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Stress and Psychotherapy Outcome: Implementation of a Heart Rate Variability Biofeedback Intervention to Improve Psychotherapy Outcome

Louise Fidalgo Wheeler

A dissertation submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

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ABSTRACT

Stress and Psychotherapy Outcome: Implementation of
a Heart Rate Variability Biofeedback Intervention
to Improve Psychotherapy Outcome

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Doctor of Philosophy

Research has shown that psychotherapy patients experience increased physiological responsivity to stress which might negatively impact their experience in psychotherapy and their overall progress and outcome. The purpose of the present study was to investigate the effect of a heart rate variability biofeedback intervention on the physiological stress responsiveness and the psychotherapy outcomes of participants in psychotherapy.

Forty college students attending psychotherapy at their university counseling center were divided into an experimental group and a control group. The experimental group participated in a 6-week biofeedback intervention and we assessed their physiological stress reactivity before and after implementation of the intervention, compared to a matched control group. The Trier Social Stress Test (TSST) was administered pre- and post-intervention to induce a stress reaction. It was hypothesized that psychotherapy patients involved in the biofeedback intervention would show decreased physiological stress reactivity to and faster physiological recovery from a laboratory induced stressor post-intervention compared to psychotherapy patients in the matched control group. It was also hypothesized that these participants would demonstrate larger distress reduction after implementation of the intervention.

Results of the study found no significant main effect of the TSST on systolic blood pressure, heart rate, and HRV. There however was a main effect on diastolic blood pressure. The only variable that significantly differed between groups was the LF/HF ratio. The results also revealed no significant change from pre-intervention baseline to post-intervention heart rate, blood pressure, and HRV, suggesting that the HRV biofeedback intervention was not effective in changing the stress response over time. Regarding levels of distress, results also revealed no statistical between group differences post-intervention, although the biofeedback group appeared to report significantly lower levels of distress post-intervention.

Keywords: stress, psychotherapy outcome, heart rate variability biofeedback, stress management

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Stress and Psychotherapy Outcome: Implementation of a HRV Biofeedback Intervention to Improve Outcome

Presentation of the Problem and Rationale for the Study

There is increasing evidence that psychotherapy patients reporting elevated levels of distress demonstrate higher physiological stress reactivity. It is well established in non-clinical community studies that individuals reporting high levels of distress also show increased physiological activity and negative health outcomes (Carroll et al., 2012; Chida & Steptoe, 2010; Steptoe, Brydon, &Kunz-Ebrecht, 2005). Similarly, elevated levels of psychological distress in psychotherapy have been shown to be related to increased physiological reactivity (Ehrenthal, Fey, Hermann-Lingen, 2010; Ham & Tronick, 2009; Lindauer et al., 2006). In 2014, Steffen et al. found that psychotherapy patients reporting higher levels of distress early in treatment showed a higher physiological stress reactivity as demonstrated by higher levels of cortisol and higher blood pressure compared to patients reporting lower levels of distress (Steffen, Fidalgo, Schmuck, Tsui, & Brown, 2014).

In addition, research has also shown that levels of distress reported early in psychotherapy are not only related to stress physiology but also to prediction of outcome. There is consistent evidence suggesting that not all psychotherapy patients benefit from treatment but that about 5% to 10% of them actually leave treatment reporting worse levels of distress than when they entered (Lambert, 2013). Research has also shown that initial levels of distress reported by psychotherapy patients on outcome measures are the best predictors of treatment outcome as individuals reporting lower levels of distress show more positive outcome trajectories (Lambert, 2007; 2013). For instance, Brown and Lambert (1998) found that pretreatment outcome score on the Outcome Questionnaire—45 (OQ-45) and early change between sessions 1 to 3 of psychotherapy accounted for about 40% of the variance in final outcome. In sum, not everyone benefits from psychotherapy and initial reported levels of distress might help us identify patients at risk for poor outcome.

Interestingly, there are only a few studies that attempted to understand the relationship between psychotherapy outcome and physiological stress reactivity (Steffen et al., 2014). Furthermore, no studies to date have examined how stress management interventions associated with psychotherapy might increase the rates of positive outcomes in patients with higher stress reactivity. Given the data cited above, the present study investigated how adding a stress management intervention (i.e., heart rate variability biofeedback) as an adjunct intervention to psychotherapy might help patients reporting high levels of distress early in treatment benefit more from psychotherapy.

Stress

Despite years of research on stress, researchers in the field of psychology still have difficulties providing a consensual conceptual definition of stress (Koolhaas et al., 2011; Sergerstrom & Miller, 2004). The term stress is somewhat ambiguous as to what it refers to because of its wide use in our daily language (Del Giudice, Ellis, & Shirtcliff, 2011; Woolfolk, Lehrer, & Allen, 2007). A first step to take in defining stress is to make a clear difference between stress and stressor. In his pioneer work on stress, Hans Selye made a crucial distinction between the two concepts. Indeed, he defined a stressor as an external stimulus triggering a physiological response, and stress as the physiological response to this stimulus (Everly & Lating, 2002). Another important concept in the definition of stress is the question of balance. In his research McEwen explained that our bodies are made of different systems that attempt to maintain a balance in order for us to adapt to environmental changes and demands (McEwen, 1998; McEwen & Wingfield, 2003). Taking this concept further, Sapolsky (2004) defines a stressor as any event that takes our body out of balance and our stress response as our body's attempt to reach balance again.

This attempt of our bodies to maintain balance is called allostasis. Allostasis is a central concept in the definition of stress and has been defined as physiological "stability through change" (McEwen, 1998; McEwen & Wingfield, 2003). Research has shown that being in a state of stress changes the physiological functioning of different organic systems such as the cardiovascular system, the immune system, the neuroendocrine system, and the digestive system. When an external event is perceived as threatening or dangerous (stressor), physiological resources will be mobilized differently to face the stressor and respond to it. This process is called the stress response and leads to psychological and behavioral changes, such as increased analytical thinking, or being tense or on edge (McEwen, 1998; McEwen & Wingfield, 2003). In sum, stress can be defined as the physiological response to an event perceived and interpreted as threatening, that leads to physiological, behavioral, and psychological changes.

A key physiological system involved in the stress response is the autonomic nervous system. In the autonomic nervous system the parasympathetic and the sympathetic nervous systems constantly balance each other. The parasympathetic branch of the autonomic nervous system's main function is to reduce physiological arousal and to control vegetative functions. On the other hand, the sympathetic nervous system becomes more active in situations of stress as it mediates arousal functions and the fight or flight response (Del Giudice, Ellis, & Shirtcliff, 2011). Through this activation the functioning of several systems will change. Specifically, the neuroendocrine system will release more cortisol, the cardiovascular system activity will increase through elevated heart rate and blood pressure and decreased heart rate variability, increase in respiration rate, the digestive system will become less active and the immune system's functioning will decrease as well (Burleson et al., 2003; Carroll et al., 2003; Del Giudice et al., 2011;; McEwen, 1998; McEwen & Wingfield, 2003; Ray, 2004; Sapolsky, 2004;Vrijkotte, van Doornen, & Geus, 1999). The purpose of all these changes is to enable our organism to adapt to the stressful event and respond to it appropriately. This is called allostatic state (McEwen & Wingfield, 2003). However, over-activation of these systems can potentially have damaging effects on the body and the mind.

Recurrent or chronic activation of the stress response described above can damage the body's systems involved and cause serious medical problems (McEwen 1998; McEwen & Wingfiel, 2003; Ray, 2004,). In a nationally representative sample, 33% of American reported feeling chronically stressed. Results of this longitudinal study showed that perception of these high levels of stress as threatening or overwhelming was predictive of reduced life expectancy, suggesting that exposure to high and chronic levels of stress can damage the body through over-activation of the autonomic nervous systems (Keller et al., 2012). The cardiovascular system is specifically affected by prolonged exposure to stress. Indeed, elevated blood pressure and heart rate can lead to cardiovascular disease such as hypertension, coronary heart disease, and cardiovascular accidents.

But perceived stress does not only damage physical health, it also has damaging effects on mental health. Studies have shown that high levels of perceived stress is a significant risk factor for poorer mental health (Bovier, Chamot, & Pernerger, 2002; Sapolsky, 2004). Specifically, research has established a relationship between levels of stress and depression and anxiety. For instance, several studies and research reviews have found that most individuals diagnosed with major depressive episodes reported higher levels of stress before the onset of the episode, and that most depressive episodes were preceded by major stress events in the patients' lives (Hadjyannakis, 2002; Kendler, Karkowski, & Prescott, 1999; Kessler, 1997; Mazure, 1998; Monroe & Paykel, 1997; Tennant, 2002). Given this data, research in health psychology has emphasized the importance of teaching adaptive ways to cope with stress in order to prevent physical and psychological illness.

Psychotherapy Outcome

Although the primary goal of psychotherapy is to reduce individuals' distress, there is substantial evidence suggesting that it is not always the case. Indeed, a meta-analysis by Swift and Greenberg (2012) showed that 19.7% of psychotherapy patients terminate psychotherapy after only a few sessions, suggesting that they interrupt treatment before experiencing desired outcomes. Furthermore, it has been shown that about 5% to 10% of adult psychotherapy patients get worse over the course of treatment (Hansen, Lambert, & Forman, 2002; Lambert & Brown, 1998; Lambert 2013). Similarly, Hansen et al. (2002) showed that an average of 8% of community mental health centers' clients significantly worsen or report significantly higher levels of distress after entering treatment. More research is needed to identify factors that contribute to negative responses to psychotherapy.

In order to understand patterns of response to psychotherapy, it is important to define psychotherapy outcome. Research in psychotherapy outcome has provided different ways to define and assess outcome. For instance, it can be assessed by measuring reported levels of wellbeing pre- and post-treatment, based on symptom reduction only. In this case, psychotherapy outcome can be defined as the overall final response to treatment. However, this definition of outcome only provides an overall picture of the effect of psychotherapy and limits the understanding of session-by-session changes in symptoms and overall levels of distress (Lambert, 2013). Furthermore, psychotherapy outcome research has shown that individuals who experience sudden positive changes early in treatment are more likely to maintain their positive gains and changes at termination and up to two years after treatment (Haas, Hill, Lambert, & Morrell, 2002). This research suggests that there are different patterns of treatment response over the course of psychotherapy that are observable early and can be predictive of long-term outcome (Lambert, 2013).

Changes observed early in treatment are not the only predictors of change and outcome. Interestingly, several studies consistently found that early (or pretreatment) distress scores are the best predictors of end of treatment outcome (Lambert, 2013; Stulz, Lutz, Leach, Lucock, & Barkham, 2007). Psychotherapy patients that report lower psychological distress early in treatment have significantly better final psychotherapy outcome than those that report higher levels of distress as illustrated by positive and consistent change through the course of treatment. On the other hand, those reporting higher levels of distress at the beginning of treatment are less likely to improve and might even worsen (Lambert, 2006; 2013). As a result, it appears essential to gain better understanding of factors that maintain symptoms and levels of distress throughout psychological treatment in those reporting higher levels of distress at the beginning of treatment.

Psychotherapy Outcome and Stress

Accumulating evidence is showing that individuals undergoing psychotherapy experience increased reactivity to stress. For instance, Blanchard et al. (2002) demonstrated that patients diagnosed with PTSD had elevated heart rate reactivity following exposure to trauma-related stimuli in psychotherapy. In the same study, it was found that patients that responded more positively to cognitive behavioral therapy had decreased heart rate reactivity when presented with trauma-related cues. In the context of depression, clinically depressed women showed higher stress reactivity during exposure to a stressor compared to non-depressed women (Cyranowski, Swartz, Hofkens, & Frank, 2009). Similar results have been found in adolescents receiving psychological services for behavioral problems. Mathijssen, Koot, and Verhulst (1999) found that adolescents experiencing significant stress while receiving treatment had worse psychotherapy outcome at the end of treatment. Cortisol levels, a physiological indicator of stresss, have also been shown to be positively correlated with treatment outcomes in adolescents (Schechter, Brenna, Cunningham, Foster, and Whitmore, 2012).

Several studies investigating the relationship between stress reactivity and psychotherapy outcome have shown that progress made while in treatment is correlated with decreased physiological stress reactivity (Aubert-Khalfa, Roque, & Blin, 2008; Blanchard et al., 2002; Cyranowski, Swartz, Hofkens, & Franck, 2009). In 2010, a pilot study found that physiological stress reactivity at pretreatment predicted outcome by the end of psychotherapy in a clinical population hospitalized for depression (Ehrenthal et al, 2010). Specifically, the study found that patients with lower stress reactivity had significantly better psychotherapy outcome than those with elevated physiological stress reactivity. Similar results have been found in outpatient settings. Steffen et al. (2014) showed that psychotherapy patients at a university counseling center reporting higher levels of distress at the beginning of treatment had higher heart rate and systolic blood pressure. In addition, these patients took more time to physiologically recover from exposure to a laboratory stressor. Despite this growing evidence, no studies to date have examined how incorporating stress management interventions such as heart rate variability biofeedback might help psychotherapy patients with higher physiological stress reactivity to benefit more from psychotherapy as demonstrated through positive outcome trajectories.

Heart Rate Variability Biofeedback

Biofeedback is an area of stress management that relies on the assumption that the mind and the body are connected, and influence each other's functioning. The goal of biofeedback practice is to learn to use this connection to change physiological activity and improve physical and mental health (Association for Applied Physiology and Biofeedback, 2011). In order to do so, individuals practicing biofeedback use physiological indicators such as heart functions, skin temperature, muscle activity, and breathing to learn and gain understanding of the functioning of their body and the impact of their thinking, emotions, and behaviors on it. Put simply, biofeedback uses physiological functions to provide feedback to the individual, which brings awareness of the influence of these functions on overall functioning (Lehrer, 2007).

There are different types of biofeedback that have been developed to respond to different types of physiological stress arousal. Heart rate variability (HRV) biofeedback is a type of cardiovascular biofeedback that focuses on the changes in variability in heart rate (Lehrer, 2007; Lehrer et al., 2013). Specifically, HRV Biofeedback is based on the fact that, just like every other system in the body, heart rate and the time between heart beats vary continuously throughout the day. Heart rate variability is the variation in time intervals between heart beats. It represents the interaction between the sympathetic and parasympathetic nervous systems according to internal and external demands (Eddie, Vaschillo,, Vaschillo, & Lerher, 2015). Heart rate variability can thus be thought of as a self-regulatory mechanism or an indicator of adaptability to one's environmental demands (Lerher, 2007). Furthermore, research on heart rate variability has found that higher levels of HRV, as illustrated by high amplitude and complexity of oscillations between heart beats, is linked to more emotional resilience as well as lower stress vulnerability (Appelhans & Luecken, 2006; Thayer, Hansen, & Johnsen, 2010). In addition, it has also been shown that individuals with better physical health have higher levels of HRV (Vanderlei, Pastre, Hoshi, Cavalho, & Godoy, 2009). In sum, a more flexible and complex heart rate variability is an indicator of a well-functioning system.

Heart rate variability is not only related to good health. Indeed, lower levels of heart rate variability have been linked to illness (Goldberger, Peng, & Lipsitz, 2002; Lehrer & Eddie, 2013) and to psychopathology. For instance, it has been shown that individuals with substance use disorders have a lower resting HRV (Ingjaldsson, Laberg, & Thayer, 2003; Weise, Müller, Krell, Kielsten, & Koch, 1986). Furthermore, lower resting levels of HRV have been found in individuals with anxiety disorders such as panic disorder (Klein, Cnaani, Harel, Braun, & Ben-Haim, 1995), and phobias (Kawachi, Sparrow, Vokonas, & Weiss, 1995), as well as in individuals with post-traumatic-stress disorder (Cohen, Benjamin, Geva, Matar, Kaplan, & Kotler 2000). Finally, research on HRV and depressive disorders has shown that lower resting levels of HRV are found in individuals with major depressive disorder and that there is a negative relation between lower levels of HRV and the severity of depressive disorders (Agelink et al., 2001; 2002; Nashoni et al., 2004; Udupa et al., 2007;).

Based on the evidence of the crucial role of HRV in mental and physical health, HRV biofeedback aims at restoring balance to promote health. In order to understand the mechanisms of change of HRV biofeedback it is important to be aware of two different phenomena: the respiratory sinus arrhythmia (RSA) and the baroreflexes. First, the RSA is the fact that heart rate changes as we breathe. Indeed, heart rate increases when we inhale and decreases when we exhale (Eddie et al., 2015; Lehrer, 2007; 2013; Lehrer & Gevirtz, 2014). Second, the baroreflexes are mechanisms involved in the control of blood pressure. When blood pressure increases, arteries stretch which stimulates baroreceptors (i.e., stretch receptors located in the aortic arch and the carotid sinus), and this mechanism triggers the baroreflexes. The baroreflexes lead to a decrease in heart rate as blood pressure increases which enables blood pressure to lower and go back to baseline (Eddie et al., 2015; Lehrer, 2007). Based on these two phenomena, HRV biofeedback teaches individuals to increase their HRV through paced breathing. Research on HRV biofeedback has shown that the amplitude of heart rate oscillation increases when the cardiovascular system is rhythmically stimulated by breathing at a paced rate of about six breath-per-minute (i.e., a frequency of 0.1hz) (Eddie et al., 2015; Lehrer, 2007; Lehrer et al., 2013; Lehrer & Gevirtz, 2014). In sum, through following a specific breathing rate, the cardiovascular system of individuals practicing HRV biofeedback attains the resonance that triggers activation of the baroreflexes which brings their cardiovascular system back to balance.

There is growing evidence of the potential of HRV biofeedback as the treatment of various psychiatric disorders and as a valid stress management intervention. Specifically, HRV biofeedback has been shown to have positive effects in the reduction of the symptoms of different anxiety disorders as well as on reduction of physiological, psychological, and behavioral symptoms of stress (Henriques, Keffer, Abrahamson, & Horst, 2001; McCraty, Atkinson, Lipsenthal, & Arguelles, 2009; Nolan et al., 2005; Reiner, 2008). Furthermore, the effect of HRV biofeedback on depressive symptoms has also been studied and positive results have also been found on symptom reduction (Karavidas, Vaschillo, Vaschillo, Marin, Buyske, & Hassett, 2007; Siepmann et al., 2008; Zucker et al., 2009). Positive results have been demonstrated as well for physiological illness such as hypertension (Lin et al., 2012; McCraty et al., 2009; Nolan et al., 2005), chronic pain, (Hassett et al., 2007; Sowder, Gevirtz, Shapiro, & Ebert, 2010), and asthma (Lehrer, Smetankin, Potapova, 2000; Lehrer et al., 2004). Although these results are encouraging, more research is needed on the efficacy of HRV biofeedback to validate it as an efficacious treatment of psychological conditions.

Rationale and Hypotheses of the Current Dissertation

Based on the evidence presented above, there appears to be a need to evaluate the impact of HRV biofeedback on the outcome of psychotherapy patients with elevated physiological stress responsivity. The present study investigated this effect on a group of psychotherapy patients reporting high levels of distress and examined whether psychotherapy patients involved in an adjunct stress management intervention showed decreased physiological stress reactivity and faster recovery from a stressor compared to psychotherapy patients receiving treatment as usual (i.e., attending psychotherapy but not receiving biofeedback training). It is hypothesized that psychotherapy patients participating in the HRV biofeedback intervention will demonstrate a larger reduction in distress as measured by the OQ-45 relative to a treatment as usual control group.

Present Study Method

Participants

We assessed the eligibility of three hundred college students receiving psychotherapy services from the Brigham Young University (BYU) counseling center. The BYU counseling center offers psychotherapy services free of charge to students enrolled in class full time. All participated screened for the study were at the beginning of treatment (i.e., had just completed intake paperwork). Potential participants were only approached if they had agreed on participating in research when completing their intake paperwork. They were contacted through emails advertising for the study sent by the staff of the counseling center. Individuals interested in participating completed online questionnaires to assess eligibility for the study. We excluded individuals who had received previous biofeedback training, had a diagnosis of heart or blood pressure related disorders, were taking medications affecting blood pressure, and reported levels of distress above 63/64 on the Outcome-Questionnaire—45.

Participants that qualified for participation were randomly assigned to one of two groups (i.e., biofeedback group and control group). The final sample was comprised of forty college students, receiving psychotherapy services from their university counseling center. Figure 1 illustrates flow of participants through the different phases of the study, from recruiting to data analysis. Research studies that investigated the relationship between stress and psychotherapy had sample sizes ranging from ten to twenty-seven participants (Blanchard et al., 2006; Cyranowki et al., 2009; Ehrenthal et al., 2010; Wiederhold et al., 2002). Based on the significance of the results of these studies and the pilot nature of the present study, the sample was divided into two groups representing two different conditions. The first condition included participants who received a 6-week HRV biofeedback intervention in addition to psychotherapy. The other group participated in treatment as usual (i.e., only psychotherapy). Every participant was informed about the implications and conditions of the study through an informed consent form completed before participation in the study began. The study was reviewed and approved by the Institutional Review Board of the Brigham Young University before collection of pilot data.

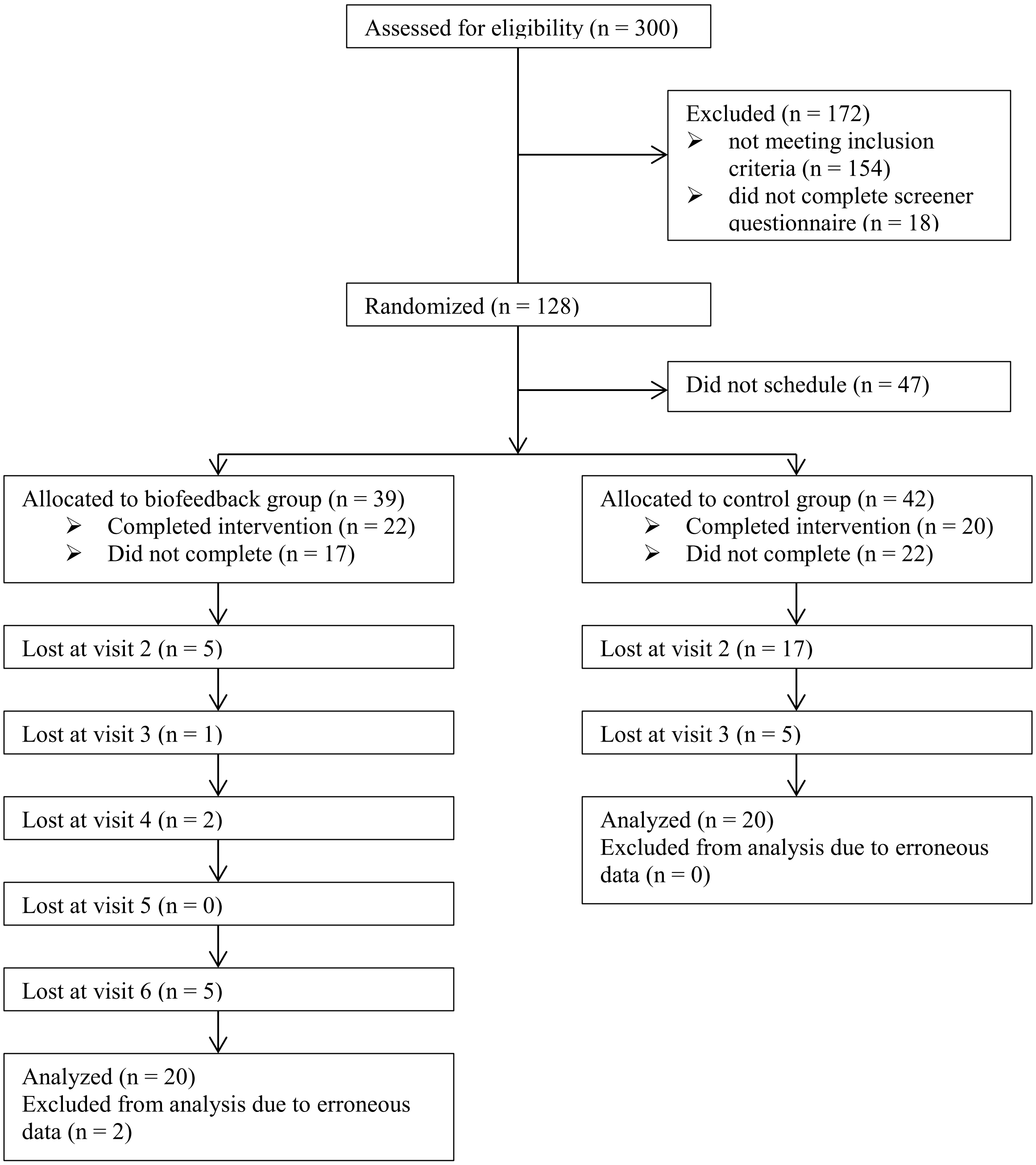

Figure 1. Flow diagram of participants through the phases of the study from recruitment to data analysis.

Measures

The Trier Social Stress Test (TSST). Physiological stress reactivity was measured in the first and last laboratory visits through induction of a stressful situation using the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993). The Trier Social Stress Test (TSST) was developed by Kirschbaum et al. (1993) to induce moderate to intense psychosocial stress in laboratory conditions (Kirschbaum, 2010; Miller & Kischbaum 2013). The protocol of the TSST has been shown to trigger a social-evaluative threat and a sense of uncontrollability that activate the physiological stress response rapidly (Miller & Kirschbaum, 2013). The TSST has been widely used in research over the past ten years for its significant activation of endocrine and cardiovascular indicators of stress. As a result, the TSST has become the gold standard protocol for laboratory induction and measure of stress in the clinical population as well as with healthy participants (Miller & Kischbaum, 2013). In the present study, the TSST will be administered by trained graduate and undergraduate research assistants.

The TSST is divided in two different performance tasks: a speech and a math task. The first phase of the protocol involves a rest condition of about thirty to forty-five minutes during which baseline blood pressure and heart rate are monitored and recorded. The purpose of this preliminary rest period is to minimize the impact of prior stressors or any other factors that might influence the activation of the physiological indices monitored during the protocol (Kudielka, Hellhammer, & Kirschbaum, 2007). During the rest period the participant is instructed to sit still until further instructions are given to him or her. Following the rest period, the subject is asked to prepare for a job interview. The participant is given five minutes to prepare after which he or she will have to present a five-minute speech describing what qualifies them for the job. The participant is told by the research assistant that the performance will be recorded and later analyzed by experts specially trained to monitor verbal and nonverbal performance. Specifically, it is explained that a voice-frequency analysis will be performed following the interview. After the preparation period the subject presents its speech to a critical audience (i.e., two research assistants wearing white laboratory coats). If the participant finishes its speech before the five minutes are over he or she is prompted to continue until indicated to stop. Following the job interview the subjects are asked to serially subtract the number 17 from 2023 as quickly and accurately as possible. Every time the participants give an incorrect answer they are told to stop and start over at 2023. The math portion of the TSST lasts five minutes as well. The subject physiological stress reactivity is monitored through each portion of the TSST.

Research has shown that the TSST can be used for repeated measures of stress physiology with minor habituation effects manifesting after three exposures (Kudielka et al., 2007). Kirschbaum (2010) explains that habituation effects to the TSST can be avoided by environmental changes. As a result, participants will not be tested by the same research assistants in their first and last visits. In addition, we decided to modify the math portion of the TSST and replace it by the Paced Auditory Serial Addition Task (PASAT). In the PASAT, participants are presented with a series of one digit numbers and are asked to add the two most recent numbers they hear. The numbers are presented at different rates and participants are expected to provide an answer before the following number is presented. The PASAT was originally developed to assess attentional processing memory. However, it has been shown that the PASAT triggers significant stress and anxiety in individuals taking it (Tombaugh, 2006). As a result, we predict that the PASAT will be an appropriate trigger of the stress response in participants.

The Outcome Questionnaire—45 (OQ-45). Psychotherapy outcome and participants' distress will be assessed using the Outcome Questionnaire—45 (OQ-45) (Lambert, Kahler, Harmon, Burlingame, & Shimokawa, 2011). The questionnaire was administered online during the screening process to assess for participants' eligibility for the full procedure. Based on results published by Steffen et al. (2014), only participants having a total outcome score of 63/64 and above will qualify to participate in the study. Participants completed the questionnaire during each one of their laboratory visits. The OQ—45 is a 45-item self-report measure developed to track and evaluate clients' progress and outcomes in psychotherapy. Items are rated on a 5-point Likert scale ranging from 0 ("Never") to 4 ("Almost always"). Total scores can range between 0 and 180 with a cutoff score of 63 which represents clinically significant levels of distress. Higher scores on the OQ-45 reflect more severe levels of distress. The measure assesses symptom distress, interpersonal relationships, social role, and quality of life (Lambert, 2013). The measure will evaluate change in overall levels of distress (i.e., progress or deterioration) in participants.

The OQ-45 has been widely used in research settings (Hansen et al., 2002; Okiishi, Lambert, Nielsen, & Ogles,2003; Wampold and Brown, 2005) and has been validated across different ethnic groups such as African American, Asian, Pacific Islander, Latino, and Native American clients (Lambert et al., 2006). The measure has been shown to be validly and reliably sensitive to change in clients' reported distress and interpersonal difficulties (Lambert, Burlingame, Umphress, Hansen, Vermeersch, Clouse, & Yanchar, 1996). A change of 14 points on the scale is considered significant (Lambert et al., 2013). According to Lambert et al. (2004) the OQ-45 is a well-established measure of psychotherapy outcome and levels of distress, and is reported to be a reliable and valid instrument with an internal consistency of .93 and a 3-week test-retest reliability of .86. Furthermore, it has a significant concurrent validity (p =.01) with measures of self-reported symptoms and psychopathology such as the Beck Depression Inventory and the Spielberger State Anxiety Inventory (Lambert et al., 1996; Lambert et al., 2011). Finally, the measure has established norms for a population with ages ranging from 18 to 80 in university, community mental health, outpatient, and inpatient settings (Lambert et al., 2011).

Procedure Overview

Participants were randomly assigned to two experimental conditions to evaluate the impact of HRV biofeedback on psychotherapy outcome. Each condition was manipulated in a laboratory setting by trained research assistants. The study proceeded in four phases: (a) screening of participants through online completion of the OQ-45, (b) pre-measure of physiological stress reactivity and introduction of the intervention for the experimental group, (c) implementation of the intervention, and measure of physiological indicators of stress, and (d) post-measure of physiological stress reactivity. The four phases were divided into three (control group) to six (experimental group) laboratory visits and practice assignments to complete in between each visit for the experimental group. The control group did not receive practice assignments. Participants completed questionnaires in each of their visits. The questionnaires administered in their first visit included self-report measures of psychological well-being, physical health, and demographic information. Throughout the procedure participants' blood pressure, skin conductance, and heart rate were monitored. In addition, participants' heart rate variability was calculated. Participants were financially compensated with a total of thirty dollars cash.

General Procedure

Pre and post measures of physiological stress response were collected for each group during their first and last laboratory visits using the Trier Social Stress Test. During these two visits, blood pressure, heart rate and heart rate variability were measured before, during, and after exposure to two stressors to assess changes in the physiological stress response. Physiological data was collected using the Biopac MP150 (Biopac Systems, Inc). Biopac is a research tool that enables data collection and analysis of physiological indicators simultaneously through a software called Acqknowledge 4.2 (Biopac Systems, Inc). Participants will also complete the OQ-45 at be beginning of each of their laboratory visits. Between their first and last visits, participants in the biofeedback condition attended four other appointments in our laboratory to receive HRV biofeedback training. Participants in the control condition attended one session between their pre- and post-assessment. Each of the control group's sessions were held two weeks apart from each other. In addition to the questionnaires administered at the beginning of each visits, blood pressure data was collected for each participants in each laboratory visit. Overall, the procedure extended from six to ten weeks, with no more than two-week intervals in between sessions.

Biofeedback condition. Twenty psychotherapy patients were assigned to the biofeedback condition and attended six laboratory visits. The biofeedback protocol is an adaptation of the Lehrer protocol for research (Lehrer et al., 2013). Research has shown that a few biofeedback visits are enough to teach biofeedback skills to patients (Vaschillo, Vaschillo, & Lehrer, 2006).

Biofeedback visit 1. At the beginning of their first visit, biofeedback participants completed the OQ-45 on a laptop through Qualtrics. The research assistants attached sensors to their wrists and placed a blood pressure cuff on their left arm as well as a respiration belt around their waist. The sensors were connected to the Biopac System. Signals and physiological readings were checked by the second research assistant before starting the procedure. Three steps were involved in the first appointment: measure of baseline and diaphragmatic breathing training, exposure to stressor, and recovery period. Before starting the diaphragmatic breathing training participants received the following instructions: "We now are going to give you some training in relaxed breathing. Allow yourself to relax and feel comfortable. When you are relaxed, your chest and your abdomen relax and you begin to breathe more naturally, so that your abdomen expands when you inhale and contracts (goes back in) when you exhale. Breathe into your abdomen, a few inches below your navel. This will help you breathe in a more relaxed way." The participant then breathed the indicated way and the instructions continued as follow: "Good, now let's do abdominal breathing. Place one hand on your chest and the other on your abdomen, just below your navel. As you inhale and exhale, the bottom hand moves up and down, and the top hand doesn't move much at all." The research assistants demonstrated with three inhalations and exhalations and asked the participant to try the same. After the participants demonstrated their ability to practice the diaphragmatic breathing, they were asked to practice the same breathing for fifteen minutes while sitting back and relaxing (baseline). Research assistants checked on the participant several times to ensure that the breathing was done appropriately and that the participants did not over-breathe or hyperventilate. Physiological indicators of stress were recorded three times during the fifteen minutes at minutes 10, 12, and 14. Following the fifteen minutes, participants completed questionnaires about their experience.

The TSST took place in the second phase of the visit and was fifteen minutes-long during which the stress response was monitored and recorded for each participant. Following the TSST, a rest period took place for ten minutes during which physiological indicators of stress will be recorded to assess the participants' physiological ability to recover from a stressful situation. They then answered questionnaires about their experience. After the recovery period, participants scheduled their following appointment with research assistants and received practice instructions for the week: "Breathing abdominally for 20 minutes, one time a day, will stabilize your automomic nervous system, blood pressure, and emotion, and prevent your symptoms from arising. Please do your best to practice the technique regularly. We don't know if it will have any immediate effects on your symptoms, so regular practice is very important."

Biofeedback visit 2. The purpose of the second visit was to introduce the participants to resonance frequency breathing using the emWave software. The emWave records heart rate readings using a pulse oximeter placed on the participant's earlobe. Blood pressure was also recorded throughout the session. Participants received the following instructions early in the session: "Today, we are going to practice breathing at the rate that will keep you the most balanced for help with your symptoms, about 6-breaths per minute. When you breathe at this rate, your breathing will produce calming effects on your nervous and cardiovascular systems. That is very good for you and may help you to control your symptoms. I will briefly explain what each measurement is." Before starting the procedure, a research assistant trained in biofeedback recorded two blood pressure readings two minutes apart and the participant completed the OQ-45. Following this, the research assistant presented the emWave screen and explained to the participant: "In this graph, the black line is your heart rate (HR) in terms of beats per minutes. You'll notice that the black line moves up as you breathe in and down as you breathe out. Your heart rate varies with each breath, and with various other processes in your body. Your heart rate speeds up as you inhale and slows down as you exhale. We call this variation of your heart rate as heart rate variability (HRV). This variability is good and is a sign of health. We will now let you practice breathing at 6-breaths per minute for three minutes. You should not find this task difficult. However, if you feel uncomfortable at any time, you can simply stop the task and tell us. You will be able to use this breathing rate to best help your symptoms. Breathe easily and comfortably, but not too deeply. Do not try too hard. Do you have any questions?"

The participant practiced for three minutes using a visual breathing pacer to become familiar with the slow rate of breathing. After the participant became comfortable with the slow paced breathing, he or she practiced again for fifteen minutes during which four blood pressure readings were recorded. Participants were asked to practice at 6 breath-per-minute using a free breathing pacer for 20 minutes about five times a week. The following instructions were given: "Breathing abdominally for twenty minutes, once a day, will stabilize your autonomic nervous system, blood pressure, and emotion, and prevent your symptoms from arising. Please do your best to practice the technique regularly. The benefits take time to develop so regular practice is very important." Questionnaires were emailed to them to assess the frequency and quality of practice during the week.

Biofeedback visits 3 to 5. The purpose of the third to fifth visits is to enhance diaphragmatic breathing practice and ensure that participants practice at the appropriate rate. During each of the visits participants completed the OQ-45 and a research assistant monitored and recorded blood pressure. Participants' heart rate variability was recorded using the EmWave program. Participants first practiced diaphragmatic breathing with a breathing pacer set at 6-breath-per-minute for eight minutes. After the practice participants continued breathing at 6 bpm, but with no pacer. During this practice blood pressure readings were recoded every two minutes. At the end of each visit participants were asked to practice diaphragmatic breathing for twenty minutes about four to five times a week. Questionnaires were emailed to them to assess the frequency and quality of their practice.

Biofeedback visit 6. During the last visit research assistants delivered the same protocol as the first visit to obtain a post-measure of the physiological stress response and recovery. Participants completed all questionnaires at the beginning of the appointment and then practiced the diaphragmatic breathing for fifteen minutes with no pacer while baseline measurements of stress were collected. The TSST was then administered to compare the stress response pre- and post-biofeedback training. Finally, the participants sat quietly for ten minutes while the research assistants measured their recovery stress profile.

Control condition. Twenty participants were randomly assigned to a control condition. These psychotherapy patients did not receive any stress management training and simply attended their psychotherapy sessions at the BYU Counseling Center. The participants assigned to the control condition attended three laboratory visits, two-weeks apart, and participated in the TSST.

Control condition visits 1 and 3. The first and last visits of the protocol included the same components as the protocol of the intervention group. Participants completed all questionnaires at the beginning of their visits and their physiological data was recorded using the Biopac Systems. Baseline data was recorded while participants watched nature videos for fifteen minutes. Following the baseline, the research assistants administered the TSST to the participants. During the TSST their stress response was also recorded every two minutes. They then engaged in a ten-minute recovery period.

Control condition visits 2. At the beginning of the follow-up appointment the control participants completed the OQ-45. After completion of the questionnaires the research assistant placed a blood pressure cuff on the participants' left arm. Participants will then be asked to sit back for fifteen minutes while watching nature videos. During the fifteen minutes their blood pressure was recorded three times at two-minute intervals starting at minute 10. At the end of the visit they will complete a questionnaire about their experience.

Results

Preparation of Data for Analysis

Cardiovascular data for each step (i.e., baseline, stress, and recovery) of pre- and post-intervention sessions were collected using the Acqknowledge 4.2 system (Biopac Systems, Inc) and imported to Kubios HRV Analysis Software v2.0 (Biosignal Analysis and Medical Imaging Group, Kupio, Finland) for analysis of HRV. Strong-level corrections were implemented using the artifact correction feature of the software to correct erroneous data. The following variables of HRV were collected in Kubios and averaged for each step of the procedure: (1) the root mean square differences of successive heartbeats (RMSSD), the standard deviation of normal to normal heart beats (SDNN), the power in low and high frequency ranges (LF and HF), and the LF/HF ratio. HRV data was missing for one participant of the control group in the pre-intervention session and for another participant of the control group in the post-intervention session due to problems with the Biopac System that led to flat physiological readings. Data was accounted for as missing data in the final statistical analysis.

Systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate data (HR) were also averaged to represent each step of the procedure. There was no missing blood pressure or heart rate data.

Outcome data was extracted from the OQ-45 questionnaires and checked for any missing data. Pre-intervention OQs were completed by all participants. One participant from each condition did not complete post-intervention questionnaires. As a result, there was one missing post-intervention OQ score in each group. Those scores were accounted for as missing data in the final statistical analysis.

Preliminary Analyses

Several analyses were conducted prior to running final analyses to test the hypotheses, including comparison of demographic characteristics and baseline data of the experimental and control groups, assessment of relations between different variables to identify potential covariates, and analysis of cardiovascular and affective responses to laboratory stressor to demonstrate that the TSST elicited significant changes in cardiovascular and emotional functioning.

Demographics Differences

Analyses (i.e., independent *t*-test; chi-square) were performed to evaluate potential differences between treatment and control groups regarding sex, BMI, and ethnicity, as well as differences in baseline blood pressure (i.e., SBP, DBP), heart rate, and levels of distress (i.e., OQ-45 scores). There were no significant differences in ethnicity, BMI, baseline levels of distress, blood pressure, heart rate, and OQ-45 scores between groups (*ps* > .05). However, despite randomization, there were significant differences in sex ($p < .05$), which shows that the control group had significantly more male participants than the experimental group. Table 1 summarizes demographic information for each group.

Table 1

Summary of Demographic Information of Study Participants

		Biofeedback	Control	Total
Gender	*Male*	2 (10%)	8 (40%)	10 (25%)
N (%)	*Female*	18 (90%)	12 (60 %)	30 (75%)
Race	*White*	18 (90%)	19 (95%)	37 (92.5%)
N (%)	*Other*	2 (10%)	1 (5%)	3 (7.5%)
BMI	*Mean*	24.13	22.72	23.43
	Range	17.47-35.27	13.35-30.61	17.47-35.27
	SD	4.35	3.68	4.04

(continued)

Table 1. Summary of Demographic Information of Study Participants (continued)

Baseline OQ	*Mean*	85.8	81.9	84.25
	Range	66-125	45-115	45-125
	SD	16.15	16.5	16.58
Baseline SBP	*Mean*	106.87	107.24	107.06
	Range	94-128.6	96-118	94-128.6
	SD	8.70	6.36	7.52
Baseline DBP	*Mean*	64.93	64.85	64.89
	Range	57-78.6	54.6-73.6	54.6-78.6
	SD	6.17	4.63	5.39
Baseline HR	*Mean*	68.96	67.92	68.44
	Range	50-82	45.3-92	45.3-92
	SD	9.23	11.13	10.11

Potential Covariates

As previous analyses demonstrated that sex was significantly different between groups, a correlational analysis was performed to determine potential significant relations between sex and the study's independent variables. The analysis revealed a significant relationship between sex and SBP ($p < .05$; see Table 2). Therefore, sex was taken into account as a covariate in analysis of this variable. It is important to note that, although BMI tends to be associated with systolic blood pressure, heart rate , and HRV (Bonnemeier et al., 2003; Felber Dietrich et al., 2006), it did not significantly differ between the groups of the present study and, as a result, was not taken into account in data analysis.

Table 2

Correlations Between Physiological Outcomes and Gender

		Gender
SBP		
	Baseline	.476*
	Pre-speech	.233
	Speech	.209
	Math	.426*
	Recovery 1	.274
	Recovery 2	.405*

Table 2. Correlations Between Physiological Outcomes and Gender (continued)

DBP	
Baseline	.034
Pre-speech	-.233
Speech	-.067
Math	.068
Recovery 1	-.045
Recovery 2	-.104
HR	
Baseline	-.126
Pre-speech	-.406
Speech	-.094
Math	-.148
Recovery 1	-.162
Recovery 2	-.138
SDNN	
Baseline	-.150
Pre-speech	.106
Speech	.003
Math	-.142
Recovery 1	.294
Recovery 2	-.50
RMSSD	
Baseline	-.013
Pre-speech	.038
Speech	.085
Math	.148
Recovery 1	.297
Recovery 2	-.147
LF	
Baseline	.012
Pre-speech	.111
Speech	.301
Math	-.137
Recovery 1	.260
Recovery 2	-.091
HF	
Baseline	.012
Pre-speech	-.002
Speech	-.032
Math	.042
Recovery 1	-.092
Recovery 2	-.146
LF/HF RATIO	
Baseline	-.045
Pre-speech	.081
Speech	.203
Math	-.146
Recovery 1	-.092
Recovery 2	-.146

Note: $^{*}p < .05$

Primary Analyses

Mixed factors 2 (Group: Biofeedback, Control) x 3-time (Baseline, Stress, Recovery) repeated measures of variance (ANOVA) were performed to evaluate differences in the physiological response to and recovery from stress between groups, and assess the effectiveness of the HRV biofeedback intervention. As mentioned above, gender was controlled for as a covariate in the analysis of SBP. The dependent variables included SBP, DBP, HR, SDNN, RMSSD, LF, HF, LF/HF ratio, and OQ-45 scores post-intervention, and baseline data from the pre-intervention session was ran as a covariate to assess change over time. Mauchly's tests of sphericity indicated that the assumption of sphericity was violated in the analysis of SDNN, RMSSD, LF, and HF (*ps* < .05; see Table 3). As a result, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity in those analyses.

In addition, a univariate general linear model was performed to compare levels of distress between groups pre- and post-intervention and assess change over time.

Table 3

Mauchly's Test for Sphericity for Repeated Measures ANOVAs

Within Subjects Effect	Mauchly's W	$\chi 2$	df	*p*	Greenhouse-Geisser	Epsilon Lower-bound
SBP	.855	5.487	2	*.064*	.873	.500
DBP	.967	1.224	2	*.542*	.968	.500
HR	.907	3.512	2	*.173*	.915	.500
SDNN	.000	289.305	2	*.000***	.500	.500
RMSSD	.110	72.69	2	*.000***	.529	.500
LF	.039	107.463	2	*.000***	.510	.500
HF	.824	6.386	2	*.041**	.850	.500
LF/HF	.930	1.734	2	*.420*	.935	.500

Note: **p* < .05, ***p* < .01

Blood Pressure and Heart Rate. 2 Group (Biofeedback, Control) x3-time (Baseline, Stress, Recovery) repeated measures analyses of variance (ANOVAs) were performed using post-intervention physiological data and baseline pre-intervention physiological data to evaluate main differences in blood pressure and heart rate responses to stress over time. The analysis yielded no significant main effect of time (*ps* > .05; see Table 4) on SBP, or HR compared to baseline in the post-intervention session. These results suggest that systolic blood pressure and heart rate were not significant impacted by the TSST. There however was a main effect of time on DBP in the post-intervention session, $F(2, 74) = 3.44$, $p < .05$, indicating that DBP reactivity and recovery were significantly different from baseline DBP in the post-intervention. This effect is illustrated in Figure 2.

Table 4

Main Effect of the TSST on Blood Pressure and Heart Rate Post-Intervention

	df	SS	MS	F	*p*
SBP Post-Intervention	2	42.27	21.13	.642	*.529*
Error	72	2369.64	32.91		
DBP Post-Intervention	2	67.3	33.65	3.44	*.037**
Error	74	724.57	9.79		
HR Post-Intervention	2	195.98	97.99	3.03	*.054*
Error	74	2389.45	32.29		

Note: * $p < .05$

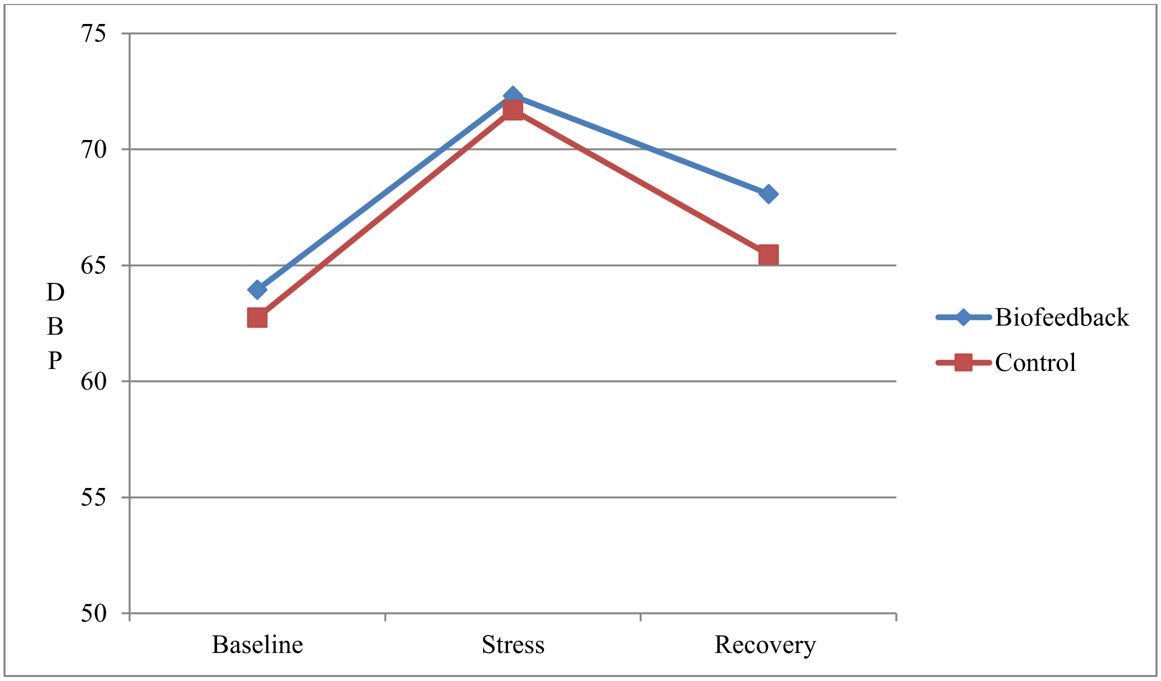

Figure 2. Main effect of TSST on DBP post-intervention.

In addition, the Group x Time Interaction revealed no differences between groups in SBP, DBP, or HR in the post-intervention session (all *ps* > .05; see Table 5), indicating that the groups did not differ in their blood pressure and heart rate response to and recovery from the TSST. Furthermore, there was no significant difference between post-session blood pressure and heart rate response to the TSST and pre-intervention baseline data (all ps > .05; see Table 5). These results indicate that the HRV biofeedback intervention did not significantly impact the response to and recovery from stress of the individuals who received it.

Table 5

Between Groups and Pre- to Post-Intervention Changes in Blood Pressure and Heart Rate

	df	SS	MS	F	*p*
SBP x Group	2	6.3	3.15	.096	*.909*
Error	72	2369.64	32.91		
SBP Post x Baseline	2	30.36	15.18	.461	*.632*
DBP Group	2	19.71	9.86	1.01	*.370*
Error	74	724.57	9.79		
DBP Post x Baseline	2	30.77	15.38	1.57	*.215*

Table 5. Between Groups and Pre- to Post-Intervention Changes in Blood Pressure and Heart Rate (contined)

HR x Group	2	75.91	37.95	1.175	*.314*
Error	74	2389.45	32.29		
HR Post x Baseline	2	76.85	38.43	1.19	*.310*

Heart Rate Variability. 2-Group (Biofeedback, Control) x 3-time (Baseline, Stress, Recovery) repeated measures analyses of variance (ANOVAs) were performed on HRV data (i.e., SDNN, RMSSD, LF, HF, LF/HF ratio). Results of the analyses yielded no significant main effect of the TSST on HRV indices compared to baseline (all *ps* > .05; see Table 6), which reveals that HRV did not change following exposure to stress. In sum, it appears that HRV did not respond to the TSST.

Table 6

Main effect of the TSST on HRV Post-Intervention

	df	SS	MS	F	*p*
SDNN Post-Intervention	1	321216.5	321191.5	.168	*.685*
Error	68	65080700.8	1913989.1		
RMSSD Post-Intervention	1.06	863.66	815.9	1.761	*.193*
Error	68	16670.7	463.23		
LF Post-Intervention	1.02	66344447.8	6506654.42	.018	*.897*
Error	68	1.238E+10	356982938		
HF Post-Intervention	1.70	4990.39	2934.21	.731	*.465*
Error	68	232094.37	4013.68		
LF/HF Ratio	1.87	34.6	17.3	.747	*.479*
Error	50	1157.67	23.153		

More importantly, the Group x Time Interaction revealed no differences in SDNN, RMSSD, LF, and HF post-intervention (*ps* > .05; see Table 7). However, there was a significant between group difference in LF/HF ratio post-intervention, $F(2, 50) = 4.851$, $p < .05$ revealing a long-lasting effect of the HRV biofeedback intervention on the ratio. In addition, the analyses revealed no differences between post-intervention HRV indices and baseline (all ps > .05; see Table 7), indicated that there was no long-lasting effect of the biofeedback intervention on HRV.

Table 7

Between Groups and Pre- to Post-Intervention Changes in HRV

	df	SS	MS	F	*p*
SDNN x Group	2	773976.1	773915.8	.404	*.669*
Error	68	65080700.8	1913989.1		
SDNN Post x Baseline	2	677504.8	677452	.354	*.556*
RMSSD x Group	1.06	1595.88	797.9	3.25	*.078*
Error	68	16670.7	463.23		
RMSSD Post x Baseline	1.06	1071.92	1012.68	2.186	*.147*
LF x Group	1.02	137138296.8	134496726.1	.399	*.547*
Error	68	1.238E+10	356982938		
LF Post x Baseline	1.02	62305346.6	61105215.2	.171	*.687*
HF x Group	1.701	5185.63	3049	.760	*.453*
Error	68	232094.37	4013.68		
HF Post x Baseline	1.701	12824.5	7540.46	1.879	*.167*
LF/HF x Group	1.87	224.63	120.14	4.851	*.014**
Error	50	1157.67	23.153		
LF/HF Post x Baseline	1.87	9.441	5.05	.204	*.802*

Note : * $p < .05$

In sum, it can be concluded that the HRV biofeedback intervention did not significantly impact blood pressure and heart rate overtime. In addition, the only HRV variable that appeared to be significant impacted by the intervention over time was the LF/HF ratio.

OQ-45. Independent *t*-test and univariate general linear model were run to compare OQ-45 scores at baseline and post-intervention. Results of the independent *t*-test are presented in table 8. Results of the analyses showed that the two groups did not differ in reported levels of distress pre-intervention. Scores on the OQ-45 above 63 represent clinically significant levels of distress, and changes of 14 points and above are significant changes (Lambert, 2013). The mean scores of the experimental group (M = 85.80, SE = 3.61) and the control group (M = 81.90, SE = 3.70) pre-intervention indicated that both groups reported levels of distress falling in the moderate range of distress, but were not significantly different (see Table 8).

Table 8

Comparison of Group Means Pre- and Post-Intervention

		Mean	SD	SE Mean	*t*	df	Sig.
Biofeedback Group	Pre-Intervention	85.80	16.45	3.611	.755	38	.455
	Post-Intervention	65.47	26.44	6.07	-1.235	36	.225
Control Group	Pre-Intervention	81.90	16.5	3.69	.755	37.98	.455
	Post-Intervention	74.58	18.25	4.19	-1.235	31.98	.226

Based on statistical significance presented in the questionnaire's manual, mean scores indicate that the biofeedback group reported significantly lower levels of distress post-intervention, as their mean scores displayed a twenty-point drop from pre- to post-intervention reports. However, the control group's scores did not significantly change according to Lambert et al.'s statistical standards, and only displayed a seven-point decrease in scores post-intervention (Biofeedback Condition: M = 65.47, SE = 6.05; Control Condition = 74.58, SE = 4.19). However, results of the univariate general linear model showed that there were no significant differences between groups post-intervention (*ps* > .05; see Table 9, and Figure 3). Although the score differences between groups were not statistically different post-intervention, the OQ-45 statistical standards indicate that the experimental group displayed a significant positive change in reported levels of distress, but not the control group.

Table 9

Test of Between Group Differences in Pre- to Post-Intervention OQ-45 Scores

	Type III SS	df	MS	F	*p*
Group	894.59	1	894.89	2.18	.149

Note: Dependent variable was post-intervention OQ-45 mean score

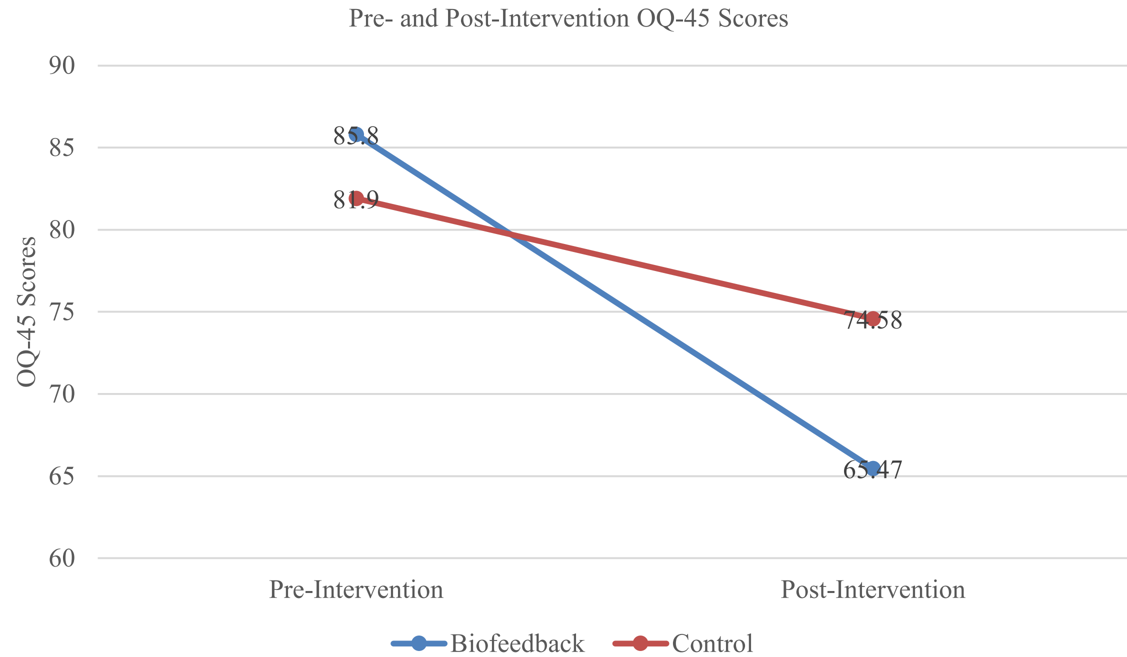

Figure 3. Comparison of Group Differences in Changes in OQ-45 Scores from Pre- to Post-Intervention.

Discussion of the Results

The present study was designed to evaluate the effectiveness of an HRV biofeedback intervention in reducing reported levels of distress in psychotherapy patients. HRV biofeedback has been shown to be an effective intervention in the treatment of various psychological disorders, including anxiety disorders, and depression (Henriques, Keffer, Abrahamson, & Horst, 2001; Karavidas, Vaschillo, Vaschillo, Marin, Buyske, & Hassett, 2007; Siepmann et al., 2008; Zucker et al., 2009). Previous research has shown the effectiveness of biofeedback in reducing anxiety symptoms when used as an adjunct intervention to psychotherapy. However, although the literature on HRV biofeedback continually increases, no study to date has examined the potential effect of HRV biofeedback in helping people benefit more from psychotherapy and improving outcome, by improving their physiological stress response. Previous studies have also lacked proper control groups to compare outcomes to.

A prior study (Steffen et al., 2014) demonstrated that psychotherapy patients reporting clinically significant levels of distress on the OQ-45 exhibited a higher physiological reactivity to stress and a slower recovery after exposure to a stressor. Other studies have shown that psychotherapy patients with lower physiological stress reactivity demonstrated significantly better outcome at the end of treatment (Ehrenthal et al., 2010). Therefore, the aim of the current study was to determine whether implementation of a six-week HRV biofeedback intervention as an adjunct to psychotherapy improved the physiological stress response and recovery from stressor, as well as psychotherapy outcome and levels of distress as evaluated by the OQ-45.

Blood pressure and heart rate.

Results of the study showed that there was no main effect of the TSST on SBP, and HR in the post-intervention session. Specifically, systolic blood pressure and heart rate did not significantly change during and after exposure to stressors, compared to baseline. However, there was a main effect of the TSST observed on DBP, in both the pre- and the post-intervention sessions, suggesting that diastolic blood pressure responded to the TSST. Furthermore, there were no differences between groups in SBP, DBP, and HR in the post-intervention session, indicating that the cardiovascular response of the participants who received the HRV biofeedback intervention did not differ from the response of those who did not. Additionally, there was no significant difference in blood pressure and heart rate when comparing post-intervention reactivity to pre-intervention baseline. The results of the study indicate that the HRV biofeedback intervention did not improve impact the blood pressure and heart rate reactivity to and recovery from stress after six weeks of practice.

Before concluding that results of the study conflict with the literature on the TSST, it is important to note that a main effect was observed on systolic blood pressure and heart rate pre- and post-intervention when not controlling for gender. The present results mean that the effect of the TSST differed by gender. In sum, the TSST was an effective tool of stress induction when not controlling for those variables, which has consistently been shown in the literature. Indeed, the TSST has been validated by multiple studies as a gold standard of laboratory stress induction (Miller & Kischbaum, 2013). Regarding the study's hypotheses, the results did not reveal a difference in reactivity to and recovery from stress between groups and from baseline post-HRV biofeedback intervention, revealing that the intervention did not have an effect on blood pressure. The HRV biofeedback literature has studied the impact of the intervention on individuals suffering from blood pressure related health conditions but not on healthy individuals. These studies have suggested that slow diaphragmatic breathing biofeedback was effective in lowering blood pressure in the treatment of individuals with hypertension (Lin et al., 2012; Wang et al., 2010). However, because of the vast differences in participants' characteristics, there are no studies to compare the present results to.

Heart rate variability.

Regarding HRV variables, the study found no main effect of the TSST on SDNN, RMSSD, LF, HF, and LF/HF ratio over time in the post-intervention session, revealing that changes observed during and after exposure to laboratory stressors were not significant compared to baseline. These results go along with the blood pressure and heart rate data and indicate that TSST did not impact the physiological stress response. In addition, the only HRV variable that differed between groups post-intervention was the LF/HF ratio. Overall the groups did not differ in their HRV reactivity over-time post-intervention, and did not show benefits of the 6-week biofeedback intervention in the post-intervention session. Furthermore, HRV reactivity and recovery did not significant differ from baseline pre-intervention response. In sum, it appears that the HRV biofeedback intervention did not improve participants' HRV over-time.

One other study within the HRV biofeedback literature has explored changes in HRV during exposure to stressors (Hallman et al., 2011). The study found that individuals who received HRV biofeedback displayed increased resting LF, increased overall HRV during stress, and increased SDNN at recovery, suggesting that the intervention improved HRV over time. Significant differences in population and protocol make comparisons between it and the present study difficult to draw. Indeed, Hallman et al. (2011) studied changes in HRV during exposure to a physical stressor in individuals with chronic stress-related neck pain, and the present study focused on college students presenting elevated clinically significant levels of distress. Therefore, although the present results should be interpreted with caution because of limitations that will be presented later, they show that laboratory induced stressors did not significantly impact HRV indices.

Regarding the non-significance of the present between group comparisons, it appears that the results conflict with previous biofeedback research. For instance, Karavidas et al. (2007) conducted a study on individuals diagnosed with major depressive disorder who participated in a 10-week HRV biofeedback training following the same protocol used in the present study (Lehrer, 2000). This study found that post-intervention SDNN and LF had significantly increased compared to pre-intervention data. However, it is important to note that the study did not use a control group to compare data. On the other hand, the current study's results appear to replicate previous findings relative to post-intervention baseline differences. Indeed, another study (Zucker et al., 2009), focused on individuals diagnosed with PTSD and found that individuals who received paced breathing biofeedback training demonstrated increased SDNN at baseline post-treatment, compared to a control group who received progressive muscle relaxation training. These studies and the results presented here provide evidence of long-term carry over benefits in individuals reporting psychological distress who received biofeedback training.

Psychotherapy outcome and levels of distress.

In a recent article, Lehrer explained that psychotherapy mostly focuses on cognitive and behavioral symptoms, and often ignores physiological factors that are significantly involved in the experience of psychological distress (Lehrer, 2016). In his article, he pleads for more rigorous research on the efficacy of biofeedback in the treatment of psychological distress and disorders. To this day, most studies that have studied HRV biofeedback in the context of mental health have focused on specific diagnoses rather than on the overall levels of distress and experience in psychotherapy. The second hypothesis of the present study regarded overall levels of distress post-treatment in patients attending psychotherapy. Results found, that although individuals in the biofeedback group reported levels of distress significantly decreased from pre- to post-intervention, there were no significant differences between groups in post-intervention OQ-45 scores. However, according to the OQ-45 standardized manual (Lambert et al., 2013), participants in the biofeedback condition seem to have benefited from the HRV biofeedback intervention, as their OQ scores post-intervention displayed a significant decreased of 20 points, whereas the control group only showed a drop of 7 points.

These results are similar to previous studies that have assessed changes in diagnostic-specific symptoms post-biofeedback training, and found that HRV biofeedback was a helpful intervention in the treatment of depression, anxiety, or PTSD. In addition, Ratanasiripong et al. (2012) conducted a study using biofeedback as an adjunct intervention to psychotherapy.

Participants were college students who attended four sessions of psychotherapy at their university counseling center, and four biofeedback sessions outside of the counseling center. Results of that study found that participants who received weekly counseling and weekly biofeedback demonstrated a higher reduction in anxiety symptoms than the control group who only received psychotherapy services, suggesting that the biofeedback intervention positively influenced symptom reduction. Although these studies did not address the same hypotheses as the current study, they can be used to argue in favor of the effectiveness of biofeedback training in the treatment of psychological disorders.

In sum, the current study found that a six-week HRV biofeedback intervention was not effective in improving heart rate variability indices and blood pressure reactivity to and recovery from stress post-intervention. Regarding blood pressure, the present results cannot be compared to past literature because of significant differences in population and methods. However, they appear to conflict with previous HRV biofeedback research results. Regarding psychotherapy outcome and overall levels of distress, the results of the study conflict with symptom-specific research that demonstrated significant benefits of biofeedback training in symptom reduction over time. However, there are no other studies to date that focused on using HRV biofeedback to improve psychotherapy outcome. Therefore, further research is needed to make solid conclusions regarding biofeedback as an adjunct intervention to psychotherapy.

Study Limitations and Recommendations for Future Research.

The current study presents several limitations that should be considered when interpreting its findings. First, the sample was small. Although most biofeedback studies have small sample size, if the field wants to continue growing and be established as an efficacious intervention, more methodological rigor should be expected from the studies. Our sample size prevents us from drawing solid conclusions as it might have been more subject to error and more sensitive to minor changes. In addition, gender and ethnicity were not evenly distributed between our groups and our sample was mostly comprised of white women. Therefore, our findings cannot be generalized across populations. Further research should seek more diversity in their samples in order to assess effectiveness of the intervention across populations.

Several aspects of the study's methods might have impacted the results. HRV biofeedback training was completed using the emWave system. The system was not designed for research use and, although it is widely used by biofeedback practitioners, no research protocol has been established for its use in clinical trials. The program manual provides guidelines for clinicians to follow indicated important steps and parameters of treatment delivery (Culbert et al., 2007), no research has validated specific protocols for implementation of interventions through the emWave. The present study followed specific biofeedback protocols (Lehrer, 2013) and followed the emWave manual for treatment delivery. In addition, the protocol developed for the study was standardized across participants and delivered by research assistants who received training in the use of the emWave. However, further research is needed to assess the efficacy of the emWave in a research setting, standardize training and delivery protocols, and develop a protocol that can be followed in clinical trials.

Another limitation of the study regards participants' adherence to practice. Participants in the biofeedback condition were instructed to practice biofeedback in-between sessions. Reminder emails were sent to them several times a week to complete practice. However, weekly home practice was no controlled for in the study because of lack of data. Although research assistants emailed participants questionnaires weekly to assess for practice, only a minority of participants completed the questionnaires and reported on practice. As a results, there was insufficient data to get a valid representation of participants' practice. Although changes in LF suggest that participants gained from practicing weekly (Lehrer, 2007), weekly home practice could not be concretely evaluated. In addition, although practice guidelines were given at the end of each laboratory visit, participants were asked to download a free software to complete practice, and they might not have completed the request. Future research on should implement more consistent control for home practice by asking participants to report on their practice at the beginning of each laboratory visit as e-mail reminders might not be enough and can easily be avoided. In addition, portable biofeedback device lent to the participants weekly might enhance our ability to control for practice and increase the likelihood of practice by participants. Accurate assessment of participants' weekly practice would enable researchers to make more reliable conclusions regarding the effectiveness of the intervention.

Regarding the lack of between group differences, it is interesting to note that the control group might have benefited from passive relaxation practice. As the results indicate the experimental group did not differ from the control group, it is important to wonder whether the absence of difference is due to HRV biofeedback itself or to the nature of the laboratory procedure used in the present study. In fact, control participants watched a nature video which is played with relaxing music. The nature of the video might have helped them relax without pressure to learn a new skill, pressure that might have impacted biofeedback participants. Future research should consider using a control group that does not engage in any type of relaxation.

An additional limitation to consider is related to the nature of the population. As shown in Figure 1, it was difficult to recruit participants that completed the full procedure. College students are known to not always be reliable due to academic stress and busy schedules. As a result, participants might not have been committed to biofeedback practice enough to notice an effect or a difference. As a result, their motivation to practice might have been negatively impacted.

A final limitation of the current study regards psychotherapy attendance. Because the HRV biofeedback intervention took place weekly, it would have been optimal for participants to attend weekly psychotherapy as well. However, just as most counseling centers in the nation, the counseling center where participants were recruited from encounters very high services demands during Fall and Winter semesters and often struggles to offer weekly psychotherapy services. As a result, the study was not able to control for psychotherapy attendance which presents a major limitation to the project. This limitation could explain lack of significant difference between groups in outcome data post-intervention as participants may not have attended as many psychotherapy sessions as biofeedback sessions.

Conclusions

Firm conclusions cannot be made in the present study due to significant methodological limitations, although some variables appeared significantly impacted by the intervention. The current study is one of a few studies to evaluate the use of HRV biofeedback training as an adjunct intervention to psychotherapy, and the very first to evaluate its impact on psychotherapy outcome. Further research is needed to evaluate long-lasting impact on treatment outcome and overall levels of distress. The biofeedback community will benefit from continuing improving research methods and practice in order to assert HRV biofeedback as a valid adjunct intervention to psychotherapy.

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