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Stress recovery with social support: A dyadic stress and support task

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A R T I C L E I N F O

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A B S T R A C T

How does social support bolster resilience? Here, we present a new dyadic paradigm to study causal mechanisms of acute and ecologically valid social support in the laboratory. The Dyadic Stress and Support Task (DSST) consists of a psychosocial stress phase and a recovery phase. During *DSST stress*, a pair of participants take turns to perform public speaking and mental arithmetic in front of a panel. Unable to see or touch each other, they witness each other's performance and feedback. During *DSST recovery*, the pair either interact freely with each other for 5 min (social support condition) or interact separately with an experimenter (non-support condition). To establish the validity of the DSST, we tested 21 pairs of long-term close friends in a pilot study. Primary outcome measures were ratings of affective state and bodily arousal (VAS scales 0–100). Secondary outcome measures were heart rate and salivary cortisol. *DSST stress* successfully induced subjective Stress Activation, increased Negative Affect and decreased Positive Affect. We also observed increased heart rate and salivary cortisol. After DSST recovery, Stress Activation and Negative Affect ratings were reduced in both groups. Positive Affect was completely restored to pre-stress baseline levels in the Social support group, while remaining significantly lower in the Non-support group. The DSST successfully induced stress and negative affect and captured stress recovery in both groups. Free-form interaction with the friend enhanced recovery of affective state, supporting the validity of spontaneous interaction between friends as a model of social support.

1. Introduction

Supportive social relationships are pivotal to mental and physical health, providing not just a buffer against the potentially adverse effects of stressful experiences (Cohen and Wills, 1985), but also a resource for positive experiences and growth (Feeney and Collins, 2015). Social support is closely linked to resilience. The epidemiological literature outlines the benefits of social support as reduced risk of mortality and mental illness (Seeman, 1996), drug addiction (Stone et al., 2012) and suicide (Christensen et al., 2014; Kleiman and Liu, 2013), also in populations with otherwise heightened risk of these adversities (Harris et al., 2020; Trujillo et al., 2017). Still, given the descriptive and correlational nature of this literature, the question remains of how exactly social support facilitates this resilience boost.

To establish the causal nature, and to investigate the physiological and psychological mechanisms of socially mediated stress recovery, experimental studies are necessary. For ethical reasons, stressors in the lab have to be relatively mild and transient. Existing paradigms such as the Trier Social Stress Test (TSST - (Kirschbaum et al., 1993)) nevertheless reliably elicit physiological and psychological stress responses such as increased heart rate and hypothalamic-pituitary-adrenal (HPA) axis activity (i.e. ACTH and cortisol secretion), and heightened self-reported stress, anxiety and negative mood (Allen et al., 2014). The TSST also offers reasonable ecological validity since it mimics the common experience of social evaluative threat during a job interview (Frisch et al., 2015).

The TSST and other stress induction tasks have been employed to probe the effects of social support (Kanthak et al., 2016; Thorsteinsson

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and James, 1999; Uchino et al., 2011). In these studies, social support is typically available either before or during the stressful event, in the form of the physical presence of a friend, romantic partner, supportive stranger, or supportive messages or feedback. Social support immediately *before* the stressful event is reported to attenuate heart rate, blood pressure and cortisol responses to the stress task, and reduce self-reported anxiety (Ditzen et al., 2008; Heinrichs et al., 2003; Kirschbaum et al., 1995). Studies where support is available *during* the stress task also indicate that a supportive environment can improve stress coping (Lepore et al., 1993; Uchino and Garvey, 1997). On the other hand, stress reactivity can increase when the participants' performance is likely to be evaluated by the person present - even when this is a friend (for a review of effects of different types of social support on stress responses, see Thorsteinsson and James, 1999).

Stressful experiences in life often occur in situations where you are away from your supportive others, or where they are facing the same stressor as you. Social support will then typically be available afterwards. The social support received after a traumatic event is pivotal to resilient coping (Hobfoll et al., 2007). Here, we present a dyadic adaptation of the Trier Social Stress Task designed to enable the study of social support experienced *after* a shared stress experience. We have called it the Dyadic Stress and Support Task (DSST). The DSST differs from previous TSST-based approaches in that i) the social support is provided by someone who shared the stressful experience, and ii) the social support is provided *after* the stress task. To demonstrate the validity of the DSST, we conducted a pilot study with 42 participants. In brief, we recruited pairs of participants who were close friends. The friends took part in the DSST together and could hear, but not see each other. In the social support condition, the friends were left to communicate freely for five minutes after completing the stress task. In the non-support control condition, each participant instead communicated with a panel member instructed to remain neutral.

As we show here, this new paradigm enables the study of acute social support effects after a lab stressor at the level of physiology (heart rate, cortisol), mood and behaviour. Specifically, the purpose of this data collection was to demonstrate the utility of the DSST paradigm for laboratory studies of acute social support after stress. As such, our primary aims were i) to verify that the dyadic stress and support task increased physiological and psychological stress measures and decreased mood; and ii) demonstrate that the social support interaction facilitated stress recovery. We also assessed the duration of the effects of acute stress and social support interactions by measuring mood and heart rate responses over a ~40-minute test session in which participants performed additional stress induction and other behavioural tasks.

2. Methods and materials

2.1. Overview of experimental setup

In this between-subject pilot study, pairs of real-life same-sex friends arrived together and were randomized to receive either social support or a non-supportive control interaction during a recovery period after stress induction. With exception of the stress and recovery periods, participants were seated in individual test rooms throughout the session. Primary outcome measures were mood ratings, heart rate and salivary cortisol levels. The session consisted of a baseline period (~90 min), the DSST (~30 min), and a subsequent downstream test period (~40 min). Pre-stress mood, heart rate and cortisol measures were collected during the baseline period. In the stress induction part of the DSST, participants both stood in front of the panel and could hear, but not see each other. The task consisted of four parts in pseudorandom order: performing the job interview and mental arithmetic tasks, and listening to the other performing each task (total duration 20 min; see DSST section below for details). After completing post-stress subjective state questionnaires, participants interacted either with their friend (social support condition) or one of the panel members (non-support control condition) for 5 min during the DSSt recovery phase. The social support/non-support interactions were followed by collection of mood, heart rate and cortisol measures. During the downstream test period, participants completed several behavioural tasks, including two stress reinstatement (re-stress) tasks (see section below for detailed description). Participants were fully debriefed at the end of the session. See Fig. 1 for an illustration of the experimental setup. For a detailed timeline of the entire session, see Figure S1 in the Supplementary materials.

2.1.1. Participants

Pairs of real-life friends who had known each other for a minimum of 6 months and viewed each other as safe and trusted friends were recruited through social media and posters/flyers distributed on campus and at community centres. Participants had to be between 18 and 65 years of age, and in general good health both physically and mentally. Exclusion criteria were self-reported ongoing mental illness and specific phobia for public speaking. Each participant completed a pre-session screening and recruitment form online. Screening data was stored on a secure server via the University of Oslo's Service for sensitive data. Participants were asked to join the study together with a same-sex friend (one dyad consisted of opposite sex friends). In all, 42 volunteers volunteers (31 female, mean age: 25.5, SD: 8.0) participated in the study. All participants provided written informed consent. The study was approved by the Regional Ethics Committee (REK Sør-Øst D: 2018/672). Participants received a gift card of NOK 300 (~EUR30) as compensation for their time.

2.2. Procedures

2.2.1. Baseline period

Participant pairs arrived together. Each participant was then escorted to one of two small adjacent test rooms where they provided informed consent. They were fitted with a pulse meter chest strap and watch. At approximately 10 – 40 min, participants completed several baseline tasks unrelated to the dyadic stress task, with a total duration of ~30 mins (see Supplementary methods for details; data not shown). Around 40 min after arrival, baseline heart rate was recorded while participants were instructed to relax in a chair for 7 min, accommodating adequate recording time for analysis of heart rate variability (HRV) (Malik et al., 1996). At approximately 60–90 min, participants completed three stress-related baseline activities: 1) the Perceived Stress Scale questionnaire (PSS, Cohen et al., 1983), 2) reading from a selection of predetermined online material detailing how health can be negatively affected by stress, and 3) the Stress Mindset Measurement scale (Crum et al., 2013). Reading time of online material was adjusted individually according to how much time they had spent on previous tasks, so that the dyad would complete the stress-related baseline activities at the same time.

Ratings of subjective state were collected three times during the baseline period, approximately 10, 60 and 90 min into the session. The ratings at 90 min served as the pre-stress baseline measurement. A saliva sample for cortisol quantification was collected at ~90 min, see description of the collection below. Note that the duration of the baseline period can be substantially reduced from our 90 min, depending on the aims of the particular study.

2.2.2. Dyadic Stress and Support Task period

2.2.2.1. DSST stress: dyadic stress induction. The original TSST consists of three parts: i) a preparation period; ii) a mock job interview; and iii) a mental arithmetic (maths) task. Stress-induction in the DSST contains two additional parts: iv) listening to the other's mock job interview; and v) listening to the other's math task. Parts ii-v are performed in front of a panel of researchers trained to refrain from normal positive communication signals such as nodding or smiling. We also adapted the tasks

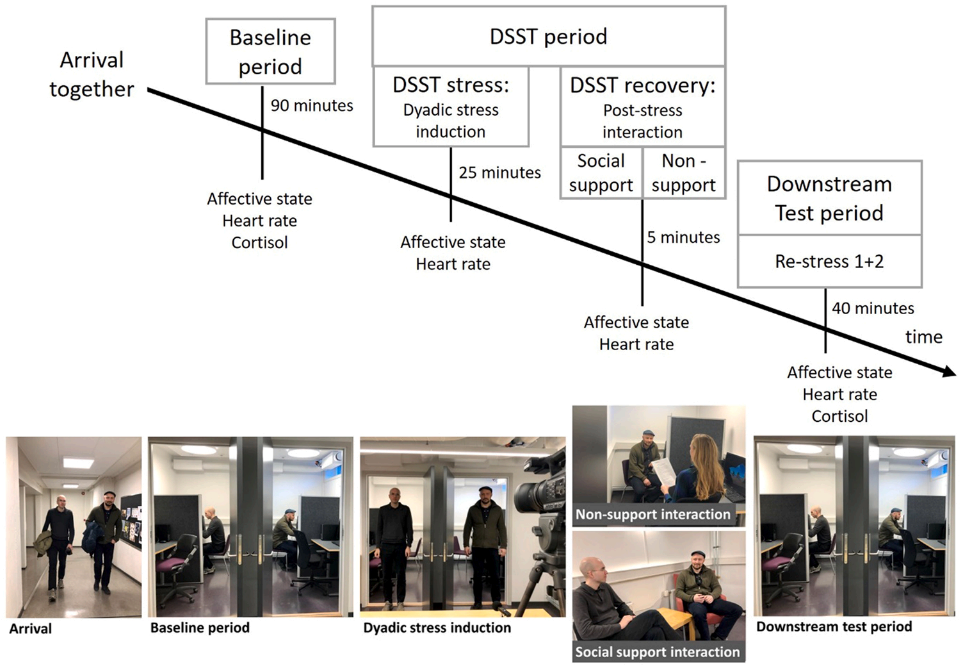

Fig. 1. Scematic timeline of the experimental session. Procedures are listed above the timeline and measures collected shown below the timeline. Illustration of the physical setup in the bottom row.

somewhat to reduce predictability and ensure a robust psychosocial stress response across participants.

Procedure. Each participant was told (separately) that the next task would be to give a 5-minute talk in front of a panel, about themselves and why they are the best candidate for the ideal next job in their career based on their personal qualities (not skills or experience). The participants were informed that they would be doing the task in parallel with their friend, and were given 3 min to prepare the talk in their separate cubicles with instructions to make notes on a sheet of paper. When the 3 min were up, participants were told to hand over their notes and stand on a mark in front of the door opening of their cubicle, facing a video camera, an audio recorder and the two experimenters who would now constitute the panel. Participants remained standing for the duration of the stress task separated by the cubicle doors, so that they were standing close to each other and could hear each other well, but not see each other. The experimenters were seated behind a large table directly in front of the dyad and switched on the camera and audio recorder in full view of the participants.

The experimenters decided which participant would begin by lottery draw. Up until now, all instructions and tasks had been given in Norwegian. To reduce predictability of the task, at this point participants were instructed that the talk had to be given in English, purportedly for "analysis purposes of the audiovisual material". To ensure an element of unfamiliarity, experimenters assumed roles as lead panel member for the participant they had not yet interacted with. When the first participant had finished the job talk, the other participant was not asked to present, but instead, again to reduce predictability, instructed to perform a 3-minute mental arithmetic task. After this, the first participant performed a similar mental arithmetic task, before the second participant's speech task. Finally, each participant returned to the cubicle to fill out the state/mood questionnaires.

Presentation task.

During the 5 min presentations, the panel members kept a neutral face expression and provided feedback and follow-up questions with the aim of increasing stressfulness of the task. Participants who had a good presentation flow were frequently interrupted with questions, or instructions to for instance keep to descriptions of their personal abilities or to "say something more relevant/interesting". For participants who struggled to find their words, the panel aimed for long, awkward silences and instructions to elaborate and keep talking. At 5 min, the participants were interrupted and told time was up.

Mental arithmetic task.

The mental arithmetic tasks involved counting down to zero from 2023 in steps of 17 (Participant A), or 3333 in steps of 27 (Participant B). Participants were instructed to complete the task as quickly and precisely as possible, and that every time they made a mistake, they would have to start over from the top. The task was presented as a simple calculation task designed to test attention, analytical thinking, and processing speed. Participants who performed the task slowly were prompted to go faster, and if they were stalling too long, to start again from the beginning. If the participant did not manage to complete 1–2 steps within 3 min, they were given a simpler version of the task (counting down from the same number but in steps of 7).

2.2.3. DSST recovery: post-stress interaction

Upon completion of the post stress questionnaires, participants interacted for 5 min either with each other (support condition) or with the experimenter who had been the lead panel member during their talk (non-support condition).

2.2.3.1. Social support condition. Participants were asked to walk out of their cubicles and take a seat together in a "relaxation area" for 5 min, where they were left to interact freely with each other while the experimenters went to "check on something". Participants were not informed that this interval was a part of the experiment, and received no instructions for this interaction. The conversation between the participants was recorded with an audio recorder placed out of the participants' view. After 5 min, the panel re-entered the room and took the participants back to their respective cubicles. Audio recordings of the interaction were not analyzed.

2.2.3.2. Non-support condition. The non-support interaction consisted of a structured interview on the participant's experience during the stress task. Participants were asked how pleased they were with their own performance, what they made of their friend's performance and how that compared to their own performance. The experimenters were instructed not to give any feedback on the participants' answers, and to remain as neutral as possible in facial expression and tone. In the event that the experimenters ran out of questions before the 5 min were up, they simply informed the participant that they had no further questions, turned to their note pad and sat in silence until the next task was due. This occurred only in a few participants.

2.2.3.3. Blinding of experimenters and participants. Initially, experimenters were aware of the assigned social support condition of pairs before the baseline period. After observing a session and pre-stress baseline difference in subjective state ratings between dyads in the support condition versus those in the non-support condition at initial data analysis of the first 15 dyads, we implemented a blinding procedure that would blind experimenters to the dyad's support condition until after the stress task. Blinding was conducted for the last 6 dyads. The blinding procedure involved changing the session protocol that experimenters used to log events so that the recovery phase condition (support/non-support) was unspecified. Just before the recovery phase started, the experimenters opened a textfile that stated the recovery condition – thus unblinding them.

2.2.4. Downstream test period

After the DSST, we assessed potential downstream effects of social support on i) reactivity to further stress exposure, ii) social perception and ability to deal with social rejection, and iii) affinity for flexible reward learning. Participants completed two re-stress tasks (see Supplementary materials for further details). They also completed two behavioural tasks unrelated to the DSST, involving social feedback, social perception and reward learning (data now shown).

2.3. Subjective state measurements

Subjective mood and state were the main outcome variables, measured before and after tasks (nine time points) using a locally developed subjective state questionnaire (see Figure S1 in the Supplementary materials for a detailed timeline). Before each subjective state questionnaire, participants completed a two-item *state change questionnaire* probing whether the preceding procedure had made them feel better or worse overall.

2.3.1. State change questionnaire

In an attempt to capture task-induced changes in participants' overall sense of subjective state, we made a brief two-item 'State-Change'questionnaire that asked to what degree the task participants had just engaged in (presentation & maths task in front of panel / break together with a friend / break together with the experimenter) made them feel better, and to what degree it made them feel worse. The questions of better/worse were asked separately, and participants indicated their response on a 0–100 visual sliding scale anchored not at all / very much. StateChange was administered immediately after DSST stress, DSST recovery, Re-stress1 and Re-stress2.

2.3.2. Subjective state questionnaire

2.3.2.1. Questionnaire development. To avoid questionnaire fatigue and ensure engagement throughout the session, we developed a brief questionnaire with items probing relevant mood and physiological states. The questionnaire was developed during a pre-pilot test phase conducted to identify mood and state items that were sensitive to the stress task. We administered the expanded 60-item version of the Positive and Negative Affect Schedule (PANAS-X, Watson & Clark, 1994) and the 20 state-anxiety items from the State Trait Anxiety Inventory (STAI, Spielberger, 1983) to 13 participants right before and after the classic Trier Social Stress Task. Pre-pilot questionnaire data were inspected visually and descriptively, and a final subjective state questionnaire was created based on a short-list comprising i) the items from PANAS and STAI that had showed the greatest sensitivity to the stress task; ii) selected items from Beck's Anxiety Inventory (selected due to sensitivity to physiological stress arousal); and iii) items from our previously developed checklist for opioid drug side effects and relevant opioid drug effects measures (Løseth et al., 2019, Eikemo et al., 2016, Chelnokova et al., 2014).

2.3.2.2. Presentation of the subjective state questionnaire. The subjective state questionnaire consisted of 24 items formulated as statements about how one feels in the moment, starting with "*Right now, I feel/I am* …". Participants indicated to which degree this statement corresponded to their current state on a 100-point unnumbered visual sliding scale with anchors 'not at all' and 'very much'. The items tapped positive and negative affect as well as psychological and physiological states that could be sensitive to stress reactions and to effects and side effects of the drug manipulations planned for later studies. See Table 1 for an overview of the included items in the order that they were presented at each measurement point (Norwegian version shown in Table S1 in Supplementary Materials).

2.3.2.3. End-of-session questionnaire. At the end of the session, participants completed a questionnaire about various experiences during the session. This questionnaire was administered before the debrief conversation with the friend and experimenters. The initial five questions concerned how stressful the participants had found the DSST and subsequent re-stress, with responses recorded on a 1–10 scale (not at all stressful/extremely stressful), and in addition, participants could fill in a free-text field with qualitative notes on their experience. The following ten questions about the different experimental tasks had free-text-only responses. These responses were collected for future task and study development.

2.3.3. Debrief

During a face-to-face debrief conversation with the experimenters, the two participants were together informed of the true nature of the DSST set-up and the purpose of the study as a whole. To counter the negatively focused information about stress, they had read during the baseline period, participants were also provided with a link to a TED-talk that details positive effects of stress and of having a positive stress mind-set (McGonigal, 2013).

Table 1
Subjective state questionnaire.

1.	"Right now, I am stressed.",
2.	"Right now, I feel safe.",
3.	"Right now, I feel vulnerable",
4.	"Right now, I am shaky.",
5.	"Right now, I feel discomfort in my stomach",
6.	"Right now, I am relaxed.",
7.	"Right now, I feel my heart pounding.",
8.	"Right now, I feel indifferent.",
9.	"Right now, I am angry.",
10.	"Right now, I don't feel quite like myself.",
11.	"Right now, I am happy.",
12.	"Right now, I have a dry mouth.",
13.	"Right now, I feel exhausted.",
14.	"RIght now, I feel confident.",
15.	"Right now, I feel blunted.",
16.	"Right now, I feel red/warm.",
17.	"Right now, I feel distressed.",
18.	"Right now, I am bored.",
19.	"Right now, I feel good.",
20.	"RIght now, I feel dizzy/lightheaded.",
21.	"Right now, I am nauseous.",
22.	"Right now, I feel anxious.",
23.	"Right now, I feel high (drug high).",
24.	"Right now, I am euphoric."

2.4. Physiological measurements

We recorded heart rate throughout the session as a measure of participant activation in response to experiment tasks and interventions. Increased heart rate during stress tasks was expected and considered a measure of stress-related activation. Heart-rate variability was calculated and analysed due to indications that changes in HRV-related factors indicating low parasympathetic activity (decrease in high-frequency band and increase in low-frequency band) are associated with stress reactivity (Kim et al., 2018).

2.4.1. Heart rate measurements

2.4.1.1. Data collection. Heart rate was recorded as R-waves (reflecting the depolarization of the main mass of the ventricles as the heart beats) continuously throughout the session using a Polar V800 heart rate monitor with a Polar H7 chest strap at a sampling rate of 1000 Hz. The Polar V800 produces data that is highly consistent with electrocardiograms for both supine and standing positions (Giles et al., 2016). We used the Polar FlowSync application to extract data from the watches. During the continuous recording, two 7-minute periods were dedicated to recording heart rate while participants rested in their chairs, and the RR-intervals (time between two R-waves) from this period formed the basis for pre- and post-stress heart rate variability calculations (detailed below).

2.4.1.2. Data pre-processing. All data pre-processing was conducted in R (R Core Team, 2020) using the RHRV package (Rodriguez-Linares et al., 2020). Timestamps were used to isolate the recording segment for each activity during the session. R-waves were then converted to heart rate (beats per minute (BPM)) and filtered automatically using default parameters. This involved removing beats with unacceptable physiological values (BPM < 25 and BPM > 200) and beats flagged as outliers based on the algorithm presented in García Martínez et al. (2017). This algorithm uses adaptive thresholds to determine whether individual beats deviate from the previous or the following beat (threshold starting point: 13%, possible range: 12–20%), or from the mean of the 50 preceding beats (threshold starting point: 19.5%, possible range: 18–30%) by improbable values. Next, we calculated the average BPM. To facilitate frequency analysis, we applied linear interpolation to the data. From the interpolated heart rate data, we extracted the average low-frequency (0.04–0.15 Hz) and high-frequency (0.15–0.4 Hz) power using short-time Fourier transform with a window size of 300 s and a displacement of 30 s

2.4.2. Salivary cortisol sampling

Two saliva samples were collected from each participant (at 90 and ~140 min, 5 min before and 45 min after DSST stress induction onset) using Sarstedt Salivette® synthetic swabs specially designed for cortisol determination (Sarstedt, Nümbrecht, Germany). Samples were immediately placed in a refrigerator at ca 4 °C, and were kept refrigerated for maximum 7 days before being centrifuged for 2 min at 1000 x g. After centrifuging, the empty swab was removed from the tube, and the tube containing saliva was kept frozen at − 20 degrees Celsius until analysis.

2.4.2.1. Cortisol level analysis/assay. Samples where thawed and centrifuged again in 1000 x g for 2 min before diluted in the Assay buffer of the DetectX® Cortisol Enzyme Immunoassay Kit (Arbor Assays, Ann Arbor, MI, USA). Thereafter, the manufacturer's instructions were followed. The assay has a sensitivity of 27.6 pg/ml and samples were averaged from duplicates.

2.4.3. Interpersonal and relational pre-session questionnaires

Participants' reactivity to a psychosocial stressor and ability to benefit from subsequent social support during stress recovery can be influenced by the idiosyncratic psychosocial context that each individual carries with them. The amount of stress one experiences in life and the appraisal of this stress also contributes to the psychological context of an individual, and can greatly affect how further stressors are dealt with. As part of the pre-session online form, participants completed a series of different questionnaires measuring aspects of stress, social support and loneliness in participants' lives, as well as characteristics of the specific friendship with the dyad partner. Five questionnaires were part of the pre-session online form (Interpersonal Support Evaluation List (including the Giving Support version, both from Cohen et al., 1985), McGill Friendship Questionnaires (Mendelson and Aboud, 1999), Short Loneliness Scale (Hughes et al., 2004), and two were administered during the baseline period of the session (Perceived Stress Scale (Cohen et al., 1983)) and Stress Mindset Measurement (Crum et al., 2013)). Scores were used to compare groups in the social support and non-support conditions.

2.5. Statistical analyses

All statistical analyses were conducted in R (R Core team, 2021). All graphs were made using the R package ggplot2 (Wickham et al., 2021). Where *experiment stage* is added as a factor, the level 'DSST stress' refers to the DSST stress induction, 'DSST recovery' refers to the post-stress phase of the DSST where participants interact with an experimenter (non-support) or their friend (support). Data from the downstream test period were analyzed separately (see Supplementary materials).

2.5.1. Group characteristics

Group characteristics as defined by participant age, gender and participants' responses to interpersonal, relational and life stress questionnaires were analysed with descriptive statistics and student's T-tests.

2.5.2. Subjective state measures

2.5.2.1. State change questionnaire. StateChange ratings of 'feeling better' and 'feeling worse' (rated after each task) were analysed in two separate linear mixed models in the analysis software R using the *lme* function of the *nlme* package (Pinheiro et al., 2021). Fixed factors were *experiment stage* (levels: DSST stress, DSST Recovery) and *support condition* (levels: Social support, Non-support), with random intercepts for participants nested within dyads. Estimated means and factor contrasts were calculated, with Tukey corrections where appropriate, using the R package *emmeans* (Lenth et al., 2022).

2.5.2.2. Subjective state questionnaire

2.5.2.2.1. Exploratory factor analysis. Four questionnaire items were omitted from further analysis since they were intended to measure known side effects of certain drugs we plan to use with this setup in future studies (nausea, dizziness/light-headedness, feeling high and euphoria). The remaining 20 items were subject to an exploratory factor analysis to uncover the underlying relationships between questionnaire items. Items tapping into the same latent constructs could then be grouped together by calculating factor-based scores, which simplifies further analysis and interpretation of the responses. Raw rating scores of the 20 relevant items collected at all nine time points during the session were included in the analysis, which was performed with maximum likelihood extraction method using the *efa* function within the R package *jmv* (Selker et al., 2021). We used oblique rotation (oblimin) since the latent constructs measured by the questionnaire were different dimensions of subjective state, including positive and negative mood. A correlation between these dimensions were assumed a priori, given the typically inverse relationship between negative and positive affective state, and the expected correlation between stress and negative affect. An oblique rotation would therefore be considered the most appropriate rotation method to reveal the factor structure (Costello and Osborne, 2019). Initial inspection of the factor structure using an orthogonal rotation (varimax – assuming no correlation between factors) did indeed reveal several items with significant loadings onto more than one factor, indicating that factors were not truly uncorrelated (factor loadings with varimax rotation shown are in Table S Supplementary materials).

Factor retention was based on parallel analysis, which was chosen as extraction method since it adjusts for effects of sampling error and least-squares bias in finite samples such as ours. Such effects could otherwise lead to inflation of initial eigenvalues and hence extraction of fewer factors if Kaiser's population-based criterion of only retaining factors with eigenvalues above 1 was followed (Hayton et al., 2004). Scree-plot inspection was used to corroborate results of the parallel analysis. Factor-based scores per participant for each stage were calculated as the arithmetic average rating of all items with significant loadings to the factor (factor loading > 0.4, items with negative loadings were reversed). Group differences in subjective state at pre-stress baseline were assessed by inspecting factor-based scores calculated from raw ratings using descriptive statistics and Student's T-tests.

2.5.2.2.2. Linear mixed effects models. Effects of the experimental manipulations on subjective state were assessed with linear mixed models conducted on baseline corrected factor-based scores using the same procedure as for StateChange analyses (see above).

2.6. Physiological measurements

2.6.1. Heart rate and heart rate variability

Heart rate (average BPM) and heart rate variability (low- and high-frequency power) data were analyzed with linear mixed models implemented in R using the packages lme4 (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017). We ran three separate models, all with random intercepts for dyads and participants nested within dyads: i) Changes in heart rate during the different segments of the DSST period were analysed in a model with average BPM as outcome and support condition, experiment stage (levels: baseline rest, DSST stress, DSST recovery) and their interaction as fixed factors; ii) low-frequency power HRV and iii) high-frequency power HRV were analysed in two separate models where support condition, experiment stage (levels: baseline rest, post-DSST rest) and their interaction were added as fixed factors. We used ANOVA and F-tests to assess main effects and interaction of support condition and experiment stage. The R package emmeans was used to calculate estimated means and factor contrasts with Tukey corrections (Lenth et al., 2022).

2.6.2. Salivary cortisol

Salivary cortisol (ng/ml) levels were analysed with linear mixed models using the *lme* function within the R package *nlme,* with Sample number (1 = pre-DSST, 2 = post-DSST) and Support condition as fixed factors, and time of day for sample 1 (hh:mm) added as a nuisance covariate.

Open practices statement

Data and analysis code is publicly available at OSF Open Science Framework: DOI 10.17605/OSF.IO/5K2WJ. This pilot study was not preregistered.

3. Results

The aims of this pilot study were to i) verify that the DSST stress induction works to increase physiological and psychological stress measures; and ii) test whether the Social support condition mediated stress recovery. We first present group characteristics of the two social support condition groups. Next, we describe results from the factor analysis of subjective state items. The subjective measures of stress activation are presented together with physiological stress measures. The subjective state effects and any group differences in positive and negative affect are presented at the end of the results section.

3.1. Group characteristics

Participant pairs were randomized to either the social support or non-support condition. The resulting groups did not significantly differ in age or other pre-session characteristics as measured by the interpersonal, relational and life stress questionnaires (Table 2).

3.2. Subjective state questionnaire: dimension reduction by exploratory factor analysis

The overall Kaiser-Meyer-Olkin measure verified the sampling adequacy for the exploratory factor analysis (KMO = 0.896), and all KMO values on individual items were 0.73 or higher, which is well above the acceptable limit of.6 (insert ref - Kaiser 1975 or similar). Four factors were retained on the basis of a parallel analysis, and justified also based on the scree plot which showed an inflexion at the fifth factor (see Figure S2 in the Supplementary materials). Table 3 shows the factor loadings after rotation. Loadings above 0.4 were considered salient and are shown in bold. None of the items showed salient loadings on more than one factor. Items "not quite like myself", "indifferent" and "angry" did not load to a significant degree on any of the four factors.

3.2.1. Four factors: Positive affect, Stress-related activation, Negative affect and Tiredness

Inspecting the structure matrix and items that loaded on the same factors (Table 3) suggests that factor 1 represents positive affect (comprising items 'good', 'happy', 'self-confident', 'relaxed' and 'safe'), factor 2 represents stress-related physiological activation/arousal (comprising items 'shaky', 'red/warm', 'pounding heart', 'dry mouth' and 'stressed', factor 3 represents negative affect (comprising items 'anxious', 'abdominal discomfort', 'distressed' and 'vulnerable), and factor 4 represents tiredness (comprising items 'blunted', 'exhausted' and 'bored').

Correlations between factors were expected due to the natural inverse relationship between positive and negative affective responses (hence the oblique rotation), and a negative correlation was indeed found between the positive and negative affect factors ($r = -0.56$). The stress activation factor was negatively correlated with positive affect ($r = -0.43$), and positively correlated with negative affect ($r = -0.55$). The factor tiredness was more weakly correlated with the other factors and had a negative correlation with positive affect ($r = -0.43$), positive correlation with negative affect ($r = 0.32$) and a very weak negative correlation with Stress activation ($r = -0.05$).

T-tests of the raw factor-based scores at pre-stress baseline revealed no statistically significant differences in subjective state between support-condition groups even at the uncorrected level (all *p*-values

Table 2
Participant characteristics.

	Support (N = 22)		Non-support (N = 20)	
Female: N = 31	16		15	
Male: N = 11	6		5	
	mean	*SD*	mean	*SD*
Age	25.3	8.9	25.3	5.8
Mean score Short Loneliness Scale	5.0	1.2	4.7	1.1
Mean score Interpersonal Support Evaluation List (ISEL12)	42.0	3.9	41.9	4.9
Mean score Giving Support-ISEL	41.7	4.5	40.7	4.8
Mean score McGill Friendship Questionnaire FF	6.6	1.1	7.2	0.7
Mean score McGill Friendship Questionnaire RA	3.5	0.8	4.0	0.5
Perceived Stress Scale	28.6	3.5	29.7	3.5
Stress Mindset Measure	1.4	0.8	1.3	0.7

Table details mean age and average scores on scales with relevant measures of loneliness, social support relations, and dyadic relationship characteristics, as well as recent life stress (Perceived Stress Scale) and tendency to view stress as positive or negative (Stress Mindset Measure).

Table 3
Structure matrix with factor loadings.

	Factor				
	Positive affect	Stress activation	Negative affect	Tiredness	Uniqueness
Good	0.900	-0.018	-0.002	-0.009	0.172
Happy	0.809	0.132	0.017	-0.169	0.327
Self-confident	0.759	-0.101	0.002	0.014	0.362
Relaxed	0.456	-0.365	-0.128	0.169	0.431
Safe	0.438	-0.053	-0.339	0.074	0.536
Shaky	0.004	0.724	0.126	0.042	0.379
Red/warm	-0.105	0.710	-0.169	-0.031	0.521
Pounding heart	0.141	0.622	0.261	0.123	0.464
Dry mouth	0.013	0.621	-0.125	0.132	0.674
Stressed	-0.204	0.504	0.369	-0.069	0.263
Anxious	0.051	-0.007	0.836	0.066	0.312
Abdominal discomfort	-0.075	0.183	0.527	0.084	0.515
Distressed	-0.308	-0.028	0.516	0.107	0.448
Vulnerable	-0.397	0.179	0.417	-0.092	0.383
Blunted	0.028	0.084	0.046	0.787	0.368
Exhausted	-0.178	0.123	0.011	0.744	0.324
Bored	0.034	-0.296	0.063	0.553	0.586
Not myself	*-0.300*	*0.081*	*0.175*	*0.089*	*0.763*
Indifferent	*0.068*	*-0.357*	*-0.059*	*0.343*	*0.716*
Angry	*-0.266*	*-0.082*	*0.305*	*0.264*	*0.644*
Initial eigenvalues	6.62	1.88	0.89	0.43	
Sum of squares loadings	3.48	2.89	2.54	1.91	
% of variance	17.39	14.46	12.68	9.54	Total variance: 54.1%

>0.23).

3.3. Subjective and physiological measures of stress

3.3.1. Subjective state: Stress activation

There was a significant main effect of Experiment stage on Stress activation [$F_{1,\ 40} = 52.7$, $p < .0001$]. As illustrated in Fig. 2, the DSST stress task led to increased ratings of stress activation compared to pre-stress baseline across groups [estimated mean change from baseline ± SEM: 23.6 ± 2.21]. Stress activation scores were reduced after *DSST recovery* in both groups relative to after *DSST stress* [estimated mean within-group reduction from DSST stress Non-support: − 15.4 ± 3.4, Social support: − 18.1 ± 3.2]. There was no statistically significant main effect of Support condition [$F_{1,\ 19} = 1.1$, $p = .31$] or interaction between Experiment stage and Support condition [$F_{1,\ 40} = 0.34$, $p = .56$]. There were no statistically significant contrasts in Stress activation scores between groups at any stage (see Table S4 in Supplementary materials for further details).

3.3.2. Heart rate measurements

RR recordings were analysed for n = 36 (18 dyads; data was missing for six participants due to an error with the Polar V800 watch configuration. Heart rate variability data was analysed from n = 35 (one recording was incomplete). The quality of the remaining RR recordings was high. Across participants and activities, only 0.94% (*SD* = 2.58) of the beats were on average flagged as artefacts and consequently filtered out.

3.3.2.1. Heart rate. There was a significant main effect of experiment stage on beats per minute (BPM) [$F_{2,\ 68} = 93.78$, $p < .0001$]. As expected, the *DSST stress* increased heart rate [estimated mean change from baseline (SEM) = 17.97 (1.6), $t_{68} = 11.25$, $p < .0001$]. Heart rate returned to baseline levels during the *DSST recovery* [− 1.83 (1.6), $t_{68} = -1.15$, $p = .49$]. Neither the main effect of support condition [$F_{1,\ 16} = 0.01$, $p = .93$] nor its interaction with *experiment stage* [$F_{2,\ 68} = 0.93$, $p = .40$] was statistically significant. A detailed overview of changes in heart rate throughout the session is available in Fig. 2 C. Heart rate was substantially increased during all phases (listening and speaking) of the DSST stress task, details are reported in the Supplementary and illustrated in Figure S4.

3.3.2.2. Heart rate variability. Contrary to the hypothesis, there were no significant main effects of *experiment stage* (pre vs post DSST) [$F_{1,\ 33.5} = 1.5$, $p = .22$], or *support condition* (Social support vs Non-support) [$F_{1,\ 34.2} = 0.6$, $p = .45$, or interaction effect, $F_{1,\ 33.5} = 0.78$, $p = .39$], on low-frequency power [estimated mean (SEM): *Social support pre DSST*: 906 (153), *Non-support pre DSST*: 657 (174), *Social support post DSST*: 691 (153), *Non-support post DSST*: 621 (171)] (Fig. 2 F). Similarly, effects of *experiment stage* [$F_{1,\ 33.8} = 1.06$, $p = .31$] and *support condition* [$F_{1,\ 34.36} = 0.01$, $p = .92$] and their interaction [$F_{1,\ 33.8} = 0.05$, $p = .83$] on high-frequency power were not statistically significant [*Social support pre DSST*: 470 (116), *Non-support pre DSST*: 437 (132), *Social support post DSST*: 371 (116), *Non-support post DSST*: 373 (129)] (Fig. 2 G).

3.3.3. Salivary cortisol

Salivary cortisol was overall higher after the DSST, consistent with an overall increase in cortisol after the DSST stress induction (main effect of Sample number [$F_{1,\ 39} = 4.9$, $p = .03$; estimated mean cortisol levels ± SEM *Sample 1*: 1.14 ± 0.24, *Sample 2*: 1.64 ± 0.35]. There was no statistically significant main effect of Support condition [$F_{1,\ 19} = 1.6$, $p = .22$], and no statistically significant interaction between Sample number and Support condition [$F_{1,39} = 0.18$, $p = .67$]. On a within-group level, post-hoc contrasts showed a statistically significant increase in salivary cortisol from pre-stress baseline in the Non-support group [estimated mean increase ± SEM: 0.57 ± 0.26 ng/ml, $t_{19} = 2.2$, $p = .04$]. The cortisol increase in the Social support group was somewhat weaker and not significant [0.42 ± 0.25 ng/ml, $t_{19} = 1.7$, $p = .10$].

3.4. Subjective state effects

Subjective state effects are illustrated in Fig. 3.

3.4.1. State change questionnaire

3.4.1.1. Feeling worse. There was a statistically significant main effect of *Experiment stage* [$F_{1,\ 40} = 68$, $p < .0001$] but not of *Support condition* [$F_{1,\ 19} = 0.02$, $p = .8$] on ratings of ‘Feeling worse’. The interaction effect between *Experiment stage* and *Support condition* was significant [$F_{1,\ 40} = 9$, $p = .0039$]. As expected, participants in general reported ‘feeling worse’ after the *DSST stress* induction [estimated mean ± SE across groups: 63.5 ± 4]. Ratings of ‘feeling worse’ were lower after *DSST*

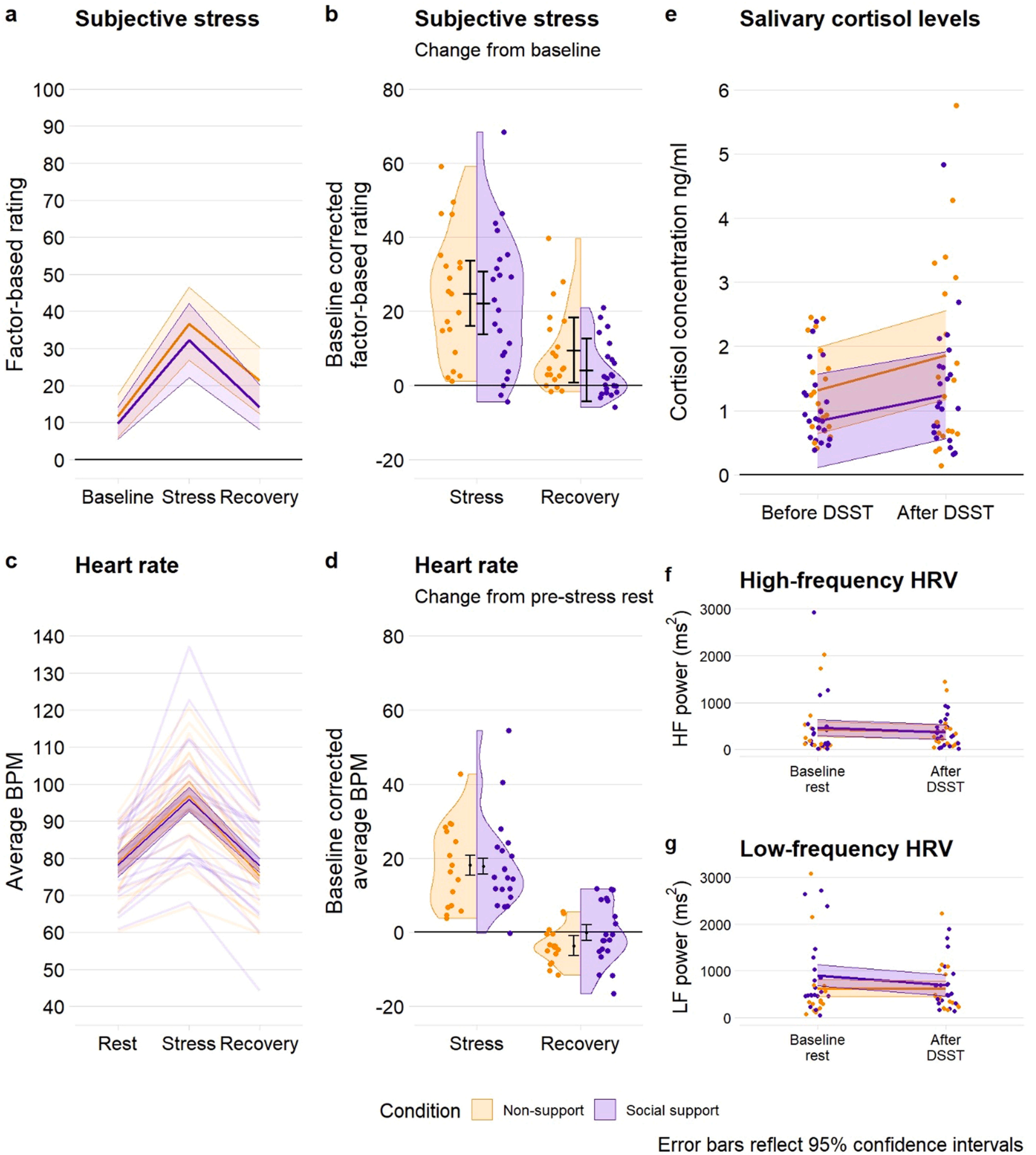

Fig. 2. Overview of subjective and physiological stress responses. Error bars and ribbons indicate 95% confidence intervals. a) Ratings of Stress Activation were increased after DSST stress and reduced after the DSST recovery. b) Illustration of the means, distributions and the individual baseline-corrected scores of Stress Activation that were entered into the statistical analyses. c) Heart rate was significantly elevated during DSST stress and returned to baseline after DSST recovery for both groups. d) Illustration of the means, distributions and the individual baseline-corrected heart rate data that were entered into the statistical analyses. e) Salivary cortisol levels were significantly increased after the DSST compared to baseline. f, g) Both high- and low-frequency heart rate variability measures were comparable before and after the DSST.

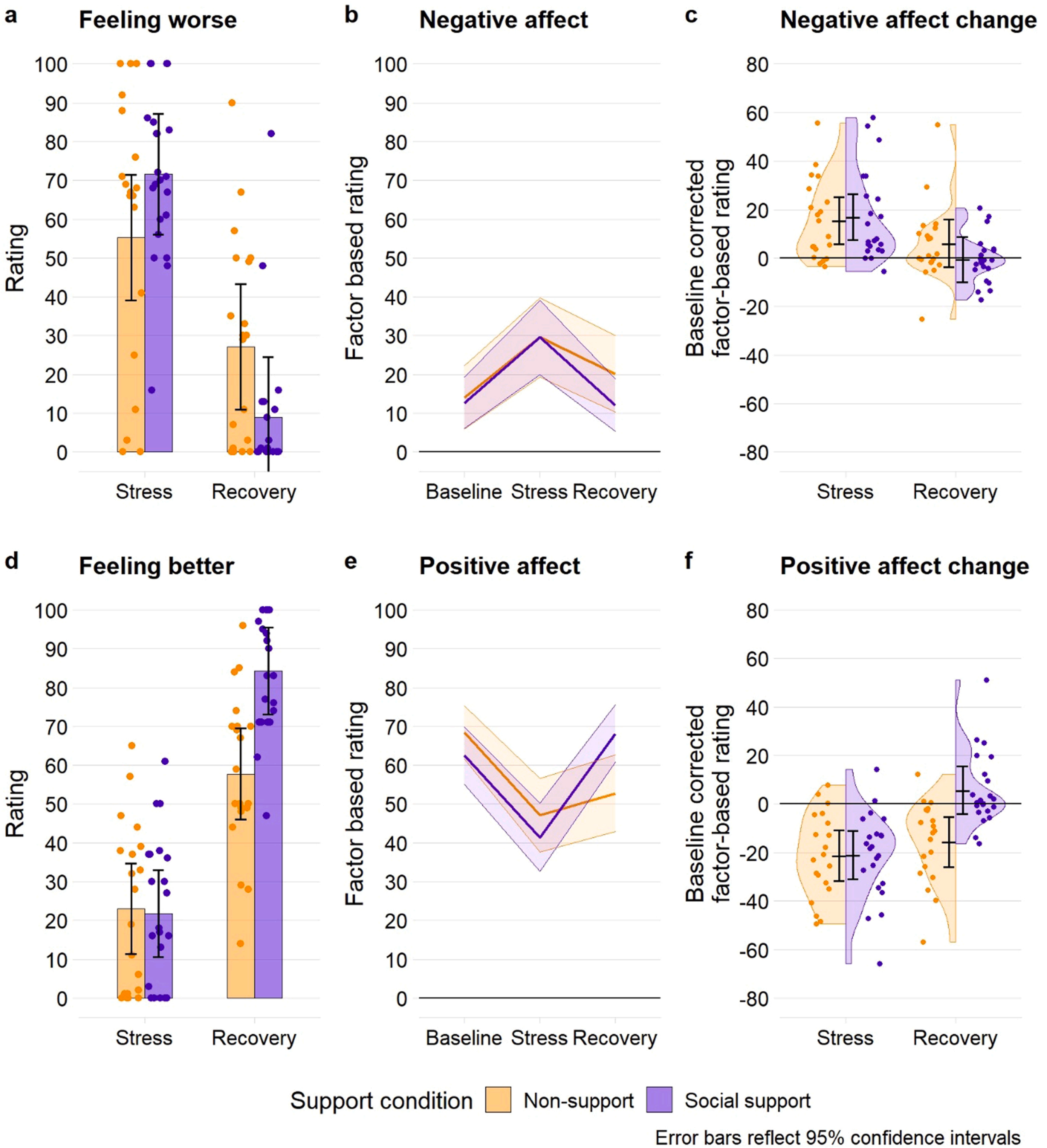

Fig. 3. Overview of affective responses. Error bars and ribbons indicate 95% confidence intervals. a) Ratings of feeling worse were high after DSST stress and low after DSST recovery. There was a significant group difference after DSST recovery, with lower ratings of feeling worse in the Social support compared to the Non-support group. b) Negative affect ratings were overall low, but increased following DSST Stress and brought back down after the recovery phase. c) Estimated mean Negative affect and variance from the statistical model, shown with the distributions and individual baseline-corrected scores that were entered into the analyses. d) Participants gave low ratings of feeling better after DSST stress, but relatively high ratings of feeling better after DSST recovery. The Social support group felt significantly better than the Non-support group after the recovery phase. e) Ratings of positive affect were overall high, decreased markedly following DSST Stress and were brought back up after DSST recovery. In the Social support group, Positive affect was restored to baseline levels following DSST recovery. f) Estimated mean Positive affect and variance from the statistical model, shown with the distributions and individual baseline-corrected scores that were entered into the analyses.

recovery for both groups [Social support: 9 ± 5.6, Non-support 27.1 ± 5.9]; the between-groups comparison showed that ratings of feeling worse were significantly higher in the Non-support compared to the Social support group [$t_{1,19} = -2.2$, $p = .038$]. See Fig. 3 A below and Table S5 in Supplementary materials for further details.

3.4.1.2. Feeling better. There was a statistically significant main effect of *Experiment stage* [$F_{1,\ 40} = 140$, $p < .0001$] and Support condition [$F_{1,\ 19} = 9$, $p = .0069$] and interaction between the two [$F_{1,\ 40} = 11$, $p = .0019$] on ratings of 'Feeling better'. The pattern of ratings of 'feeling better' after the stress and recovery tasks complemented ratings of 'feeling worse'. While the DSST stress induction yielded overall low ratings of 'feeling better', participants in both groups reported 'feeling better' after the post-stress interactions during DSST recovery. Ratings were substantially higher in the Social support condition compared to the Non-support condition [estimated mean±SE: Support: 84 ± 4.1, Non-support: 58 ± 4.2, Support > Non-support: $t_{19} = 4.5$, $p = .0003$]. See Fig. 3B below and Table S6 in Supplementary materials for further details.

3.4.2. Subjective state questionnaire

3.4.2.1. Negative affect. There was a statistically significant main effect of *Experiment stage* on Negative affect [$F_{1,40} = 37$, $p<.0001$]. There was no significant main effect of *Support condition* [$F_{1,\ 19} = 0.35$, $p = .56$], and no significant overall interaction between *Experiment stage* and *Support condition* [$F_{1,\ 40} = 3.3$, $p = .078$]. Negative affect scores were increased from baseline in both groups following *DSST stress* [estimated mean across groups ± SE: 16 ± 2.5]. *DSST recovery* brought Negative affect scores significantly down again in both groups, with the greatest reduction occurring in the *Social support* group [estimated mean within-group reduction from DSST stress ± SE: Non-support = - 9.4 ± 3.2, t_{40} = - 2.9, $p = .0061$, Social support = - 17.5 ± 3, t_{40} = - 5.7, $p < .0001$]. There were no statistically significant contrasts in Negative affect scores between groups at any stage (see Table S7 in Supplementary materials for details).

3.4.2.2. Positive affect. There was a statistically significant main effect of Experiment stage on Positive affect [$F_{1,\ 40} = 51.3$, $p < .0001$]. There was a significant main effect of Support condition [$F_{1,\ 19} = 5.4$, $p = .032$], and a significant interaction between Experiment stage and Support condition [$F_{1,\ 40} = 20.3$, $p < .0001$]. Positive affect was brought down from baseline by *DSST stress* in both groups*:* [estimated mean reduction across groups ± SE: - 21.3 ± 3.7]. *DSST recovery* led to fully restored Positive affect in the Social support group, but not for the Non-support group. The difference between groups after the social interaction was substantial [estimated contrast Social support - Non-support ± SE = 21.3 ± 5.2, $t_{19} = 4.1$, $p = .0006$] (see Table S8 in Supplementary materials for further details).

3.4.2.3. Tiredness. There was a significant main effect of Experiment stage on Tiredness [$F_{1,\ 40} = 7.7$, $p = .008$], while main effect of Support condition and interaction with Experiment stage were not significant. Tiredness scores were reduced from pre-stress baseline in both groups after DSST stress [estimated mean decrease across groups ± SE: − 5.5 ± 3.6], and were back at baseline levels for both groups after DSST recovery. See Supplementary Materials for further details.

3.4.2.4. Effects of post-DSST stress reinstatements. Stress reinstatement tasks (Re-stress 1 and Re-stress 2) increased Stress activation and Negative affect ratings across support condition groups. There was no statistically significant main effect of support condition or contrasts between groups at any level. See Supplementary Materials for details.

4. Discussion

Our primary aims were i) to verify that the stress induction part of the Dyadic Stress and Support Task increased physiological and psychological stress measures and decreased mood; and ii) demonstrate that the DSST social support interaction was effective in mediating stress recovery. With data from 21 pairs of healthy volunteer friends, we demonstrate that subjective Stress activation, Negative affect ratings, cortisol levels and heart rate were increased after the dyadic stress induction, whereas Positive affect ratings were reduced. During the DSST recovery phase, heart rate, Stress activation and Negative affect ratings dropped significantly in both groups. The benefit of social support as produced by free interaction with a good friend during recovery was evident via a strong boost in Positive affect ratings, compared to the Non-support control condition. We interpret the relatively short duration of stress responses in both groups as an indication of a flexible and adaptive stress system in this population.

The DSST was developed as a paradigm for investigating ecologically valid social support in a laboratory setting. The spontaneous and free-form nature of the supportive interaction is central to the design. Free text responses from an end-of-session questionnaire confirmed that interacting with their friend felt natural and that the pairs of friends discussed their experiences of the experiment during their unstructured interaction. Three design factors facilitate each participant's receipt of effective social support. First, long-standing close friends are likely to be spontaneously supportive of each other in ways that both find helpful. Second, social support is improved by empathy (Trobst et al., 1994), and the shared stress experience could facilitate empathic understanding. Third, the support interaction took place immediately after post-stress ratings. Unlike cortisol's delayed peak, healthy participants' subjective responses to stress tasks are short-lived (Kiecolt-Glaser et al., 2020). To provide relief from a negative state, social support was timed to occur before spontaneous recovery.

The non-support control interaction, where each participant was interviewed by a panel member, was designed to control for aspects of the support interaction such as face-to-face conversation about their experience. The panel members were instructed to communicate in a neutral manner but not to provide participants with feedback or reassurance. Several measures confirm the validity of the non-support interaction as a control condition. Heart rate returned to baseline levels, consistent with absence of acute stress, and participants reported feeling substantially better compared to after stress induction.

The DSST stress induction yielded increases in negative affect and heart rate acceleration comparable with previous studies using the TSST in single participants, e.g. (Lupis et al., 2014). Heart rate increases were somewhat larger under active versus passive (listening to one's friend) participation in the DSST stress induction. Contrary to the initial hypothesis, we did not find evidence of an effect of either DSST stress or recovery condition on heart rate variability. The increases in Negative affect and Stress activation that we observed in response to the dyadic stress induction were short-lived, indicative of adaptive stress responses, which are flexible and quickly habituate to repeated stressors (Kiecolt-Glaser et al., 2020). Increased cortisol levels were detected in both groups after subjective stress responses had recovered, illustrating how cortisol diverges from feelings of stress in its temporal profile. In contrast to affective and heart rate responses to a stress induction, which start at the instructions and resolve quickly, cortisol peak after TSST is estimated at approximately 40 min after TSST onset (Goodman et al., 2017). Many studies treat cortisol as a measure of stress, despite a well-documented lack of correspondence between cortisol release and the subjective experience of stress (Allen et al., 2017). Elevated cortisol has been associated with increases in negative feelings, but also with a protective effect and reduced negative affect (Admon et al., 2017; Het et al., 2012). The current pilot study was not optimized to check for potential effects of social support on recovery of stress-induced cortisol increases.

The social support interaction during DSST Recovery efficiently countered the stress-induced shift in affect, and robustly increased positive mood. This could indicate that positive mood induction might be a central route through which social support contributes to stress recovery. Social support during stress recovery did however not buffer responses to subsequent stressors during the downstream test phase. It is possible that a longer support interaction could lead to longer lasting positive affect. In this pilot study, we opted for a 5-minute support interaction to capture the effects of social support before participants in the control condition would have time for full spontaneous recovery. The question of “support dose” in relation to stress severity would however be an interesting one to explore in future studies. Moreover, since the control condition included interaction with a panel member, we cannot exclude the possibility that the efficient stress recovery observed in the social support condition could be comparable to recovery alone, e.g. during rest.

The DSST paradigm can be used to study several aspects of stress and support responses. Here, we focused on subjective responses to the stress and support interactions, and optimised design and timing of self-report questionnaires to capture dynamic changes in subjective state and mood. The factor analysis yielded four factors of high theoretical validity: positive and negative affect, stress activation and tiredness. Changes in positive and negative affect were mirrored by ratings of feeling globally ‘better’ or ‘worse’ after DSST Stress and Recovery, as assessed via our StateChange questionnaire. We included this measure to accommodate the study of a series of events with a dynamically changing affective ‘baseline’. By asking simply how much better and how much worse the participants felt, we could record their snapshot assessments of how they felt they were affected by each experimental task.

A benefit of the DSST design is its emphasis on facilitating efficient and ecologically valid data collection. A dyadic setup allows shared stress experiences and subsequent social interactions where support can occur spontaneously, all while producing two data sets per session. We included pairs of friends to enable a broader selection of participants than testing romantic couples. Handholding with a friend or partner may yield comparable benefits on stress regulation (Coan et al., 2017). Same-sex dyads also avoids potential effects related to interacting with members of the opposite sex, e.g. (Kirschbaum et al., 1995). The setup is suitable to investigate stress and support within different types of dyads and population groups, including divergent effects of dyadic stress and support in patient groups with maladaptive and prolonged stress responses, as well as conditions where reduced ability to benefit from immediate social support is expected.

4.1. Limitations

The free-form social support that is central to the DSST design increases ecologically validity of the social support also comes with some inherent limitations. By allowing the interaction between participants in the social support condition to be natural and spontaneous, without any prior instructions, we introduce a potential for considerable variability in both content and quality of the interaction. This contrasts with the non-support condition, where the interaction between experimenter and participant is more like a standardized interview. Recruiting friends that trust each other and have a long-lasting and supportive relationship should increase the possibility for the interaction to be naturally supportive, as in the current protocol. Studies that wish to employ the DSST to investigate effects of support provided by a stranger should look into providing simple instructions to participants explicitly encouraging them to be supportive towards the dyad partner. Another limitation of the current protocol is the timing of the cortisol samples, which lacks the detail needed to assess the impact of social support on the cortisol recovery curve. Future studies should include cortisol measures after stress but before social support, as well as additional time points after support interactions.

5. Conclusion

In sum, we present initial validation data for a Dyadic Stress and Support Task (DSST) that enables the study of shared stress and ecologically valid social support in the laboratory. The DSST setup is suited to investigate different aspects of post-stress social interactions and their effect on stress recovery. The DSST set-up could be used to investigate how sharing a stressful experience can modulate stress responses; whether it matters who you share it with; and the affiliative consequences of a shared stress experience. One could contrast the effects of social support from a friend with social support from a stranger, or with a classic TSST setup where participants undergo stress alone, to investigate effects of a shared stress experience for instance on social bonding. We hope the DSST can be used to further our knowledge about how social support buffers and alleviates stress, including the causal mechanisms involved.

CRediT authorship contribution statement

Guro Engvig Løseth: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization. **Marie Eikemo**: Conceptualization, Writing – reviewing and editing, Funding acquisition. **Martin Trøstheim**: Formal analysis, Visualization, Writing – original draft (heart rate data). **Isabell M. Meier**: Methodology, Writing – review & editing. **Herman Bjørnstad**: Investigation, Writing – review & editing. **Anna Asratian**: Formal analysis, Writing – review & editing. **Claudia Pazmandi**: Software, Investigation, Project administration, Writing – review & editing. **Vegard Wathne Tangen**: Investigation, Writing – review & editing. **Markus Heilig**: Resources, Writing – review & editing. **Siri Leknes**: Conceptualization, Methodology, Supervision, Writing – review & editing.

Statements and declarations

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.psyneuen.2022.105949.

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