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Research Paper

Psychophysiological assessment of trauma-focused Group Music and Imagery therapy for women with PTSD or CPTSD using script-driven imagery. A randomised controlled study.

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ABSTRACT

Background: In posttraumatic stress disorder (PTSD), physiological reactions during trauma scripts have been anchored to the diagnosis. According to the construct of research domain criteria, physiological reactions and self-rating scales could be used to evaluate treatment effects.
Objective: In the present study, self-rated PTSD symptoms combined with physiological reactions during trauma script were used as outcome measurements in the domain of arousal/regulatory systems in a controlled randomised study of Group Music and Imagery (GrpMI) treatment for females with PTSD or complex posttraumatic stress disorder (CPTSD) related to violence and/or sexual abuse.
Methods: 45 traumatised women were randomised to 12 weeks of active treatment or waiting. Before and after the intervention, an assessment was done using physiological measurements during script-driven imagery (SDI) procedures. Subjective Units of Distress (SUD) were collected immediately after the trauma script (TS). Reactions during the SDI procedure were reported using the Responses to Script Driven Imagery (RSDI) scale, measuring re-experiencing, avoidance, and dissociation. Self-reported PTSD symptoms were accessed using the PTSD checklist for DSM-5 (PCL-5). Heart rate (HR), heart rate variability (HRV), and electrodermal activity were sampled during the baseline (BL) and TS conditions of the SDI procedure. As a measure of trauma-related reactivity, the difference between TS and BL was used for statistical calculations. HRV measures included high (HF; 0.15-0.4 Hz) and low (LF; 0.03-0.15 Hz) frequency band power, the LF/HF ratio, and the root mean square of successive inter-beat differences (RMSSD). Measures of electrodermal activity included skin conductance levels (SCL) and frequencies of non-specific skin conductance responses (NS-SCR). Further, correlations between self-rated PTSD symptoms and physiological reactivity measures were analysed.
Results: During the TS, the absolute levels of HR, LF/HF-ratio, and NS-SCR, as well as the trauma-related reactivity of HR, RMSSD, HF, LF/HF-ratio, SCL, and NS-SCR, showed significant changes indicating decreased arousal during trauma script after treatment. Compared to the waitlist control, an interaction analysis showed significant treatment effects in the BL level of HR, the absolute TS level of HR and HF, and the trauma-related reactivity of RMSSD and HF, suggesting an improvement of vagal function in the treatment group. Significant treatment-related reductions were found in symptoms of PTSD, re-experiencing and avoidance, as well as SUD. The changes pre- to post-treatment in HR reactivity and self-rated PTSD symptoms correlated significantly. Furthermore, the initial HR reactivity predicted treatment outcome as measured with PCL-5.
Conclusion: In the evaluation of treatment methods for PTSD, a combination of self-report and physiological measures seems to be feasible. The physiological measures, in combination with a robust decrease in self-rated PTSD symptoms, indicate that trauma-focused GrpMI is a promising treatment for PTSD or CPTSD. More studies are needed to confirm the results, and further research comparing with other active treatments is necessary to establish the precise role of the treatment.

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1. Introduction

Posttraumatic stress disorder (PTSD) is often caused by interpersonal violence, war, or disaster. Hallmark symptoms of PTSD are re-experiencing, active avoidance, and hyper-reactivity (World Health Organization, 2018). In the case of prolonged traumatisation, complex posttraumatic stress disorder (CPTSD) can develop. Apart from the core symptoms of PTSD, CPTSD involves permanent changes in self-organisation, manifesting in negative self-concepts, dysregulation of affects, and interpersonal problems. These difficulties cause significant impairment in daily life (World Health Organization, 2018).

PTSD is most often treated individually, and the predominant treatment models, e.g., trauma-focused cognitive behavioural therapy (CBT) and eye movement desensitisation and reprocessing (EMDR), are based on exposure to the core traumatic experiences (American Psychological Association, 2017; Bisson et al., 2013; Forbes, 2020; U.S. Department of Veteran Affairs, Department of Defense, 2017; Watkins et al., 2018). Group treatment is less often used for PTSD. Still, according to a recent meta-analysis that includes several randomised controlled studies where active treatment has been compared with waitlist or routine treatment, it is a viable alternative (Schwartze et al., 2019). Another branch of methods, less researched, is arts-based psychotherapies such as expressive art therapy, music therapy, and dance therapy. Group Music and Imagery (GrpMI) is an internationally acknowledged receptive music therapy technique, where listening in a relaxed state to carefully selected music pieces is used for spontaneous inner imagery, which is then further processed by drawing and verbal communication (Bonny & Summer, 2002; Bruscia & Grocke, 2002; Grocke, 2019; Jerling & Heyns, 2020; McKinney & Honig, 2017). This article presents results from a randomised controlled study on traumatised women suffering from PTSD or CPTSD, investigating GrpMI treatment effects. As reported elsewhere, the 12-week program of GrpMI resulted in a significant decrease in self-rated PTSD symptoms with a large effect size compared to a waitlist control group (Rudstam et al., 2022). In the present paper, physiological measures of treatment-related changes are examined.

Measurement of treatment outcomes is routinely done by the "gold standard" Clinician Assessment of PTSD (CAPS; Weathers et al., 2018). In controlled studies, it is often assumed that the assessment can be carried out blinded, i.e., the clinician assessing the symptom load is unaware of which group the subjects are randomised into. However, it might be difficult to arrange a completely blind assessment and for the clients to effectively hide the control condition from the assessor. Thus, a truly double-blind study is therefore challenging to achieve in psychological treatment, especially as a trustworthy placebo might be difficult to establish, given the possibility of assessor bias. An alternative might be to include psychophysiological measures that can provide an objective assessment of arousal and emotional reactivity, which, combined with the self-rating scales, may reduce the risk of observer bias (Bauer et al., 2013; Wangelin & Tuerk, 2015). Furthermore, recent studies indicate that psychophysiological measures can give complementary data, not captured in the subjective ratings, that can provide important information regarding the choice of treatment and predict or measure treatment outcomes (Acheson et al., 2014; Maples-Keller et al., 2017, 2019; van Rooij et al., 2016). The use of physiological markers, together with self-report data, in evaluating the treatment effect on PTSD symptoms is also encouraged by The US National Institute of Mental Health's (NIMH) Research Domain Criteria (RDoC) framework (Acheson et al., 2014).

Physiological measurements in PTSD research are often assessed in terms of reactivity and recovery to neutral stressors (such as math stress or public speaking) or trauma-related stimuli. The trauma-related stimuli could either be generic (e.g., war sounds or images) or individualised (for example, scripts based on self-experienced traumatic events). Another physiological research approach examines reactivity, recovery, and habituation to startle stimuli (reactions to sudden and unexpected stimuli).

Psychophysiological measurements have for a long time proven effective in distinguishing individuals with and without PTSD (Acheson et al., 2014; Bauer et al., 2013; Orr et al., 1998, 1998; Orr & Roth, 2000; Pineles et al., 2013; Pitman et al., 1987, 1990; Pole, 2007). Pitman et al. (1987) did pioneer work using a script-driven imagery (SDI) method in this area. They found that physiological variables (heart rate (HR), skin conductance (SC), and electromyogram (EMG)), measured during individualised trauma script (TS) differentiated between veterans with and without PTSD in a multivariate analysis, where the trauma exposure was similar in both groups. Differences between PTSD and non-PTSD have also been found in physiological resting baseline levels. For example, several studies have reported an increased resting heart rate (HR) of approximately five beats per minute in PTSD groups compared to non-PTSD controls (Buckley & Kaloupek, 2001; Rabe et al., 2006). Furthermore, in recent meta-analyses comparing resting heart rate variability (HRV) in subjects with and without PTSD, a reduced HRV was found in subjects with PTSD relative to healthy controls (Ge et al., 2020; Schneider & Schwerdtfeger, 2020).

Because the physiological reactions to TS are stable, reliable, and show a good discriminant function, they have been suggested as methods for evaluating PTSD treatments (Orr & Roth, 2000) and more recently as RDoC for PTSD (Acheson et al., 2014; Bauer et al., 2013; Pineles et al., 2013). Only a few studies, however, have used physiological measures as a complementary method to evaluate PTSD treatment. Pitman et al. (1996) evaluated the effect of imaginal flooding on veterans with PTSD. A reduction in intrusive recollections of traumatic events between the first and the last treatment session was associated with greater HR reactivity in the first session. Lindauer et al. (2006) showed that successful psychotherapy normalized the HR response to trauma-related imagery and that the reduction in HR reactivity correlated positively with changes in clinical PTSD symptoms in civilian outpatients with PTSD. A heightened physiological reactivity was found in the individualised trauma script but not in the neutral and generally stressful script. Wangelin and Tuerk (2015) examined HR and SC during three assessment points using SDI to evaluate the effect of prolonged exposure (PE) combined with the presynaptic alpha-2 adrenergic receptor antagonist yohimbine. They found that HR and SC reactivity to trauma imagery decreased after treatment and that higher HR reactivity to trauma imagery at baseline predicted better treatment results. The same method was used in a controlled pilot study comparing either yohimbine or placebo in combination with PE (Tuerk et al., 2018). Yohimbine combined with PE led to lower trauma-cued HR reactivity one week later. The authors found an improvement regarding depression but no improvement in the long-term outcome of PTSD. Soder (2019) discovered that higher high-frequency HRV (HF-HRV) at baseline could predict a better outcome of PTSD treatment in a sample with PTSD and co-occurring substance abuse. They proposed that since subjects with low HF-HRV had poorer autonomic nervous system (ANS) regulation and, therefore, less capacity to tolerate emotions, they would be less responsive to psychotherapy. Maples-Keller et al. (2019) treated subjects with an intensive period of prolonged exposure and measured HR, SC reactivity, and startle reactions to acoustic white noise bursts during virtual reality trauma-relevant scenes. Highly treatment-responding participants had lower trauma-related startle reactions after treatment than low responders. Also, HR reactivity, but not SC reactivity, showed a significant main effect of treatment. Katz et al. (2020) explored whether arousal measured by SC responded to treatment by comparing PE, virtual reality (VRE), and waitlist control. They used the Clinician-Administered PTSD Scale (CAPS), self-rating scales, and a 15-minute physiological stress test with idiographic trauma cues (recalling the index trauma). The result showed that the physiological reactivity was reduced in all groups but most evident in the VRE group, and changes in the reactivity correlated modestly with changes in anxiety and PTSD symptoms. Griffin et al. (2012) studied women with rape or assault experiences. Physiological responses to loud auditory tones were measured before and after trauma-focused CBT, and treatment

responders were compared with nontreatment responders. The EMG, HR, and SC startle responses showed significant reductions in the treatment responders but not in the non-responders.

The present study uses an SDI method with psychophysiological outcome measures to evaluate an arts-based psychotherapy intervention, trauma-focused GrpMI (TFGrpMI), for females exposed to physical/psychological and/or sexual abuse as adults, often in combination with previous childhood trauma. Physiological reactions during trauma-related SDI have proven to be robust and stable measures for assessing PTSD and have been proposed as research domain criteria (Bauer et al., 2013). However, few studies use this method to evaluate treatment effects. The physiological measures used in this study are known to reflect the reactivity of the autonomic nervous system. They are chosen because they are relatively easy to obtain in a clinical setting and have also frequently been used in previous PTSD studies. As a reflection of sweating, SC is controlled solely by the sympathetic nervous system and is an often-used indication of arousal (Boucsein et al., 2012). The tonic HR levels and the phasic fluctuations in heart rate (i.e., HRV) are controlled by both the sympathetic and the parasympathetic branches of the ANS (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Since HF-HRV is mediated by the vagal nerve (predominantly through the myelinated fibres of the ventral branch), it is often used as a measure of parasympathetic activity (Porges, 2011; Shaffer & Ginsberg, 2017). A low HRV is associated with stress and health problems (Porges, 2001; Thayer & Lane, 2007) and has been found in PTSD (Ge et al., 2020). An increased HF-HRV is thought to promote self-regulation and the social engagement system (Petrocchi & Cheli, 2019; Porges, 2003, 2011; Whitehouse & Heller, 2008), which makes it potentially interesting as a measure of treatment outcome, especially in the context of CPTSD in which dysregulated self-organisation is a hallmark symptom (Cloitre, 2021; Knefel et al., 2015; Maercker, 2021).

The present study is part two of a randomised controlled study of a phase-oriented arts-based group therapy intervention, TFGrpMI, for PTSD or CPTSD in women traumatised in relationships and/or their childhood. In part one, we showed that self-reported PTSD symptoms decreased significantly after the TFGrpMI treatment (Rudstam et al., 2022). This sub-study aims to use psychophysiological measures to complement self-rating instruments in assessing PTSD treatment results.

The main hypothesis regarding the physiological measurements of the study was that TFGrpMI treatment would result in altered ANS regulation (hypothesis 1), manifested as decreased HR and SC activation and reactivity, and increased HF-HRV during TS. Furthermore, we predicted that subjective experiences during TS, measured with the response to the script-driven imagery scale (RSDI) and the subjective units of distress scale (SUD), would change in a favourable direction after treatment, in parallel with changes in self-assessed PTSD symptoms (hypothesis 2). We also expected that the changes in psychophysiological reactivity would correlate with changes in self-reported PTSD symptoms (hypothesis 3) and that initial HR reactivity to the individualised trauma scripts would predict PTSD treatment outcomes (hypothesis 4).

2. Method

2.1. Ethical considerations

The Regional Ethical Review Board in Stockholm, Sweden (Registration number: 2015/895-31) approved this study, which is registered at the ClinicalTrials.gov trial registry (Registration number: NCT03503526). Informed written consents were obtained from all participants and are retained by the first author.

2.2. Trial design

This is a wait list-controlled, parallel-group design study conducted in Sweden with equal randomisation (1:1).

2.3. Participants

The study population and demographic data have been described in more detail elsewhere (see Rudstam et al., 2022). Briefly, participants were recruited from an outpatient clinic specialising in the treatment of psychological trauma and were diagnosed with PTSD by a clinician based on DSM-5 criteria (APA, 2013). Eligible participants were females aged 18 or over, referred for treatment of PTSD/CPTSD, and interested in using artistic media for trauma processing. Exclusion criteria were severe dissociative/psychotic/personality/neuropsychiatric disorders, non-Swedish speaking, ongoing drug abuse, suicidality, severe medical condition, ongoing psychotherapeutic treatments, and inability to symbolise and share the imagery with the therapist or apparent reluctance to process through creative art forms. The ability to symbolise and process through music and imagery was tested in the assessment phase with a short music journey (see Rudstam et al., 2022). Females were targeted because the number of available male patients at the clinic was limited, and it was deemed necessary to keep the groups single-gendered as most of the women had been victimised by male perpetrators.

The target sample size was calculated a priori using G*Power software version 3.1.6 (Faul et al., 2009). Based on an effect size of 0.4 (Cohen's *f*), it was determined that 52 participants were required to detect pre-post within-group and between-group changes in the outcome variables for a statistical power of 0.80 and alpha = 0.05. However, the target sample size was not possible to achieve (for details, see Rudstam et al., 2022), and in the end, 45 female participants were enrolled in the study.

Patients with a background of interpersonal violence, sexual abuse, and predominantly previous childhood trauma were matched pairwise based on scoring on the PTSD Checklist (PCL-5) and age and then randomly selected to wait-list-control (WLC, $n = 23$) or active treatment (T, $n = 22$) by a blinded administrative co-worker within the pair (Fig. 1). Their mean age was 43.7 years ($SD = 9.93$; T: $M = 45.2$ years, $SD = 10.7$; WLC: $M = 42.2$, $SD = 9.10$; $t(44) = 1.02$, $p = 0.320$, Cohen's $d = 0.302$). All participants completed the protocol described below, except for one individual in the T-group who left the study due to somatic illness, yielding a final participation count of 44 subjects. Forty-seven per cent of the participants used antidepressants (10 individuals in the T-group and 11 in the waiting condition), and other stable medications were rare. Medication was kept constant during the study. Participants using medications that influenced the cardiovascular system were not allowed in the study. The pretest analysis showed that the groups were equal in demographic data (Rudstam et al., 2022).

2.4. Procedure

The intervention for the participants in the treatment arm consisted of twelve weekly 2.5 hours of TFGrpMI-therapy sessions and is described in Rudstam et al. (2017, 2022). In brief, the music pieces used in the sessions were mainly Western classical music, folk music or film music, and were chosen by the therapists according to different intensity profiles (calming or stimulating) to adapt to the treatment phases and the group's needs. In the first phase, predominantly slow, predictable, and melodic music was used to stabilise and build safety. During the trauma processing, more challenging and complex music with higher intensity levels and tempo was used to mirror the participants' imagery (for more detail, see Rudstam et al., 2022).

Treatment groups consisted of five to seven individuals. The control subjects were on a waitlist for a corresponding time (three months) and were also offered TFGrpMI treatment immediately after the wait-list period.

Before and after the intervention, the participants filled in self-rating scales (see Rudstam et al., 2022), and psychophysiological measures were obtained using a script-driven imagery procedure.

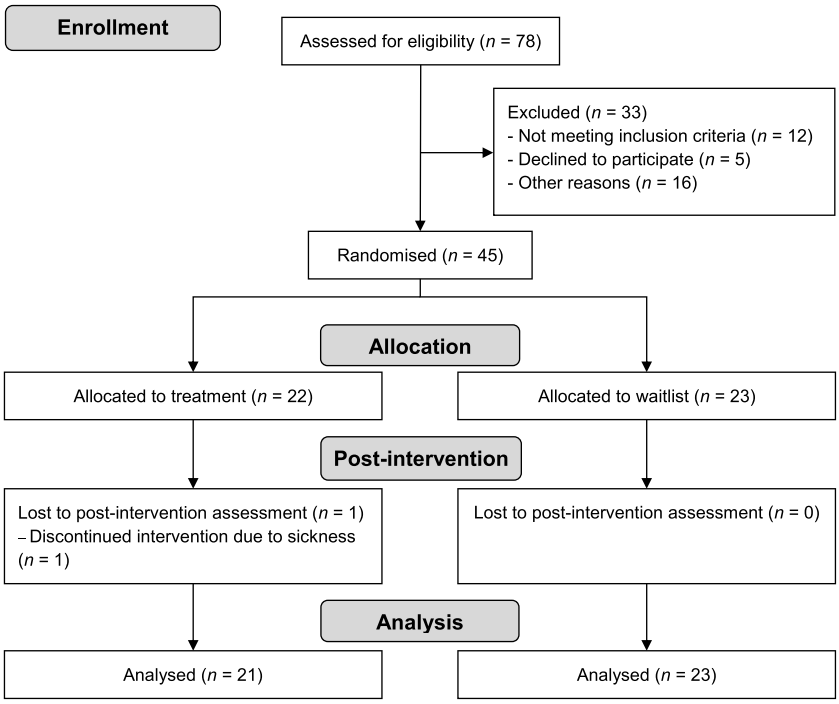

Fig. 1. Recruitment and retention flow diagram of the enrollment, intervention allocation, post-intervention assessment, and data analysis phases of the randomised controlled trial.

2.5. Script-Driven Imagery Procedure

In the standard script-driven imagery procedure for PTSD, introduced by Pitman et al. (1987), a 30-second script period was used, followed by a 30-second imagery period. This study implements an adaption of the modified protocol according to Sack, Hopper, and Lamprecht (2004) with 2-minute script lengths and without a subsequent imagery period. In addition, a personalised script of a peaceful place/memory was used.

The participants were instructed to write down two memories – one peaceful and one traumatic. A subjective distress level (SUD score) of at least seven was required for a traumatic memory to be adequate. Similarly, a SUD score of three was the maximum allowable score for a peaceful memory. The participant was asked to write in the first person and present tense, incorporating feelings and bodily sensations in their texts. To facilitate this, they were given a list with a vocabulary of bodily sensations (such as trembling, soft, sticky, hard, tense, fluid, cold, warm, or lumpy) and emotions that humans can feel during different situations (Castro-Chapman et al., 2018; Levine, 1997). Two scripts, one peaceful and one traumatic, of two minutes each, were then prepared by the first author using the wordings of the participant as a template. The participants verified the authenticity of the scripts before they were finalised.

The physiological measurement was carried out in the therapy room approximately one week after the scripts were prepared. After completing the self-rating scales, the participants were invited into the therapy room and seated in a comfortable chair, asked not to talk and to avoid movements during the recording. The first author conducted the measurement and read the two scripts aloud during the test.

After placement of the electrodes on the participants' fingers and body, the script-driven imagery task followed using a fixed order: 5 min. relaxation baseline (BL) – 2 min. peaceful place script (PP1) – 3 min. break preceding the trauma script (PreTS) – 2 min. trauma script (TS) – 3 min. break following the trauma script (PostTS) – 2 min. peaceful place script (PP2) – 3 min. break following the peaceful place (PostPP2). Immediately after the trauma script, the participants were asked to report a SUD value.

Following the psychophysiological recording, the participants completed the RSDI scale (Hopper et al., 2007), assessing symptoms of re-experiencing, avoidance, and dissociation evoked during the trauma script. The RSDI scale was administered in the presence of the first author to allow participants to ask for clarifications.

2.6. Measures

2.6.1. Self-rating instruments

As detailed in Rudstam et al. (2022), self-rating instruments were administered pre-and post-intervention. In the present paper, the following scales are used:

The PTSD Checklist for DSM-5 (PCL-5) self-report questionnaire (Weathers et al., 2013) measures PTSD symptoms. The instrument has 20 items, with a rating scale of 0-4 for each symptom (0 = not at all, 1 = a little bit, 2 = moderately, 3 = quite a bit, 4 = extremely). Cut-off scores of 33 and 38 have been suggested for PTSD detection, depending on factors such as population and trauma type (Bovin et al., 2016; Geier et al., 2019; Weathers et al., 2013).

The Response to Script-Driven Imagery Scale (RSDI) is a self-reported 7-point Likert scale (ranging from 0 = Not at all to 6 = A great deal). The RSDI scale has 11 items and measures re-experiencing, avoidance, and dissociation. The scale is developed to assess the experiences aroused by listening to the trauma script (Hopper et al., 2007). The English version of RSDI was translated into Swedish by the first author and translated back to English by the third author. The second author evaluated the back-translated English version and found it to match the original version's wording and meaning (Sack et al., 2012). The RSDI scale three-factor solution has been strongly supported by confirmatory factor analyses showing a good model fit (Hopper et al., 2007; Sack et al., 2012).

The Subjective Units of Distress Scale (SUDS) measures the intensity of distress (Wolpe, 1958, 1969). The subjects are asked to rate their distress level on a Likert scale ranging from 0 = No distress to 10 = highest possible distress (Shapiro, 1995; Tanner, 2012).

2.6.2. Physiological measures

During the individual's SDI procedure, heart rate (HR), skin

conductance (SC), finger temperature (FT), forearm electromyography (EMG), and respiration (RESP) were recorded. However, only the measures related to HR and SC were processed, analysed and reported, leaving the measures of FT, EMG, and RESP to be analysed at a later occasion.

The tonic HR is determined by both the parasympathetic and the sympathetic branches of the ANS and has frequently been used as a measure of arousal and anxiety in PTSD research (Pole, 2007).

Autonomic balance can be assessed by analysing the heart rate variability (HRV) in the frequency and time domains, and low variability has been used as a marker for pathology in various conditions (Ge et al., 2020). In the present study, high frequency (HF) activity is defined as power in the 0.15-0.4 Hz spectrum, and low frequency (LF) as the activity in the 0.04-0.15 Hz spectrum. HF and its time-domain counterpart root mean square of successive inter-beat differences (RMSSD) reflect parasympathetic activity, while LF reflects both sympathetic and parasympathetic activity (Shaffer & Ginsberg, 2017; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The LF/HF ratio is commonly used as an index of the balance between the parasympathetic and sympathetic systems (Shaffer & Ginsberg, 2017).

The tonic level of electrical conductivity of skin (Skin Conductance level, SCL) and the frequency of phasic changes in electrical conductivity of skin that occur in the absence of eliciting stimuli (non-specific skin conductance responses, NS-SCR) are both commonly used indicators of arousal and are sympathetically regulated (Kirsch et al., 2015). SCL is affected both by sympathetic innervation and other individual structural differences unrelated to sympathetic activity, such as the density of sweat glands. In contrast, NS-SCR frequency solely depends on sympathetic innervation (Kirsch et al., 2015). The frequency of NS-SCR has also been described as a sensitive index of both positive and negative emotional reactivity (Cacioppo et al., 2017).

2.7. Physiological Assessment

All physiological signals were recorded using the NeXus-10 MKII system with the Biotrace software version 2013A (Mind Media B.V., the Netherlands).

2.7.1. Cardiovascular measures

HR was derived from the blood volume pulse recorded by photoplethysmography at 128 samples/sec., with the sensor placed on the right index finger. Studies have found the photoplethysmographic method of measuring pulse rate variability to have sufficient accuracy for estimating HRV in physically healthy subjects (Elgendi et al., 2016; Lu et al., 2009; Schäfer & Vagedes, 2013). The recorded time series were visually inspected for ectopic beats and movement artefacts. For each session, the inter-beat intervals (IBI) were exported to a separate text file and later used to analyse HRV measures automatically with the Kubios HRV Standard software version 3.4.2. (University of Kuopio, Finland). Before the analysis, IBI series were further corrected for artefacts using a built-in threshold-based correction method that compares every IBI value against a local average interval and corrects them by cubic spline interpolation if they differ more than a specified threshold value. A threshold level between 0.25 and 0.45 sec was selected based on an acceptable level of $< 5\%$ corrected beats over the entire time series. No data had to be discarded based on this rule. The IBI time series were resampled at 4 Hz and detrended using "the smoothing priors" method built into the Kubios software (Tarvainen et al., 2002), with a lambda parameter of 500.

For every 2-min condition, a fast Fourier transform (FFT) spectrum was calculated using Welch's periodogram method with a 60-second window and a 50% overlap. The total power spectra (<= 0.40 Hz) were computed and then further decomposed into low-frequency (LF; 0.04-0.15 Hz) and high-frequency (HF; 0.15-0.40 Hz) components following the guidelines (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996), and the LF/HF ratios were calculated. Also, RMSSD was computed as a time-domain measure of HRV.

2.7.2. Electrodermal activity measures

Two Ag-AgCl Velcro strap snap-on electrodes were attached to the palm side of the middle phalanges of the index finger and ring finger of the non-dominant hand. The sensor was designed to measure 1/1000 micro-siemens (μS) changes in sweat activity, and the SC signal was sampled at 32 samples per second. The NS-SCR was derived from the SC signal by first detrending the SCL curve by applying a 0.05 Hz infinite impulse response (IIR) digital high pass Butterworth filter (4^{th} order) and then detecting peaks using a 0.03 μS threshold.

2.8. Data reduction and analyses

Physiological recordings were checked visually for movement artefacts and ectopic heartbeats. As a predetermined rule, the recording of any condition would be discarded if artefacts constituted more than eight per cent of the 2-minute timespan. However, no data had to be rejected based on this rule. For the analyses of HR-derived measures, two individuals were excluded from the WLC group, one due to ectopic beats and one because of accidental medication with a prescribed beta-blocker.

HR and SCL data were down-sampled to 32 Hz. For each condition (baseline, peaceful place script, and trauma scripts) and assessment time point (pre- and post-intervention), mean HR and SCL levels and frequency and time domain measures of HRV were calculated. NS-SCR was obtained as the total count of SC peaks during 2 minutes of each condition. As indexes of trauma-specific reactivity, differences between baseline and trauma conditions in mean HR, mean SCL, NS-SCR, RMSSD, LF, HF, HRV total power, and the LF/HF ratio were calculated.

All analyses were performed using the IBM Statistical Package of the Social Sciences (SPSS), version 25 (IBM Corp., 2017), or R Statistical Software version 3.6.2. (R Core Team, 2019).

To use parametric methods, histograms and analyses for skewness and kurtosis were applied to evaluate the normality of distribution. If the assumption of normality was violated, data were log-transformed. Data points located three times the interquartile range above or below the outer fences of the range were considered extreme outliers and subsequently removed. Due to this rule, one WLC subject was excluded from the HF and one from the LF analyses. For the measurements of NS-SCR, the normality assumption was still violated, and nonparametric methods were used instead.

In order to test the ability of the set-up to detect trauma script-related reactivity, analyses of mean HR, SCL levels, and NS-SCR counts during the different conditions of the pre-intervention script were performed using either one-way repeated measures ANOVA, or in the case of NS-SCR, a nonparametric test using the nparLD R package (Noguchi et al., 2012) (Fig. 2). The main effects were followed up using either pairwise comparisons based on t-statistics or Wilcoxon rank sum test, with Sidak p-value adjustment.

A linear mixed effect model (LME) was used to analyse the effects of treatment and control conditions on levels of HR, SCL, and the different HRV measures, as well as on PCL-5 scoring. Time, intervention, and the time by intervention interaction were modelled as fixed effects fitted with maximum likelihood estimation using an unstructured covariance matrix. Separate one-way analyses were done to explore within-group effects further.

Due to non-normal distribution, the NS-SCR frequency and the subjective RSDI and SUD ratings were analysed using the nparLD R package to calculate nonparametric ANOVA-type statistics.

Further, the relative differences (reactivity) between trauma script and baseline levels of HR, SCL, and HRV measures were analysed using LME with baseline as a time-varying covariate modelled as a fixed effect. For NS-SCR reactivity, ANOVA-type statistics were computed based on

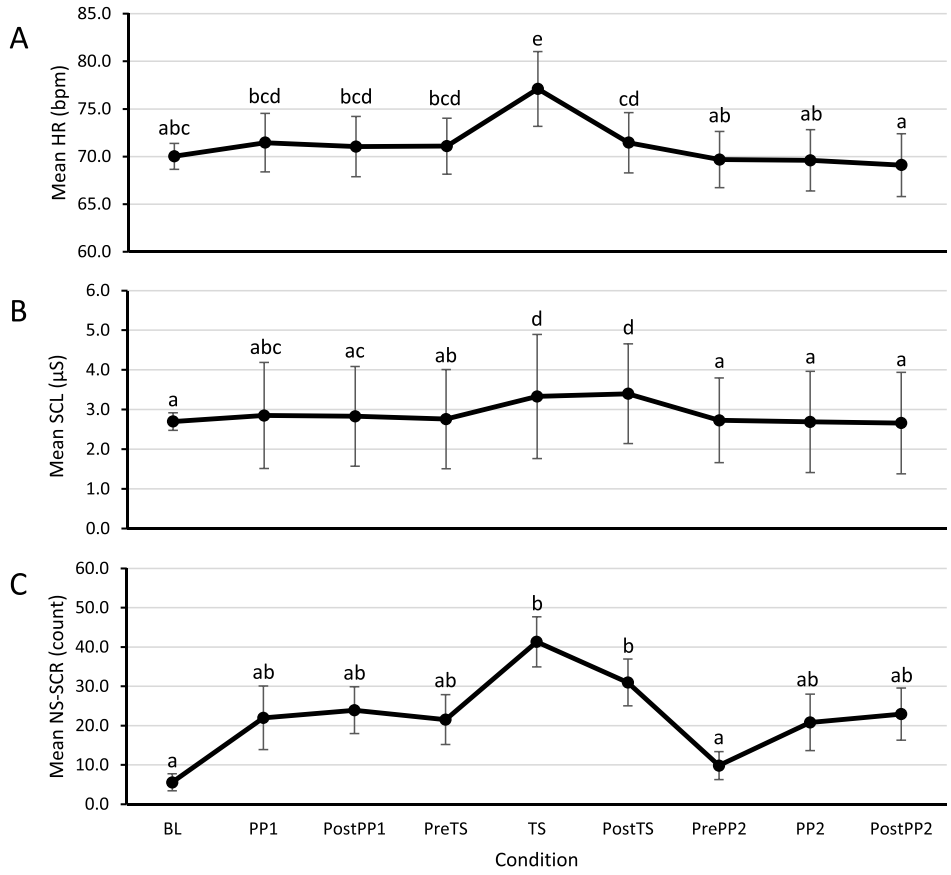

Fig. 2. Mean values and standard errors for heart rate (A), skin conductance level (B), and non-specific skin conductance reactivity (C) measurements for each condition during the first physiological assessment of the script-driven imagery procedure. Mean values not sharing any letter are significantly different at $p = 0.05$, as assessed by Sidak-adjusted pairwise comparisons. HR = Heart rate, SCL = Skin conductance level, NS-SCR = Non-specific skin conductance reactivity, BL = Baseline, PP1 = Peaceful place, first time, TS = Trauma script, PP2 = Peaceful place, second time.

Table 1
Script-driven imagery procedure baseline (BL) condition values of physiological measures pre- and post-intervention (treatment or waitlist). Values reported are means and standard deviation, and test statistics from the analysis of within-subjects and interaction effects using linear mixed effects model repeated measures ANOVA or a nonparametric ANOVA-type method.

Measure	*n*	Pre	Post	Within				Time x Intervention			
		BL	BL	*df*	*F*	*p*	η^2	*df*	*F*	*p*	η^2
HR (bpm)											
T	21	71.70 (8.53)	70.71 (10.30)	21	0.87	.362	0.040	42	4.63	.037*	0.099
WLC	21	68.36 (9.58)	71.62 (10.44)	21	4.02	.058	0.161				
RMSSD (ms)											
T	21	106.71 (54.39)	98.43 (70.26)	21	1.24	.278	0.056	42	<0.01	.969	0.000
WLC	21	119.27 (62.03)	108.45 (57.79)	21	1.16	.293	0.052				
Total power (ms^2)											
T	21	1249.35 (1135.74)	1316.89 (1493.19)	21	1.67	.211	0.074	42	<0.01	.976	0.000
WLC	21	1959.26 (2389.27)	1442 (1531.73)	21	1.02	.314	0.046				
LF (ms^2)											
T	21	606.42 (680.42)	525.11 (610.71)	21	3.49	.076	0.143	41	<0.01	.944	0.000
WLC	20	1092.77 (1399.9)	732.33 (952.55)	20	1.25	.278	0.059				
HF (ms^2)											
T	21	580.79 (565.56)	745.88 (991.13)	21	0.12	.736	0.006	41	0.11	.745	0.003
WLC	20	879.12 (1140.67)	727.72 (744.7)	20	0.69	.417	0.033				
LF/HF											
T	21	1.52 (1.24)	1.15 (1.37)	21	1.50	.234	0.067	42	<0.01	.946	0.000
WLC	21	1.69 (1.60)	1.33 (1.30)	21	1.22	.281	0.055				
SCL (µS)											
T	21	2.93 (1.63)	2.90 (1.52)	21	<0.01	.939	0.000	44	0.14	.710	0.003
WLC	23	2.50 (1.31)	2.81 (2.02)	23	0.23	.635	0.010				
NS-SCR (count)											
T	21	4.14 (14.65)	13.00 (33.18)	20	0.04	.850	0.002	40.03	0.61	.436	0.015
WLC	23	6.87 (14.65)	16.26 (31.93)	22	1.71	.191	0.072				

Note. For NS-SCR, *F* represents the value of the nonparametric analyses of variance-type test statistic.

differences between TS and BL counts.

Approximative effect sizes, expressed in partial eta squared (η^2), were calculated from *F* statistics and degrees of freedom according to a method described by Friedman (1982) with the use of the R package "effectsize" version 0.6.0.3 by Ben-Shachar et al. (2020).

Relationships between changes in self-assessed PTSD symptoms, as measured with PCL-5, and changes in physiological reactivity measures were tested using Pearson's correlation analyses (two-tailed).

As only pre-planned hypotheses were examined, without data-driven post-hoc tests, and there was a heightened risk of Type II errors (false negatives) due to a limited sample size, no adjustment for multiple comparisons was made despite the increased risk of Type I errors (false positives).

3. Results

An initial evaluation of the efficiency of the method to evoke physiological trauma-related responses was carried out by comparing the different conditions of the first pre-intervention SDI procedure (Fig. 2). Statistical analyses showed the effects of condition on HR ($F[8] = 34.09$), SCL ($F[8] = 16.00$), and NS-SCR ($F[8] = 11.82$), all significant at $p < .001$.

Post-hoc tests (using Sidak adjustments) showed a significant difference between the trauma epoch (TS) and all other conditions for HR. SCL and NS-SCR also showed significantly elevated values during TS, an increase that, in these cases, persisted into the following post-TS condition.

Table 1 shows measurements during the BL condition of the SDI procedure before and after intervention (treatment or waiting). A significant interaction effect was found for HR at baseline ($F[1,42] = 4.63$, $p = .037$). No other significant differences were found, although the treatment group showed a tendency toward decreased HR at BL after treatment and WLC an increased HR at BL after the waiting period.

Measurements during the trauma script before and after intervention are summarised in Table 2. HR was reduced in the treatment group ($F[21] = 7.63$, $p = .012$) and a significant interaction effect was seen ($F[1,42] = 4.25$, $p = .046$). The derived frequency domain measures for HRV showed a nonsignificant increase of HF in the treatment group with a significant interaction effect ($F[1,41] = 4.74$, $p = .038$). A tendency for decreased LF was seen in the treatment group. The intervention group's LF/HF ratio was significantly reduced ($F[21] = 12.30$, $p = .002$). RMSSD did not change significantly.

In the treatment group, the number of NS-SCR peaks was strongly reduced ($F[20] = 4.12$, $p = .042$), and SCL showed a tendency in the same direction ($F[21] = 4.03$, $p = .058$). However, no significant interaction effects were found for the SC measures.

The overall result showed a pattern of increased parasympathetic activity and decreased sympathetic activity during the trauma script in the treatment group but not in the waiting list control group.

Table 3 shows the trauma-specific reactivity expressed as the difference between TS and BL.

The difference in HR between TS and BL was reduced in both groups (T: $F[21.11] = 8.40$, $p = .009$; WLC: $F[20.28] = 12.72$, $p = .002$; no interaction). However, in the waitlist control group, the reduction was related to increased HR at BL, while HR during TS stayed approximately the same. In the treatment group, HR at both BL and TS decreased.

The reactivity of RMSSD diminished significantly in the treatment group ($F[20.78] = 5.94$, $p = .024$), with a significant interaction effect ($F[1, 39.52] = 4.90$, $p = .033$). For the treatment group, HF showed a similar pattern with significant within ($F[18.60] = 6.85$, $p = .017$) and interaction effects ($F[1, 38.27] = 6.71$, $p = .014$). Total power and LF reactivity showed no significant time-dependent changes, although both measures showed a tendency for a decrease in the T-group and an increase in the WLC condition. The shift in LF/HF ratio between BL and TS was significantly smaller after the intervention in the treatment group ($F[21.02] = 9.33$, $p = .006$) but not in the WLC (within group analysis). A medium between groups effect size ($\eta^2 = 0.069$) was noted, although not statistically significant.

For both electrodermal activity measures, the TS-reactivity was significantly lower in the T group after treatment than in the WLC group after the waiting period. For SCL, the analyses showed that the TS-reactivity was lower after treatment ($F[20.45] = 7.36$, $p = .013$), although there was no interaction effect. NS-SCR showed the same pattern with a significant within effect in the treatment group ($F[20] =$

Table 2
Script-driven imagery procedure trauma script (TS) condition values of physiological measures pre- and post-intervention (treatment or waitlist). Values reported are means and standard deviation, and test statistics from the analysis of within-subjects and interaction effects using linear mixed effects model repeated measures ANOVA or a nonparametric ANOVA-type method.

Measure	*n*	Pre	Post	Within				Time x Intervention			
		TS	TS	*df*	*F*	*p*	η^2	*df*	*F*	*p*	η^2
HR (bpm)											
T	21	80.60 (12.71)	75.00 (11.83)	21	7.63	.012*	0.267	42	4.25	.046*	0.092
WLC	21	73.22 (9.62)	73.52 (11.16)	21	<0.01	.933	0.000				
RMSSD (ms)											
T	21	81.34 (45.54)	92.53 (73.19)	21	0.53	.474	0.025	42	2.18	.147	0.049
WLC	21	114.86 (53.19)	105.56 (52.90)	21	2.10	.162	0.091				
Total power (ms^2)											
T	21	823.75 (769.91)	1007.27 (1199.65)	21	<0.01	.943	0.000	42	1.11	.299	0.026
WLC	21	1721.82 (1989.02)	1176.14 (1177.33)	21	1.58	.222	0.070				
LF (ms^2)											
T	21	482.54 (515.09)	427.71 (463.61)	21	3.55	.073	0.145	41	0.31	.579	0.008
WLC	20	996.33 (1399.30)	580.66 (610.83)	20	2.31	.144	0.104				
HF (ms^2)											
T	21	295.18 (290.60)	542.46 (917.41)	21	3.17	.089	0.131	41	4.59	.038*	0.101
WLC	20	715.09 (691.98)	599.31 (638.56)	20	1.66	.212	0.077				
LF/HF											
T	21	3.25 (3.58)	1.92 (2.12)	21	12.30	.002*	0.369	42	3.18	.082	0.070
WLC	21	1.48 (1.07)	1.41 (1.28)	21	0.16	.698	0.008				
SCL (μS)											
T	21	3.29 (1.66)	2.80 (1.47)	21	4.03	.058	0.161	44	1.16	.288	0.026
WLC	23	3.37 (2.26)	3.28 (2.32)	23	0.29	.594	0.012				
NS-SCR (count)											
T	21	39.76 (40.85)	18.90 (26.26)	20	4.12	.042*	0.171	41.56	1.53	.216	0.036
WLC	23	42.74 (37.02)	39.70 (39.40)	22	0.53	.466	0.024				

Note. For NS-SCR, *F* represents the value of the nonparametric analyses of variance-type test statistic.

Table 3
Trauma-specific reactivity (difference between the trauma script (TS) and baseline (BL) conditions) of different physiological measures pre- and post-intervention (treatment or waitlist) during the script-driven imagery procedure. Values reported are means and standard deviation, and test statistics from the analysis of within-subjects and interaction effects using linear mixed effects model repeated measures ANOVA, on TS levels with BL as a time-varying covariate or a nonparametric ANOVA-type method using difference scores.

Measure	*n*	Pre	Post	Within				Time x Intervention			
		TS-BL Diff	TS-BL Diff	*df*	*F*	*p*	η^2	*df*	*F*	*p*	η^2
HR (bpm)											
T	21	8.90 (5.93)	4.21 (4.26)	21.11	8.40	.009*	0.285	43.20	.27	.607	0.006
WLC	21	4.86 (3.04)	1.91 (3.53)	20.28	12.72	.002*	0.385				
RMSSD (ms)											
T	21	-25.36 (40.52)	-5.90 (17.21)	20.78	5.94	.024*	0.222	39.52	4.90	.033*	0.110
WLC	21	-4.41 (32.78)	-2.89 (14.27)	17.91	0.13	.725	0.007				
Total power (ms^2)											
T	21	-425.61 (790.05)	-309.62 (972.56)	20.32	1.19	.288	0.055	41.59	1.92	.174	0.044
WLC	21	-237.44 (1678.72)	-265.83 (1066.94)	21.43	0.45	.509	0.021				
LF (ms^2)											
T	21	-123.88 (671.96)	-97.40 (481.25)	20.75	0.93	.345	0.043	40.92	0.35	.557	0.008
WLC	20	-96.44 (1249.94)	-151.68 (848.58)	20.52	1.26	.276	0.058				
HF (ms^2)											
T	21	-285.61 (391.96)	-203.41 (650.71)	18.60	6.85	.017*	0.269	38.27	6.71	.014*	0.149
WLC	20	-164.03 (570.95)	-128.41 (280.34)	19.47	0.59	.450	0.029				
LF/HF											
T	21	1.73 (3.28)	0.07 (1.85)	21.02	9.33	.006*	0.307	40.52	3.00	.091	0.069
WLC	21	-0.21 (1.45)	0.08 (1.68)	20.89	0.01	.932	0.000				
SCL (μS)											
T	21	0.37 (1.02)	-.10 (0.40)	20.45	7.36	.013*	0.265	41.43	0.88	.352	0.021
WLC	23	0.87 (1.26)	0.47 (0.90)	20.93	1.42	.246	0.064				
NS-SCR (count)											
T	21	35.62 (43.12)	5.90 (28.21)	20	7.78	.005*	0.280	41.89	0.60	.438	0.014
WLC	23	35.87 (37.02)	23.43 (42.11)	22	2.15	.143	0.089				

Note. For NS-SCR, *F* represents the value of the nonparametric analyses of variance-type test statistic.

7.77, $p = .005$) but no significant interaction effect.

Table 4 shows SUD and RSDI scores reported during or directly after the physiological measurement and PCL-5 scores obtained pre- and post-intervention. All self-report measures showed a common pattern of lower scoring after the intervention in the treatment arm not seen in the control group. For the RSDI scale, a significant interaction effect was found for avoidance ($F[1, 41] = 4.72$, $p = .030$) and re-experiencing ($F[1, 41] = 4.42$, $p = .036$). Dissociation showed no significant interaction effect but a significant within effect in the treatment group ($F[20] = 13.17$ $p = <.001$). SUD decreased with a significant interaction effect ($F[1, 42) = 5.38$, $p = .020$). PCL-5 decreased significantly in the treatment group ($F[20] = 16.90$, $p = <0.001$), and the interaction between time and intervention was highly significant ($F[1, 42] = 8.98$, $p = .005$).

Changes in self-assessed PTSD symptoms from before to after treatment were highly correlated with changes in HR reactivity ($r = .599$, $p = .004$) and HF reactivity ($r = -.462$, $p = .035$) (Table 5). No other reactivity measure changes showed significant correlations with changes in PCL-5 scores.

Regarding HR, there was no significant correlation between PCL5 and HR reactivity (log-transformed) before treatment (Fig. 3A). However, pre-treatment trauma-related HR reactivity (log-transformed) predicted treatment-imposed changes in PCL-5 scoring with higher HR reactivity measures resulting in larger decreases in self-reported PTSD symptoms ($r = .483$, $p = .027$) (Fig. 3B). As mentioned above the changes in HR reactivity correlated significantly with the changes in PCL-5 scores (Fig. 3C).

Table 4
Self-reported RSDI, SUD, and PCL-5 scores pre- and post-intervention (treatment or waitlist). Values reported are means and standard deviation, and test statistics from the analysis of within-subjects and interaction effects using linear mixed effects model repeated measures ANOVA (PCL-5), or a nonparametric ANOVA-type method (RSDI and SUD).

Measure	*n*	Pre		Post		Within				Time x Intervention			
		Mean	*SD*	Mean	*SD*	*df*	*F*	*p*	η^2	*df*	*F*	*p*	η^2
RSDI													
Avoidance													
T	21	10.90	4.69	7.05	5.08	20	11.97	<.001*	0.374	41	4.72	.030*	0.103
WLC	23	10.09	5.82	9.65	7.38	22	<0.01	.959	<0.001				
Re-experiencing													
T	21	17.33	4.99	14.81	6.06	20	3.33	.068	0.143	41	4.42	.036*	0.097
WLC	23	15.74	6.53	17.09	5.94	22	1.03	.311	0.045				
Dissociation													
T	21	10.38	7.75	5.33	7.12	20	13.17	<.001*	0.397	41	1.93	.165	0.045
WLC	23	11.83	8.35	8.65	6.50	22	3.45	.063	0.136				
SUD													
T	21	7.81	2.27	6.38	2.29	20	5.58	.018*	0.218	42	5.38	.020*	0.114
WLC	23	7.50	1.95	7.67	2.11	22	0.12	.725	0.005				
PCL-5 Total													
T	21	49.8	8.5	38.7	13.4	20	16.9	<.001*	0.458	42	8.98	.005*	0.176
WLC	23	48.5	15.3	47.8	15.2	22	0.082	.780	0.004				

Note. For RSDI and SUD, *F* represents the value of the nonparametric analyses of variance-type test statistic.

Table 5
Pearson correlation (r) and 2-tailed significance level for the relationship between changes in PCL-5 scores and changes in different reactivity measures from before to after intervention in the treatment group ($n = 21$).

Measure	*r*	*p*
Change in PCL-5	1	-
Change in Δ SCL	.294	.195
Change in Δ NS-SCR	.179	.439
Change in Δ **HR**	**.599**	**.004**
Change in Δ RMSSD	-.358	.111
Change in Δ LF	.029	.900
Change in Δ **HF**	**-.462**	**.035**
Change in Δ Total power	-.345	.126
Change in Δ LF/HF	-.177	.442

Note. Δ = difference between trauma script and initial baseline levels (a measure of reactivity).

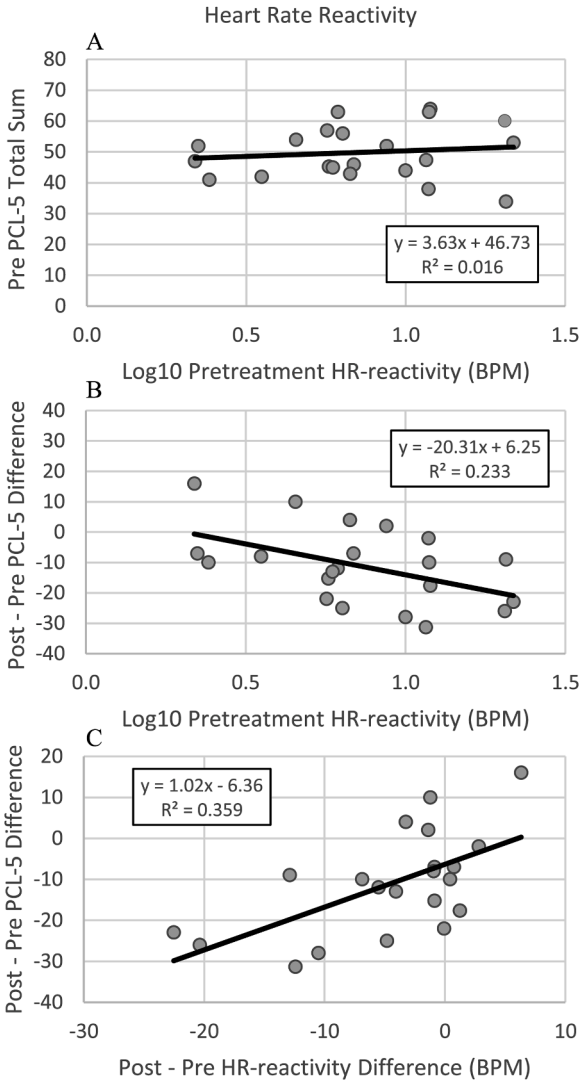

Fig. 3. From top to bottom, the figures show correlations between log-transformed pre-treatment HR-reactivity and pre-treatment PCL-5 (A), the correlation between the pre-post difference in PCL-5 and log-transformed pre-treatment HR-reactivity (B), and the correlation between PCL-5-changes and HR-reactivity changes, pre- to post-treatment (C).

4. Discussion

The present controlled study used a combination of physiological measurements, self-rating scales, and an SDI procedure to evaluate TFGrpMI, an arts-based group treatment method for PTSD.

The SDI procedure showed significant reactions to the trauma script (see Fig. 2), indicating that the set-up was functioning as intended.

The main finding was a pattern of reduced physiological reactivity to the traumatic event script, diminished self-assessed PTSD symptoms, and decreases in subjective disturbance and RSDI scale measures following active treatment. Further, the changes in PTSD symptom severity were predicted by initial HR reactivity and correlated with changes in psychophysiological reactivity.

In accordance with hypothesis 1, physiological reactivity to TS was reduced following treatment regarding electrodermal activity (SCL and NS-SCR), HR, HF-HRV, RMSSD (the time domain equivalent to HF-HRV), and the LF/HF ratio, but no apparent reactivity changes were found for LF-HRV or Total power. Likewise, the absolute TS levels of HR, HF-HRV, LF/HF, and NS-SCR also showed treatment-related changes. These measures partly reflect the activity in different regulatory systems. Both branches of the ANS control HR, while the electrodermal responses are mainly under sympathetic influence. For the frequency domain measures, HF-HRV is considered to reflect parasympathetic activity and LF-HRV, both sympathetic and parasympathetic activity. Thus, the results suggest that the treatment led to both trauma-related diminished arousal and increased vagal activity compared to the measurements before treatment. This outcome replicates findings from previous studies showing reductions in trauma-related physiological reactivity following active treatment (Bourassa et al., 2020; Lindauer et al., 2006; Wangelin & Tuerk, 2015).

Self-assessed PTSD symptoms, as measured by PCL-5, SUD during TS, and responses to the RSDI scale (re-experiencing, avoidance, and dissociation), showed a common decrease pattern in the treatment group but not in the waiting list control. This result confirms hypothesis 2, predicting a subjective reduction of trauma-specific disturbances following treatment.

A significant correlation was found between changes in self-reported PTSD symptoms and changes in psychophysiological reactivity (HR and HF-HRV) during trauma script, as predicted in hypothesis 3. Previous studies have demonstrated similar concurrent reductions in PTSD symptoms and cardiovascular reactivity after treatment (Lindauer et al., 2006; Pitman et al., 1996; Wangelin & Tuerk, 2015), while other studies have failed to show such a relationship (Bourassa et al., 2020; Sack et al., 2008). Notably, in the present study, we did not find any evidence for correlations between changes in electrodermal reactivity and PTSD symptom improvement. This suggests that the therapeutic effect is more closely associated with changes in parasympathetic activity than with the sympathetic system. However, there was still a statistically significant within effect in the treatment group in electrodermal measures, indicating a lowered arousal during trauma exposure.

Higher initial HR reactivity was associated with a greater reduction in PCL-5 rating. This relationship supports hypothesis 4 and the results from a few previous studies, suggesting that pre-treatment HR reactivity can be used as an objective predictor of PTSD treatment outcome (Pitman et al., 1996; Wangelin & Tuerk, 2015). It has previously been proposed that there are two pathways in PTSD symptomatology: undermodulation (hyperarousal) and overmodulation (hypoarousal), the latter with blunted reactions (Lanius, Frewen, et al., 2010). Subjects with higher reactivity are less blunted in their reactions, presumably making trauma processing easier and therapy more effective, which could be one possible underlying process explaining the predictive power of initial HR reactivity. Some studies have also shown that blunted autonomic responses are associated with more severe traumatisation, while moderate trauma symptoms are associated with higher reactivity (D'Andrea et al., 2013; McTeague et al., 2010). Blunted physiological reactions have also been connected to acute dissociative

symptoms during TS. Sack et al. (2012) showed that dissociative RSDI subscale scores correlated negatively with HR reactivity in response to trauma scripts. The present study found a similar tendency with a negative correlation between HR reactivity and RSDI dissociative subscale scores before intervention (not reported). An explanation might be that moderate trauma exposure leads to active defences such as fight/-flight, while severe traumatisation can lead to passive defences with immobilisation shown in shut-down and playing dead (D'Andrea et al., 2013; Porges, 2011; Schauer & Elbert, 2010; Terpou et al., 2019). This potential relationship between traumatisation severity and defence mechanisms underscores the importance of being aware of the more severe dissociative cases in treatment, as imaginal exposure techniques might be overwhelming, leading to an inability to process the traumatic experiences. In the present study, our exclusion criteria prevented potential participants with severe pathological dissociation from participation.

One notable observation in this study is that the groups tend to differ on some pre-intervention cardiovascular measurements, which could have implications for how the result should be interpreted. These differences would probably have been less pronounced if the randomisation had taken part after the first physiological evaluation, so the physiological measurements could also be a criterion in pairwise matching. Apart from the possibility that chance played a role in generating group variations in physiological baseline values, another theoretical possibility is that the difference can be attributed to the fact that the patients in the music group knew that they had been selected to belong to the treatment group and that this affected their psychophysiological state pre-treatment. However, this explanation is contradicted by the lack of influence of the physiology of the waiting list control group at the second measurement (after which they also underwent GrpMI treatment). Initial group differences in physiological variables raise the question of whether some interaction effects could partly be attributed to regression towards the mean. However, the changes in, for example, HR reactivity pre-post intervention correlates with changes in self-rated PTSD symptoms in the treatment group, indicating that the observed changes are linked to decreased PTSD symptoms rather than a statistical phenomenon.

Although exposure was a component of the study procedure, other elements potentially crucial for the clinical and physiological outcome of the present study include the group format and the use of arts-based therapy methods. Participation in group treatment involves sharing experiences with participants with similar backgrounds, which could reduce shame and feelings of loneliness. Reducing shame and increasing the feeling of belonging and safety may increase the capacity for reflection and affect regulation, essential skills in trauma processing (Lanius et al., 2020; Meyer DeMott, 2017; Nathanson, 1989; Porges, 2022). Furthermore, dissociation and avoidance inherent in PTSD counteract the emotional working through of traumatic experiences. Listening to and interacting with others in a group therapy setting may decrease avoidance. In the present study, a pronounced decrease in self-reported avoidance was found in the active treatment group (see Table 4).

Arts-based methods can help express traumatic images or sensations in other modalities when experiences are difficult to express in words. For example, a blocked affective state, part of PTSD, such as fear, which cannot be verbalised, can become accessible through the use of music that can facilitate imagery, which is then transformed into words by the individual, other participants, or the therapist, and subsequently processed (Bonny & Summer, 2002). The process of narrating and integrating the traumatic experiences with the help of group music and imagery, and expressive arts methods have shown to be helpful in the transition between implicit and explicit memories, thus helping to verbalise and integrate traumatic experiences (Gerge, Hawes, Eklöf and Pedersen, 2019; Hart et al., 2006; Körlin, 2005; van der Kolk, 2015). Additionally, the emphasis on working with inner sensations and imagery (increasing interoceptive awareness) might help to work through the traumatic experience by allowing for (imaginary) defensive actions that weren't possible during the original trauma experience (Arntz et al., 2007; Cardeña et al., 2000; Kluft, 2013; Levine, 2010; Ogden et al., 2006; Porges, 2011).

A common component of many evidence-based trauma therapy methods is building enough safety for trauma processing. The group format and the phase-based approach of Tf-GrpMI might contribute to an increased feeling of safety. Two of the theories that aim to explain the interplay between emotional regulation, social engagement, defence responses, and the autonomic nervous system, the polyvagal theory and the neurovisceral integration model, both link increased feelings of safety to physiological changes (Bourassa et al., 2021; Porges, 2022; Porges & Dana, 2018; Porges & Rossetti, 2018; Shaffer et al., 2014; Thayer et al., 2009; Thayer & Lane, 2000). These models both predict that the sense of threat leads to increased HR and decreased HRV via vagally mediated mechanisms (Shaffer et al., 2014; Thayer et al., 2012), and although their physiological postulates are under debate (Grossman, 2023; Neuhuber & Berthoud, 2022), a growing number of studies confirm the relationship between increased HRV and a feeling of safety and contentment (Duarte & Pinto-Gouveia, 2017; Oveis et al., 2009; Schwerdtfeger et al., 2022).

4.1. Limitations and implication for future studies

Several limitations were identified in this study. Firstly, the active treatment was compared with a waitlist group, whereas in future studies, an active treatment as a comparison could be beneficial.

Additionally, the exclusive inclusion of female participants limits the generalizability of the findings to male populations.

Moreover, physiological similarity was not used as a matching criterion in the present study because the first measurement was made after randomisation. Thus, we could not distinguish any physiological impact of participants' knowledge of the upcoming treatment from random differences in baseline physiology. It might be beneficial in future studies to conduct randomization after the initial physiological evaluation, enabling the use of these measurements as matching criteria.

Another potential limitation is that HR and HRV measurements were based on the blood volume pulse, a method chosen because of its nonintrusive nature. This method is known to be less accurate in comparison with electrocardiographic (ECG) measuring, at least under certain conditions, such as physical activity and mental stress (Schäfer & Vagedes, 2013), and the accuracy can be influenced by factors like age, respiratory patterns, orthostatic changes, exercise, and ambient temperature (Mejía-Mejía et al., 2020; Mejía-Mejía, May, et al., 2020; Nardelli et al., 2021). However, the use of repeated measurements and standardised condition SDI in this study may have outweighed the potential bias.

Furthermore, recovery immediately after trauma exposure was not studied, primarily because the verbal SUD rating reported after listening to TS caused an interruption in the trajectory of recovery. In future studies, recovery would be an important aspect to include in the analyses because lack of recovery seems to be a robust indicator of PTSD (Goodman & Griffin, 2018; Pole, 2007).

Lastly, subgroup analyses based on differences in dissociation, numbing, or hyperarousal were not feasible because of the limited number of participants and since highly dissociative patients were excluded for ethical reasons. Such an analysis could be an interesting subject for future studies since the optimal therapeutic approach may differ between PTSD subtypes (Cloitre, 2015; Griffin et al., 1997; Lanius, Vermetten, et al., 2010; Sack et al., 2012).

4.2. Conclusions

This study has evaluated a group treatment with trauma-focused Group Music and Imagery, using self-rating measurements and physiological recordings. An observed recovery of vagal function and reduced

sympathetic activation in response to trauma reminders, in combination with self-rating measures, indicate a robust improvement in the treatment group and thus support the usefulness of group format and arts-based methods in trauma treatment. Mechanisms involving exposure, nonverbal methods, increased social engagement, safety, and interoceptive awareness may have contributed to the treatment outcome.

The results further confirm other studies showing that higher initial HR reactivity to trauma cues predicts a better treatment outcome of trauma-focused treatment.

Finally, the observed correlation between treatment-dependent changes in physiological measures and self-rated PTSD symptoms suggests that physiological reactivity can be used as an objective outcome measure in evaluating PTSD treatment effects and that efficient treatment involves a restored regulation of the ANS.

Availability of data and materials

The datasets from the study will not be available publicly as per the Danish and Swedish Data Protection Agency rules. Also due to the sensitive nature of the collected information, the participants were assured that the raw data would remain confidential and would not be shared.

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CRediT authorship contribution statement

Gabriella Rudstam: Conceptualization, Methodology, Visualization, Investigation, Formal analysis, Writing – original draft, Funding acquisition, Writing – review & editing. **Ulf O.E. Elofsson:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Data curation, Visualization. **Hans Peter Söndergaard:** Conceptualization, Methodology, Formal analysis, Supervision, Writing – review & editing. **Bolette D. Beck:** Supervision, Writing – review & editing.

Declaration of Competing Interest

We have no known conflict of interest to disclose.

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