Effects of Respiratory Sinus Arrhythmia Biofeedback Versus Passive Biofeedback Control

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The objective of this study was to examine the acute effects of a portable respiratory sinus arrhythmia (RSA) biofeedback device as compared to passive biofeedback control on state anxiety, heart rate (HR), and Stroop task (Congedo, 2003) performance during repeated administration of the Stroop task cognitive stressor in a single brief session. Participants were individuals reporting stress levels at least 1 SD above the mean on the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). The RSA group had significantly reduced HR compared to the control group at postintervention and Stressor 2. Both groups significantly improved Stroop scores. Together, these preliminary results suggest that brief relaxation training can reduce state anxiety but that RSA biofeedback appears to have added benefits in reducing state anxiety and HR stress reactivity compared to passive relaxation techniques.

Keywords: respiratory sinus arrhythmia, anxiety, stress reactivity, biofeedback

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This work was funded by corporate Grant H1000 from Helicor, Inc (L. Sherlin).

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International Journal of Stress Management
2009, Vol. 16, No. 3, 233–248

1072-5245/09/$12.00 DOI: 10.1037/a0016047

There is now evidence demonstrating the efficacy of relaxation and meditation interventions in improving health and well-being (Agency for Healthcare Research Quality, 2007; Arias, Steinberg, Banga, & Trestman, 2006; Astin, Shapiro, Eisenberg, & Forys, 2003). Although numerous relaxation interventions have proven useful in reducing subjective and objective indexes of stress-related problems, far fewer studies have examined the impact of an intervention to reduce stress recovery and reactivity. Stress reactivity can be measured numerous ways, some of which include using subjective measures (Bolger & Zuckerman, 1995), such as heart rate (HR; Treiber, Kamarck, Schneiderman, Sheffield, Kapuku, & Taylor, 2003), HR variability (HRV; Berntson & Cacioppo, 2004), as well as neuroendocrine markers and immune responses (Cacioppo et al., 1998).

Cross-sectional and prospective studies have identified stress reactivity to be associated with illness severity and to be a predictor of later illness (Boyce et al., 1995; Cohen et al., 2002; Ehlert & Straub, 1998; Fernandez & Sheffield, 1995), particularly cardiovascular disease (Larkin, 2005; Treiber et al., 2003). In their review, Treiber and colleagues revealed that higher HR reactions to laboratory stressors are associated with increased likelihood of developing cardiovascular disease, and that reactivity is a better predictor of disease than resting HR. Consequently, it is important to examine whether the impact of an intervention reduces stress reactivity, rather than simply reducing overall arousal during resting conditions.

An early study by Goleman and Schwartz (1976) revealed that experienced meditators improved recovery from stressors compared to controls. In general, studies have supported that experienced meditators reduced stress reactivity (Cahn & Polich, 2006), and that meditation training can reduce subjective measures of perceived stress (Deckro et al., 2002; Nakao et al., 2001; Williams, Kolar, Reger, & Pearson, 2001). A number of studies have revealed that HR biofeedback with a practitioner can reduce HR during a stressor as compared to no-treatment controls or single-group designs (Goodie & Larkin, 2001, 2006; Larkin, Manuck, & Kasprowicz, 1989, 1990; Larkin, Zayfert, Abel, & Veltum, 1992; Sharpley, 1994). No studies to date have examined the impact of biofeedback techniques on stress reactivity using randomized, controlled trials with alternate relaxation techniques, in novices after a brief 15-min training period. In a more recent study, Rausch, Gramling, and Auerbach (2006) found that 3 to 4 min of training in progressive muscle relaxation (PMR) or meditation and a 20-min intervention period produced significantly improved recovery after a cognitive stressor suggesting that biofeedback techniques may be a viable avenue as a therapeutic intervention when only a brief time is available to the client.

In recent years, a body of literature has emerged on the efficacy of computer-based HRV/respiratory sinus arrhythmia (RSA) biofeedback in treating a variety of stress-related conditions, including asthma, hypertension,

anxiety, pain, depression, and heart disease; and in improving respiratory efficiency, performance in sports and at work, and overall cardiac health (Lehrer & Woolfolk, 2007). HRV biofeedback is designed specifically to reduce autonomic reactivity and attempts to regulate homeostatic mechanisms (Lehrer, Vaschillo, Vaschillo, Lu, Eckberg, Edelberg, et al., 2003; Lehrer, Carr, Smetankine, Vaschillo, Peper, Porges, et al., 1997). There are several methods for conducting HRV biofeedback, including using the RSA HR wave. RSA is the natural fluctuation of the HR in real time and is highly influenced by respiration and limbic activity. Training using the RSA wave involves individuals slowing their breathing to a rate that is unique to them so that the RSA amplitude is maximized. When the proper breathing rate is found, called the individual's "resonance frequency," real time HR and respiration covary in a perfect phase relationship such that users inhale until their HR peaks and exhale as it falls, until it begins to rise again (Vaschillo, Vaschillo & Lehrer, 2004). When this occurs, the baroreceptors are stimulated, strengthening the overall capacity of the body's homeostatic function (Lehrer et al., 2003). Gevirtz and Lehrer (2003) cited that RSA biofeedback systems increase vagal activity, promote relaxation, stimulate baroreflexes, and increase the efficiency of cardiac reflexes. In turn, this should increase the modulation of autonomically and emotionally mediated reflexes throughout the body (Lehrer et al., 2003).

The objective of this study was to examine the acute effects of a portable RSA biofeedback device versus a control group on state anxiety, HR, and Stroop word task (Congedo, 2003) performance in persons reporting moderate to severe levels of stress. The study was specifically designed to examine the effects of these interventions in novice users following 15 min of training in a single session. The importance of brief training along with objective feedback is clear when examining the barriers to the integration of relaxation/meditation techniques into mainstream medicine practices. Astin, Goddard, and Forys (2005) found that some of the barriers to physicians' integration of alternative medicine techniques into their practice included the providers' belief that they were unqualified to use these techniques and a lack of sufficient time to integrate them into practice, suggesting that empirically tested, brief interventions offering objective feedback may be useful for these practitioners.

METHOD

Participants

The participants were 43 of 121 healthy adults who responded to advertisements targeting adults self-reporting that stress was having an impact on

their lives. Patients were included if they were between 18 and 50, scored 1 *SD* above the normative mean measured by the Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983), and could obtain a regular pulse reading on the device. Participants were excluded if they were pregnant, reported previous relaxation-induced anxiety, had bipolar disorder, substance use disorder, and/or psychotic disorder, were regularly taking beta blockers or heart medication, bronchodilators, respiratory stimulants, antidepressants, thyroid supplements, anti-anxiety medications, mood stabilizers, anticonvulsants, antipsychotic medication, and/or steroids, used a pacemaker, had a medical disorder that significantly affects respiratory function, circulation or HR, were unwilling to abstain from PRN medications prior to the intervention, were unable to comprehend the consent form quiz, and/or were visibly intoxicated. These exhaustive criteria were excluded in attempt to obtain a homogeneous as possible group of individuals who were experiencing significant stress to make conclusions regarding the effect of RSA biofeedback on stress in the absence of confounding variables.

Of a total of 121 participants who were screened out of a pool of individuals primarily from the Phoenix and Mesa, Arizona areas, 80 were eligible based on the phone screening, 46 came in for an interview, and 43 participants completed the protocol. Of the 41 who were not eligible for the interview, 22 had PSS scores below the cut-off score of 17 (men) or 19 (women). A total of 34 participants decided not to participant after screening or did not show for their scheduled appointment. Of the 3 participants who did not complete the interview, 1 was excluded due to sensor errors on the device, 1 did not complete the intervention due to computer problems during data collection, and 1 needed to be rescheduled due to computer problems but never returned. Participants were primarily excluded due to low stress levels.

The study was performed at Q-Metrx and Valley Sleep Center Labs in Los Angeles, California ($n = 4$) and the East Valley Neurofeedback and Peak Performance Center in Mesa, Arizona ($n = 39$). Recruitment was significantly less at the Los Angeles site. The procedures were approved by the Western IRB, an independent IRB.

Assessments

The PSS (Cohen et al., 1983) is a 10-item global measure of self-appraised stress (e.g., “In the last month, how often have you been upset because of something that happened to you unexpectedly?”). Respondents were asked to rate the extent of agreement with these items across a 5-point Likert-type scale ranging from 0 (*never*) to 4 (*very often*). Higher scores reflect elevated levels of stress. Test–retest reliability and construct validity

have been shown to be acceptable (Cohen & Williamson, 1988). The scale range is from 0 to 40. To be enrolled participants had to score 1 *SD* above the mean as previously reported (Cohen & Williamson, 1988). The internal consistency in the current sample was .78, which is slightly lower than previously reported by Cohen and Williamson (1988). The PSS was only used as a phone screening measure.

The Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998) is a brief, structured interview used to diagnose Axis I disorders according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed. American Psychiatric Association, 1994) and *International Classification of Diseases–10* (WHO, 1992) criteria. The MINI has been shown to be reliable in multicenter clinical trials and in epidemiological and clinical studies, and is administered in a median of 15 min. It was used to screen out participants with Axis I diagnoses, which may skew results such as obsessive–compulsive disorder.

The State Trait Anxiety Inventory–State Form (STAI–S; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a 40-item self-report instrument used widely in anxiety disorder research (Barlow, 1988). It is composed of two subscales measuring state anxiety (current) and trait anxiety (dispositional). The current study uses the 20-item state anxiety scale (STAI–S), which has been shown to be sensitive to changes in transitory anxiety. Each item is measured on a 4-point scale, ranging from 1 (*not at all*) to 4 (*very much so*). The scale has shown excellent reliability and validity across populations (Spielberger, 1989). The internal consistency in the current study was .90 for baseline and .91 for postintervention. The STAI–S was used as an outcome measure as well as to randomize participants.

HR measurements were collected via the NeXus-10 physiological monitoring system (Mind Media, B. V., The Netherlands). Mean HR data were collected via ECG and photoplesysmography over 30-s intervals.

The modified Stroop task (Congedo, 2003) was performed on a computer. This task entails the presentation of a cue word, the name of one of four colors (red, blue, green, or yellow) presented in the center of a computer monitor on a white background (400-ms duration, 2 cm in height). The cue word was presented either as: (a) congruent—the presented word was either "red," "blue," "green," or "yellow" with the font in the same color, or (b) incongruent—the presented word was either "red," "blue," "green," or "yellow" with a font of a different color. The participant was required to respond as quickly as possible on a mouse by left button clicking if the color of the word (if the *color* of word is red, blue, green, or yellow) and the word itself (if *color* of word is green) on the screen are congruent or right button clicking if they were incongruent. Participants were required to use only their index fingers to press the relevant response button (right or left mouse buttons). To increase performance stress, the interviewer prompted the participant to

"hurry up please" at 1 and 3 min during the task. Each (pre- and post-) modified Stroop task entailed 330 color-word prompts with 1- s response period allowed. The test consisted of 50% congruent and 50% incongruent color words, to increase the cognitive demand on the participants. The Stroop task was used as an outcome measure and as a cognitive stressor to measure stress reactivity and was not a standardized version.

Study Treatments

Participants were randomized to either the 15-min active relaxation HRV biofeedback group or the 15-min control group.

RSA Biofeedback (RSA)

The HRV biofeedback device (the StressEraser; Helicor, Inc., New York, NY) an over-the-counter noninvasive biofeedback device that displays the natural rise and fall of real-time pulse-by-pulse activity as a wave (RSA) on the screen via an infrared finger sensor. Participants were instructed to slow their breathing to a rate that is unique to them by inhaling until their HR peaks as marked on the device by a triangle and exhaling as the wave falls, until it begins to rise again. This causes real-time HR and respiration to covary in a perfect phase relationship when done correctly. Each time an individual RSA wave meets a certain wavelength threshold ($\geq$ 10 s), users receive a "point" on the device. The number of points obtained on the device is an indicator of efficiency performing the activity correctly. Higher points indicate greater efficiency in increasing RSA. For example if in a 15-min period, one user received 50 points on the device while another receives 80; the latter participant had larger RSA waves during the intervention. Because worrying thoughts can affect HRV (Mashin & Mashina, 2000), users were also instructed to say a focus phrase or count during their exhale. Users were instructed to follow the feedback on the device to obtain long, smooth waves and achieve points successively. The number of points obtained during the 15 min was used to examine the dose-response relationship in this condition.

Passive Biofeedback Control

The passive biofeedback control alternate intervention device was a StressEraser with an altered wave that still responded to their physiology, but participants had no indication of how to manipulate the wave. This was done

by altering the algorithm so that the wave was "smoothed" to display HR over 10-s intervals rather than in real time. Participants were instructed to watch the wave and "let go" of stressful thoughts to help their mind sync with their blood circulation. They were not instructed to breathe at a specific rate. This condition was specifically designed as a control that included brief stress reduction techniques. During the training, participants were given materials on the mind–body connection and on how focusing on their physiology aids relaxation.

Procedures

Participants were recruited via targeted passive techniques using flyers in medical offices, online advertising, and print advertisements in local newspapers. The recruitment materials specifically targeted a mix of urban and rural individuals who were "stressed out." On calling the research centers, participants were asked to give verbal consent to complete a brief questionnaire to determine eligibility, without obtaining identifying information. If eligible, an appointment was scheduled. During the assessment, eligibility was further determined to assess for Axis I disorders using the MINI (Sheehan et al., 1998). Once enrolled, participants completed the STAI–S (Spielberger, 1989) and were randomized into groups based on STAI–S scores to stratify groups. Once the baseline STAI–S was completed, investigators randomly chose from envelopes grouped based on STAI–S scores that included the participants' group assignment. Once randomized, participants were given a 15-min overview for each device. RSA training included explaining the rationale behind the device and instructing how to manipulate the device to achieve long, smooth waves. Once the participant could manipulate the device, they were stopped so as not to affect baseline objective measures. Because the control group was not required to do anything except observe the wave and let go of stressful thoughts, much of the 15 min was spent discussing the rationale behind the device and how it works.

Participants were then seated and the instrumentation was applied. These were a 19-channel EEG and an ECG. EEG and other psychophysiological indexes will be examined in a future paper. Once all sensors were applied, six separate assessment periods were recorded:

1. A 5-min baseline recording while listening to a narrated audio compact disk on the history of England to distract them from focusing on their physiology.
2. A 5-min cognitive stressor (Stroop Word Color Task).
3. 15 min of active biofeedback or passive biofeedback control.

4. A 5-min postintervention rest period (audio compact disk).
5. A 5-min cognitive stressor, repeated (Stroop Word Color Task).

All participants were debriefed following the study and given a reimbursement of $25.

The data were examined using a repeated-measures analysis of variance (ANOVA) model. A repeated-measures ANOVA was used to examine change across all time periods. Dose response analyses in the RSA group were performed using hierarchical linear regression models with the baseline STAI–S score entered into Step 1, RSA efficiency entered into Step 2, and Time 2 STAI–S as the dependent variable. Paired sample *t* tests were used to measure within group differences. Exploratory analysis of the STAI–S scores revealed that one participant had the lowest possible score (20) at baseline and was subsequently removed from the STAI–S analysis. Based on results from the Stroop task, several statistical outliers were removed, consisting of participants who had more than 30% incorrect responses at baseline. This included 2 participants in the control group and 1 participant in the experimental group.

RESULTS

Of those enrolled with valid data ($N = 43$), 48.8% were women, 74.4% were White, 16.3% were Hispanic/Latino, 9.3% were African American, 21.4% were unmarried, 92.9% were high school graduates, 81.4% were employed or full-time students, and the mean age of the sample was 33.2 ($SD = 8.77$) years. The mean score on the PSS was 26.00 ($SD = 4.67$), indicating levels of stress of about 2 *SD*s above the mean from normative samples and 1 *SD* above the mean in clinical samples (Cohen & Williamson, 1988). The mean for the baseline STAI–S was 45.95 ($SD = 11.66$), which is approximately 1 *SD* above the normative mean (Spielberger et al., 1983). The correlation between the PSS and STAI–S at baseline was fair, $r(42) = .45$, $p < .01$. There were no significant differences between groups for demographic or intake variables, except that participants in the control condition were more likely to be employed full time. Employment status was not significantly associated with any outcome variables. There were no significant gender or ethnicity effects on outcome. The average number of points achieved during the 15-min intervention in the RSA group was 59.43 ($SD = 17.53$) indicating moderate efficiency.

Results indicate that participants in the RSA group and the control group significantly reduced their STAI–S scores, $t(19) = 5.36$, $p < .0001$ ($M = 47.80$; $SD = 12.02$ to $M = 33.54$; $SD = 11.54$) and $t(21) = 3.97$, $p < .001$

($M = 44.27$; $SD = 10.19$ to $M = 37.68$; $SD = 11.05$), respectively, but that participants in the RSA group were significantly more likely to reduce their STAI–S scores when compared to the control group, $F(1, 41) = 6.23$, $p < .05$ (Cohen's $d = .77$). All 20 items on the STAI–S significantly decreased in the RSA group, as opposed to 5 of 20 items in the control group. The largest between-groups effects were in feeling calm, content, and at ease.

When controlling for baseline scores using multiple-hierarchical regression, the more points users achieved in the RSA group, the more likely they were to report improvement on the STAI–S, $\beta = -0.513$; incremental $F(18) = 8.99$, $p < .01$. Points achieved uniquely accounted for 26.2% of the variance in STAI–S improvement. Points were awarded for obtaining long, smooth RSA waves. Figure 1 is a graphical representation of the change in STAI–S score for those who scored above versus those who scored below the mean points achieved. There was no dose response for HR changes in the RSA group. A statistical trend existed between change in HR from baseline to postintervention and change in STAI–S scores, $r = .31$, $p = .08$.

HR was examined at each assessment time point. Using a repeated-measures ANOVA, results indicate that there was a significant difference between groups in the overall model when examining all five time points, $F(4, 29) = 3.69$, $p < .05$ (see Figure 2). Significant differences between groups existed from baseline to postintervention, $F(1, 32) = 4.92$, $p < .05$; baseline to Stressor 2, $F(1, 33) = 8.12$, $p < .01$; and Stressor 1 to Stressor 2, $F(1, 33) = 4.93$, $p < .05$; the RSA group reported significantly reduced HR as compared to the control group. No other significant differences between groups existed.

Stroop results indicated no significant differences between groups in any domain measured ($p > .05$ for all), including incorrect versus correct response, reaction time, and missed responses, although some trends existed.

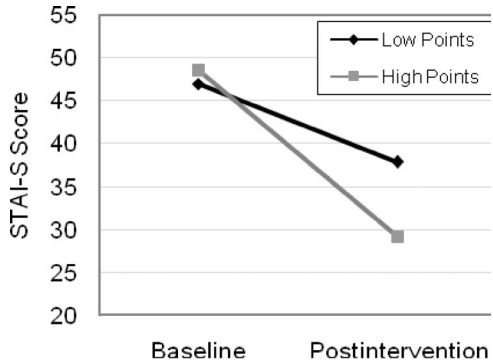

Figure 1. State anxiety dose response. High and low points were divided based on the mean points obtained during the intervention (59.43). STAI–S = State–Trait Anxiety Inventory–State Form.

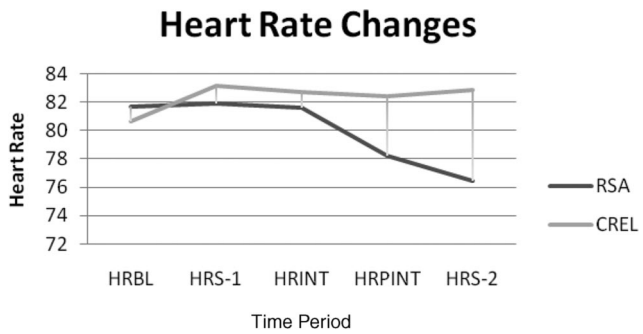

Figure 2. Heart rate changes. Each time period was 5 min. RSA = Respiratory Sinus Arrhythmia Biofeedback; CREL = Concentrative Relaxation (Passive Biofeedback); HRBL = Baseline; HRS–1 = first Stroop task; HRINT = intervention; HRPINT = postintervention; HRS–2 = second Stroop task.

The RSA group and control group significantly reduced errors from Stroop 1 to Stroop 2, $t(19) = 5.35$, $p < .0001$ and $t(17) = 2.74$, $p < .05$, respectively. A small effect (Cohen's $d = 0.29$) was found in favor of the RSA group in terms of reduced errors. There was no significant relationship between Stroop performance and state anxiety or HR changes.

DISCUSSION

Overall, these preliminary results support the beneficial effects of both stress reduction techniques in improving cognitive performance and state anxiety in persons reporting stress, but indicate that RSA biofeedback appears to be more effective in reducing state anxiety and HR and inducing feelings of calm as compared to passive biofeedback control.

There are numerous studies that indicate that relaxation can have profound effects on physiology, but to our knowledge very few (e.g., Rausch et al., 2006) examined the effects of brief training and a brief intervention period using randomized controlled procedures. The benefits of a brief training and intervention period appear to be particularly useful in settings in which time constraints limit patient contact. Relaxation/meditation studies labeled as short term typically require extensive training. For example, a study by Shapiro, Astin, Bishop, and Cordova (2005) was labeled "short term" with an 8-week intervention consisting of 2-hr sessions. Another recent study by Tang and colleagues (2007) that found dramatic results was labeled short term after 5 days of intensive training. There is now evidence that extended practice time may not be necessary to improve efficacy; in addition, it can prevent people from being compliant with meditation interventions

(Astin, 1997; Rausch et al., 2006; Sagula, 2000). Short-term initial training periods and brief intervention periods may help motivate clients learn and adhere to relaxation training and may help generalize the dissemination of these techniques to areas in which time constraints limit extended training time, such as the primary care setting.

The dose-response relationship for state anxiety during intervention is interesting for several reasons. Those who scored more points during the 15-min period were significantly more likely to reduce their anxiety scores than those with lower scores. Similar results have been reported by Hauri (1981), who found in a sleep study that the amount of feedback learning correlated significantly with sleep improvement, indicating that performing the activity correctly is an important indicator of outcome. Objective feedback combined with a record of the training clearly sets biofeedback interventions apart from other relaxation techniques. These results have important implications for the use of feedback during relaxation training to assess both one's ability to perform the activity correctly and the possible benefit derived from the training. Without such objective feedback on efficiency, it is difficult to determine who is performing the activity correctly and who is not. The drawback of objective feedback is that the loss of the initial expectancy effect can be quite powerful (Delmonte, 1985). Without objective feedback, participants may note a benefit while not performing the activity correctly because they believe that an effect is occurring. In turn, this can increase feelings of self-efficacy and motivation, which can guide persons through the learning stage. In contrast, those who are aware that they are performing poorly may become frustrated and discontinue the training without additional guidance.

Although the majority of participants in the RSA biofeedback group were able to perform the technique at least moderately well, about 30% of participants were unable to use the device efficiently following the training, as evidenced by limited points during the 15-min intervention period. Consequently, although the brief training involved is transferred well to the majority of participants, a large subgroup of participants with difficulty learning may require more than a brief training period. In a study in which the same RSA biofeedback device was used over a 3-week period, Reiner (2008) suggested that the integration of guided relaxation techniques such as diaphragmatic breathing or computer based assisted biofeedback prior to introducing self-guided biofeedback can be useful. Training in slow, paced breathing prior to office based HRV biofeedback has also been suggested by Lehrer (Lehrer, Vaschillo, & Vaschillo, 2000). It should be noted that those who performed in the bottom half of efficiency still significantly reduced their state anxiety, but the effects were only slightly better and were not significant when compared to the control group. Consequently, poor performance may have contributed to the dose response. Alternatively, those who

performed better may have simply felt more relaxed because they were breathing in better synchronicity with their HR. Moreover, baseline state anxiety was measured prior to the initial cognitive stressor and may have reduced the effect of both interventions at follow-up.

The control condition had significant within-group reductions on state anxiety and significantly reduced errors on the Stroop task. This suggests that simply sitting and focusing on a wave pattern of one's HR and being told to reduce stressful thoughts while holding this belief can reduce stress, even in the absence of slow RSA breathing, can have an effect on reducing symptoms of anxiety. In some respects, the current investigation can be considered a dismantling study, comparing the effects of viewing a wave on a biofeedback device with those of viewing the wave along with manipulation of the wave through RSA biofeedback. It is not surprising that significant changes were made in the control group. As Van Dixhoorn (2007, p. 302) highlighted, "Providing a single focus of attention is the most common way to relax and reduce tension." For example, Carrington and collègues (1980) showed significant decreases in measures of depression and anxiety using 15- to 20-min sessions with a concentration/meditation technique. It is also possible that adding the suggestion of syncing the mind with "blood circulation" may have caused an expectancy effect.

The powerful effects of concentrative relaxation may have accounted for the lack of significant differences between groups on the Stroop task. There was a small effect in favor of the RSA group, but it is difficult to draw any firm conclusions based on this study, considering there were no significant group differences as well as the practice effects associated with repeated Stroop task administration. Although RSA biofeedback and concentrative relaxation techniques may improve Stroop performance, further research should be performed to examine the utility of these relaxation strategies in increasing a variety of cognitive performance domains.

The differences in HR for postintervention recovery and Stressor 2 suggest that the RSA group had significantly reduced stress reactivity as compared to the control group. Numerous studies indicate that increased HR and HR reactivity is an independent risk factor for later illness and health problems (Moseley & Linden, 2006; Treiber et al., 2003). Although overall reductions are important, reductions in HR during stressful situations may combat the negative physiological effects of stressors because they inhibit sympathetic activity during stress, therefore limiting the harmful effects of the stress response. Results of the present study suggest that RSA biofeedback has a carryover effect that reduces HR reactions to a repeated stressor. To our knowledge, this is the first randomized, controlled trial comparing two active interventions that has found, based on objective measures, that one is superior to the other in reducing HR stress reactivity.

This study has several limitations, including a small sample size, a laboratory-induced cognitive stressor that may limit the generalization to

real-world stressors, and a brief assessment period. In particular, the brief intervention period limits the real-world application of these findings. Although several studies using HRV/RSA biofeedback (Lehrer & Woolfolk, 2007) and studies using the StressEraser (Kennedy & Pretorius, 2008; Reiner, 2008; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009) have revealed that there are long-term changes associated with this technique, the results of the current study cannot be generalized to long-term changes in HR or anxiety. It is also noteworthy that dose-response analyses were not significant for HR analyses. Therefore, it is difficult to determine the specific mechanism of the reduced HR following the intervention, apart from a contribution from slow breathing. Future studies would benefit from long-term assessments of unassisted breathing techniques, concentrative only interventions and no-treatment controls as compared to biofeedback driven interventions, to help understand the common and unique mechanisms of each of these interventions. Although the differences in HR were not significant at baseline, it is possible that the RSA group who had higher a beginning HR made greater changes because of a regression to the mean. Moreover, the Stroop task may not have been an adequate stressor as noted by the minimal HR changes—particularly in the RSA group. This may suggest that they were less reactive prior to the intervention. It is possible that a more pronounced stressor may not have revealed the same findings with respect to HR reactivity or with postintervention state anxiety. The fact that significant findings occurred is rather incredible, showing that the RSA biofeedback technique has acute effects that are easily obtainable, in most people, even when the individual has not yet acquired optimal skill in the technique when compared against a control with some active treatment components. In either condition, it is clear that nonpharmacological relaxation interventions can have a profound impact on subjective and objective markers of health and should be integrated into mainstream medical practice as a useful and safe alternative to first line pharmacological interventions.

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