/j.biopsycho.2004.11.002.
[12] S. Cohen, D. Janicki-Deverts, R.B. Turner, W.J. Doyle, Does hugging provide stress-buffering social support? A study of susceptibility to upper respiratory infection and illness, Psychol. Sci. 26 (2015) 135–147, https://doi.org/10.1177/0956797614559284.
[13] H. Sumioka, A. Nakae, R. Kanai, H. Ishiguro, Huggable communication medium decreases cortisol levels, Sci. Rep. 3 (2013) 1–6, https://doi.org/10.1038/srep03034.
[14] I. Morrison, Keep calm and cuddle on: social touch as a stress buffer, Adapt. Hum. Behav. Physiol. 2 (2016) 344–362, https://doi.org/10.1007/s40750-016-0052-x.
[15] M. Eckstein, I. Mamaev, B. Ditzen, U. Sailer, Calming effects of touch in human, animal, and robotic interaction: scientific state-of-the-art and technical advances, Front. Psychol. 11 (2020), 555058, https://doi.org/10.3389/fpsyt.2020.555058.
[16] C.S. Carter, Neuroendocrine perspectives on social attachment and love, Psychoneuroendocrinology 23 (1998) 779–818, https://doi.org/10.1016/s0306-4530(98)00055-9.
[17] A.K. Kreuder, L. Wassermann, M. Wollseifer, B. Ditzen, M. Eckstein, B. Stoffel-Wagner, J. Hennig, R. Hurlemann, D. Scheele, Oxytocin enhances the pain-relieving effects of social support in romantic couples, Hum. Brain Mapp. 40 (2019) 242–251, https://doi.org/10.1002/hbm.24368.
[18] K. Uvnäs-Moberg, Oxytocin may mediate the benefits of positive social interaction and emotions, Psychoneuroendocrinology 23 (1998) 819–835, https://doi.org/10.1016/S0306-4530(98)00056-0.
[19] K. Uvnäs-Moberg, L. Handlin, M. Petersson, Neuroendocrine mechanisms involved in the physiological effects caused by skin-to-skin contact – with a particular focus on the oxytocinergic system, Infant Behav. Dev. Advance Online Publication (2020), https://doi.org/10.1016/j.infbeh.2020.101482.
[20] A.T. Ferrell-Torry, O.J. Glick, The use of therapeutic massage as a nursing intervention to modify anxiety and the perception of cancer pain, Cancer Nurs. 16 (1993) 93–101, https://doi.org/10.1097/00002820-199304000-00002.
[21] K.D. Neff, C.K. Germer, A pilot study and randomized controlled trial of the Mindful Self-Compassion program, J. Clin. Psychol. 69 (2013) 28–44, https://doi.org/10.1002/jclp.21923.
[22] P. Ekman, v. Friesen, V. W, The repertoire of nonverbal behaviour: categories, origins, usage, and coding, Semiotica 1 (1969) 49–98.
[23] J.A. Harrigan, J.R. Kues, J.J. Steffen, R. Rosenthal, Self-touching and impressions of others, Pers. Soc. Psychol. Bull. 13 (1987) 497–512, https://doi.org/10.1177/0146167287134007.
[24] K.D. Neff, Self-compassion: an alternative conceptualization of a healthy attitude toward oneself, Self Ident. 2 (2003) 85–101, https://doi.org/10.1080/15298860309032.
[25] J.G. Breines, C.M. McInnis, Y.I. Kuras, M.V. Thoma, D. Gianferante, L. Hanlin, X. Chen, N. Rohleder, Self-compassionate young adults show lower salivary alpha-amylase responses to repeated psychosocial stress, Self Ident. 14 (2015) 390–402, https://doi.org/10.1080/15298868.2015.1005659.
[26] M. Eckstein, A.C. Almeida de Minas, D. Scheele, A.K. Kreuder, R. Hurlemann, V. Grinevich, B. Ditzen, Oxytocin for learning calm and safety, Int. J. Psychophysiol. 136 (2019) 5–14, https://doi.org/10.1016/j.ijpsycho.2018.06.004.
[27] H. Tajfel, J. Turner, An integrative theory of inter-group conflict, in: W.G. Austin, S. Worchel (Eds.), The Social Psychology of Intergroup Relations. Brooks/Cole, Monterey, Canada, 1979, pp. 33–47.
[28] J.A. Häusser, M. Kattenstroth, R. van Dick, A. Mojzisch, "We" are not stressed: social identity in groups buffers neuroendocrine stress reactions, J. Exp. Soc. Psychol. 48 (2012) 973–977, https://doi.org/10.1016/j.jesp.2012.02.020.
[29] N.K. Steffens, S.A. Haslam, S.C. Schuh, J. Jetten, R. van Dick, A meta-analytic review of social identification and health in organizational contexts, Pers. Soc. Psychol. Rev. 21 (2017) 303–335, https://doi.org/10.1177/1088868316656701.
[30] J.A. Häusser, N.M. Junker, R. van Dick, The how and the when of the social cure: a conceptual model of group- and individual-level mechanisms linking social identity to health and well-being, Eur. J. Soc. Psychol. (2020) 721–731, https://doi.org/10.1002/ejsp.2668.
[31] S.A. Haslam, S.D. Reicher, M. Levine, When other people are heaven, when other people are hell: how social identity determines the nature and impact of social support, in: J. Jetten, C. Haslam, S.A. Haslam (Eds.), The Social Cure: Identity, Health and Well-Being. Psychology Press, London, 2012, pp. 157–174.
[32] J.U. Frisch, J.A. Häusser, R. van Dick, A. Mojzisch, Making support work: the interplay between social support and social identity, J. Exp. Soc. Psychol. 55 (2014) 154–161, https://doi.org/10.1016/j.jesp.2014.06.009.
[33] J. Campbell, U. Ehlert, Acute psychosocial stress: does the emotional stress response correspond with physiological responses? Psychoneuroendocrinology 37 (2012) 1111–1134. https://doi/10.1016/j.psyneuen.2011.12.010.
[34] S.S. Dickerson, M.E. Kemeny, Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research, Psychol. Bull. 130 (2004) 355–391, https://doi.org/10.1037/0033-2909.130.3.355.
[35] J. Cohen, Statistical Power Analysis for the Behavioural Science, second ed., Lawrence Erlbaum Associate, Mahwah, USA, 1988.
[36] D.H. Hellhammer, S. Wüst, B.M. Kudielka, Salivary cortisol as a biomarker in stress research, Psychoneuroendocrinology 34 (2009) 163–171, https://doi.org/10.1016/j.psyneuen.2008.10.026.
[37] J.J. Liu, N. Ein, K. Peck, V. Huang, J.C. Pruessner, K. Vickers, Sex differences in salivary cortisol reactivity to the Trier Social Stress Test (TSST): a meta-analysis, Psychoneuroendocrinology 82 (2017) 26–37, https://doi.org/10.1016/j.psyneuen.2017.04.007.
[38] U.M. Nater, N. Rohleder, W. Schlotz, U. Ehlert, C. Kirschbaum, Determinants of the diurnal course of salivary alpha-amylase, Psychoneuroendocrinology 32 (2007) 392–401, https://doi.org/10.1016/j.psyneuen.2007.02.007.
[39] C. Kirschbaum, K.M. Pirke, D.H. Hellhammer, The "Trier social stress test": a tool for investigating psychobiological stress responses in a laboratory setting, Neuropsychobiology 28 (1993) 76–81, https://doi.org/10.1159/000119004.
[40] S.K. Hanneman, C.D. Cox, K.E. Green, D.H. Kang, Estimating intra-and inter-assay variability in salivary cortisol, Biol. Res. Nurs. 13 (2011) 243–250, https://doi.org/10.1177/1099800411404061.
[41] R. Miller, F. Plessow, Transformation techniques for cross-sectional and longitudinal endocrine data: application to salivary cortisol concentrations, Psychoneuroendocrinology 38 (2013) 941–946, https://doi.org/10.1016/j.psyneuen.2012.09.013.
[42] W. Schlotz, I.S. Yim, P.M. Zoccola, L. Jansen, P. Schulz, The Perceived Stress Reactivity Scale: measurement invariance, stability, and validity in three countries, Psychol. Assess. 23 (2011) 80–94, https://doi.org/10.1037/a0021148.
[43] P. Schulz, W. Schlotz, P. Becker, Das Trierer Inventar Zum Chronischen Stress (TICS, Version 3) – Manual, third ed., Hogrefe, Goettingen, Germany, 2004.
[44] J. Hupfeld, N. Ruffieux, Validierung einer deutschen Version der Self-Compassion Scale (SCS-D), Z. Klin. Psychol. Psychother. 40 (2011) 115–123, https://doi.org/10.1026/1616-3443/a000088.
[45] E. Kajantie, D.I.W. Phillips, The effects of sex and hormonal status on the physiological response to acute psychosocial stress, Psychoneuroendocrinology 31 (2006) 151–178, https://doi.org/10.1016/j.psyneuen.2005.07.002.
[46] C. Krueger, L. Tian, A comparison of the general linear mixed model and repeated measures ANOVA using a dataset with multiple missing data points, Biol. Res. Nurs. 6 (2004) 151–157, https://doi.org/10.1177/1099800404267682.
[47] M.G. Kenward, J.H. Roger, Small sample inference for fixed effects from restricted maximum likelihood, Biometrics 53 (1997) 983–997, https://doi.org/10.2307/2533558.
[48] J. Pek, D.B. Flora, Reporting effect sizes in original psychological research: a discussion and tutorial, Psychol. Methods 23 (2018) 208–225, https://doi.org/10.1037/met0000126.

[49] F. Faul, E. Erdfelder, A.G. Lang, A. Buchner, G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences, Behav. Res. Methods 39 (2007) 175–191, https://doi.org/10.3758/BF03193146.
[50] R. Miller, F. Plessow, C. Kirschbaum, T. Stalder, Classification criteria for distinguishing cortisol responders from nonresponders to psychosocial stress: evaluation of salivary cortisol pulse detection in panel designs, Psychosom. Med. 75 (2013) 832–840, https://doi.org/10.1097/PSY.0000000000000002.
[51] C. Triscoli, I. Croy, H. Olausson, U. Sailer, Touch between romantic partners: being stroked is more pleasant than stroking and decelerates heart rate, Physiol. Behav. 177 (2017) 169–175, https://doi.org/10.1016/j.physbeh.2017.05.006.
[52] P. Gilbert, The origins and nature of compassion focused therapy, Br. J. Clin. Psychol. 53 (2014) 6–41, https://doi.org/10.1111/bjc.12043.
[53] J.A. Häusser, A. Mojzisch, S. Schulz-Hardt, Endocrinological and psychological responses to job stressors: an experimental test of the Job Demand-Control Model, Psychoneuroendocrinology 36 (2011) 1021–1031, https://doi.org/10.1016/j.psyneuen.2010.12.016.
[54] W. Schlotz, R. Kumsta, I. Layes, S. Entringer, A. Jones, S. Wüst, Covariance between psychological and endocrine responses to pharmacological challenge and psychosocial stress: a question of timing, Psychosom. Med. 70 (2008) 787–796, https://doi.org/10.1097/PSY.0b013e3181810658.
[55] R.A. Depue, J.V. Morrone-Strupinsky, A neurobehavioral model of affiliative bonding: implications for conceptualizing a human trait of affiliation, Behav. Brain Sci. 28 (2005) 313–349, https://doi.org/10.1017/s0140525x05000063.