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Positive emotion reduces dyspnea during slow paced breathing

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Abstract

Slow breathing is used to induce cardiovascular resonance, a state associated with health benefits, but it can also increase tidal volume and associated dyspnea (respiratory discomfort). Dyspnea may be decreased by induced positive affect. In this study, 71 subjects (36 men, $M = 20$ years) breathed at 6 breaths per min. In condition one, subjects paced their breathing by inhaling and exhaling as a vertical bar moved up and down. In condition two, breathing was paced by a timed slideshow of positive images; subjects inhaled during a black screen and exhaled as the image appeared. Cardiac, respiratory, and self-reported dyspnea and emotional indices were recorded. Tidal volume and the intensity and unpleasantness of dyspnea were reduced when paced breathing was combined with pleasant images. These results show that positive affect can reduce dyspnea during slow paced breathing, and may have applications for induced cardiovascular resonance.

Descriptors: Dyspnea, Emotion, Cardiovascular resonance, Heart rate variability, Paced breathing

Resonance is an occurrence in which an oscillation at a specific frequency appears in a system in response to perturbation (Vaschillo, Vaschillo, Pandina, & Bates, 2011). This principle has been applied to the cardiovascular (CV) system through the use of paced respiration at 6 breaths per min (i.e., 0.1 Hz, a dominant resonant frequency in the CV system), which produces cardiovascular resonance (i.e., large fluctuations in heart rate and blood pressure). This technique is viewed as a form of heart rate variability (HRV) biofeedback in which the goal is to amplify 0.1 Hz oscillations in HRV (Lehrer, Vaschillo, & Vaschillo, 2000). Preliminary studies indicate that patients with various autonomic dysfunctions can benefit from slowing their respiration to this pace (Hassett et al., 2007; Karavidas et al., 2007; Lehrer et al., 2003; Nolan et al., 2005). Breathing at this rate forces the autonomic nervous system to continuously regulate the resultant CV changes, thereby exercising and eventually strengthening autonomic control over hemodynamic events. However, 6 breaths per min is considerably slower than the average respiration frequency, which is typically 12–20 breaths per min (i.e., 0.20–0.33 Hz) in healthy resting adults (Sherwood, 2006; Tortora & Anagnostakos, 1990). Consequently, breathing at this slow pace can be uncomfortable and difficult for a novice to maintain. The present study examined the utility of a positive emotion induction to attenuate respiratory discomfort (i.e., dyspnea) and consequent negative affect during slow breathing exercises.

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Cardiovascular Resonance

Comprehension of the general concept of resonance is required to understand how slow breathing protocols induce resonance in the CV system. A classic example of resonance is that of a person being pushed on a swing. The push must be in rhythm with the swinger's momentum. Resonance between the natural swinging motion and the applied force makes the swing go higher than before. The same methodology can be applied to the CV system by breathing at a rate which resonates with inherent rhythms in heart rate.

Fluctuations in heart rate that are linked to the respiration frequency are known as *respiratory sinus arrhythmia* (RSA; Angelone, & Coulter, 1964). Heart rate increases during inhalation and decreases during exhalation. RSA coincides with respiration rate, and so usually occurs in the broad range of average breathing frequencies (0.12–0.40 Hz; Allen, Chambers, & Towers, 2007). However, if respiration rate is slowed to about 6 breaths per min, the pattern of RSA overlaps with inherent 0.1 Hz oscillations in heart rate related to blood pressure modulation (Vaschillo, Vaschillo, & Lehrer, 2006). The point at which these low frequency oscillations overlap with RSA is known as the resonant frequency because the two signals summate and produce large variations in heart rate.

Cardiovascular Resonance as a Treatment of Autonomic Dysfunction

Why should treatment of autonomic dysfunction focus on CV resonance? Heart rate variability has been a target of treatment studies due to its demonstrated salubrious effects on a wide variety of physical and mental health outcomes. For example, increased 0.1 Hz HRV induced by slow paced breathing has been used beneficially in the treatment of autonomic dysfunctions associated with coronary heart disease, hypertension, asthma, fibromyalgia, posttraumatic stress disorder, and depression (Hassett et al., 2007; Karavidas et al., 2007; Lehrer et al., 2003, 2004; Nolan et al., 2005; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). Patients in these studies were instructed to slow their respiration to about 6 breaths per min because previous research has shown that HRV generally increases as respiration rate decreases, and that this effect plateaus at about 6 breaths per min, the rate which produces resonance, or maximal increases in HRV (Hirsh & Bishop, 1981).

The 0.1 Hz resonant frequency of the CV system is thought to be due to the mechanisms of the arterial baroreflex (Vaschillo, Lehrer, Rishe, & Konstantinov, 2002; Vaschillo et al., 2011). Treatments that utilize paced breathing to amplify 0.1 Hz oscillations in heart rate and blood pressure have been shown to strengthen the baroreflex system (Lehrer et al., 2003). The underlying theory is that fluctuations in blood pressure activate baroreceptors in the aortic arch and carotid arteries, which elicits autonomic modulation of heart rate to balance changes in blood pressure. This feedback loop, also known as the baroreflex, promotes CV stability and flexibility by exciting or inhibiting parasympathetic and sympathetic activity as needed. Stronger autonomic control over the CV system increases the body's ability to handle a variety of cardiac changes induced by affective and environmental events (Berntson, Norman, Hawkley, & Cacioppo, 2008).

Many patients with autonomic dysfunction would logically benefit from a treatment that increases their ability to adapt to physiological change. For example, cardiac patients with stronger baroreflexes have been shown to recover faster from myocardial infarction (Rovere, Bigger, Marcus, Mortara, & Schwartz, 1998). Patients with chronic heart failure have used slow breathing exercises with short-term effects on the baroreflex similar to captopril, an angiotensin-converting enzyme inhibitor used in the treatment of hypertension (Bernardi et al., 2002). Furthermore, asthmatics have benefited from slow paced breathing by improving autonomic control and attenuating vagal hyperactivity during asthma attacks (Lehrer et al., 2003, 2004). Methodologies that induce cardiovascular resonance are well established; however, standardized treatment protocols are still being developed.

Methodological Issues with Inducing Cardiovascular Resonance

Clinical studies have typically adopted a regimen that includes one slow paced breathing session per week for 10 weeks (Hassett et al., 2007; Karavidas et al., 2007). The first three sessions are often marked by subjects breathing too deeply, causing an excessive increase in tidal volume and decrease in end-tidal carbon dioxide, which can lead to hyperventilation and anxiety (Vaschillo et al., 2006). These complications dissipate gradually and are usually absent by the fourth week. Speculations have been made that patients experience more negative affect in the early sessions due to unpleasant perceptions of the uncomfortable breathing task. Evidence for this hypothesis has been demonstrated by patients reporting more aversive side effects during the first three sessions of the 10-week treatment (Lehrer et al., 2003). Therefore, one approach to improve paced breathing protocols would be to reduce sources of negative affect associated with slow, uncomfortable breathing.

Dyspnea (i.e., the perception of uncomfortable breathing) can vary along valence (hedonic) and arousal (intensity) continua (American Thoracic Society, 1999). Dyspnea has been shown to be perceived as less unpleasant during positive affect inductions compared with neutral or negative inductions (von Leupoldt, Mertz, Kegat, Burmester, & Dahme, 2006). Therefore, induced positive affect may also be effective in minimizing negative affect and perceived unpleasantness during slow paced breathing.

Aims of the Current Study

Positive affect inductions have been shown to reduce negative perceptions during difficult breathing tasks (von Leupoldt et al., 2006) and should diminish unpleasantness associated with paced breathing at low frequencies (Vaschillo et al., 2006). Furthermore, positive emotional states in general have been associated with increased cardiovascular resonance (McCraty, Atkinson, Tiller, Rein, & Watkins, 1995). Thus, a positive emotion induction may make the heart more coherent with the respiratory system during cardiovascular resonance. Based on this underlying theory, we hypothesized that compared to regular slow paced breathing, the combination of paced breathing with an emotion induction would be viewed as more pleasant and induce fewer reported perceptions of dyspnea. Following von Leupoldt et al. (2006), we induced positive affect via presentation of selected images from the International Affective Picture System (IAPS), a standardized affective picture series (Lang, Bradley, & Cuthbert, 2008). Some reports have shown women are more strongly affected by negative affect inductions, while men are more strongly affected by positive affect inductions (Bradley, Codispoti, Sabatinelli, & Lang, 2001). Therefore, a secondary aim was to determine if the positive emotion induction improved slow paced breathing for both men and women. The final aim was to explore whether the expected effects of the emotion induction were related to various indices of physical and psychological health. These hypotheses were tested by contrasting the standard paced breathing paradigm with a new method of paced breathing that includes a positive affect induction. Comparison of the two paced breathing tasks permitted examination of the role emotion might play during paced breathing protocols used to induce CV resonance.

Method

Subjects

College students were recruited as subjects using an online system designed to help students sign up for studies in exchange for course extra credit. Subjects were asked via e-mail to refrain from caffeine, alcohol, and exercise at least 12 h prior to the experiment, to not smoke 2 h before the experiment, and to avoid eating at least 1 h before the experiment. The study was approved by the Virginia Tech Institutional Review Board, and written informed consent was obtained from all subjects. Of the 80 subjects who completed the study, physiological data were lost for 4 subjects due to equipment failure, and 5 subjects were excluded because they failed to breathe at the prescribed respiration rate during the paced breathing tasks. By design, sampling was conducted broadly and inclusively, rather than being aimed at recruiting a narrowly defined subject sample. This strategy was chosen to enhance the generalizability of the findings to populations of interest, because the slow paced breathing protocol is often used in conjunction with treatment of various disorders. As such, the remaining 71 subjects (36 men; $M = 20.08$ years, $SE = .216$) were not excluded on the basis of psychological or physical health conditions. However, for descriptive purposes, subjects completed a computer-based questionnaire, which indexed their physical and psychological health status.

Many of the subjects reported relevant medical and physical conditions. Smoking behaviors were reported by a small segment of the sample: 80.3% were nonsmokers, 7% smoked once a month, 5.6% smoked once a week, 1.4% smoked once a day, and 5.6% smoked four or more times a day. Although population estimates vary, the percentage of smokers in this sample was somewhat lower than what has been reported among U.S. college students. For example, 37% of college students in a recent large survey reported smoking in the past 30 days (Borders, Xu, Bacchi, Cohen, & SoRelle-Miner, 2005). Asthma was reported by 18.3% of the sample, 1.4% reported lung problems, and 1.4% reported CV disease. The percentage reporting asthma in this study was higher than U.S. adult prevalence rates (8.2%; Akinbami, Moorman, & Liu, 2011). The average body mass index (BMI; calculated as (weight (kg) $\div$ [height (m)^2]); $M = 24.85$, $SD = 3.72$) was on the upper edge of the normal range, although a large portion of the sample was either overweight or obese (56.3% normal; 35.2% overweight, and 8.5% obese). These rates are substantially lower than U.S. adult prevalence for obesity (33.8%), but similar to U.S. overweight prevalence (34.2%) (Flegal, Carroll, Ogden, & Curtin, 2010).

Psychological health was assessed with the short form of the Depression, Anxiety, and Stress Scale (DASS-21; Henry & Crawford, 2005). Based upon accepted cut-off values for the DASS (Lovidbond & Lovidbond, 1995), the majority of the sample scored in the normal range for each of the subscales: depression (81.7% normal, 11.3% mild, 4.2% moderate, 2.8% severe), anxiety (71.8% normal, 7.0% mild, 16.9% moderate, 1.4% severe, 2.8% extremely severe), and stress (81.7% normal, 11.3% mild, 2.8% moderate, 1.4% extremely severe). The average anxiety score ($M = 5.52$, $SD = 4.82$) is slightly higher in the present sample compared to a recent study of a normative, nonclinical sample ($M = 3.56$, $SD = 5.39$; Crawford & Henry, 2003). However, the average stress ($M = 10.06$, $SD = 6.79$) and depression ($M = 5.10$, $SD = 5.25$) scores found in the present sample are similar to a normative, nonclinical sample ($M = 9.27$, $SD = 8.04$; $M = 5.55$, $SD = 7.48$, respectively; Crawford & Henry, 2003).

Self-Report Emotion and Dyspnea Ratings

Affect was measured following each task using the Self-Assessment Manikin (SAM; Morris, 1995). Subjects were asked to rate their experienced arousal and perceived pleasantness during each task on a 9-point scale ranging from 1 (low arousal/unpleasant) to 9 (high arousal/pleasant). Perceived dyspnea (i.e., the perception of uncomfortable breathing) was measured following each task. Subjects were asked to rate the intensity and unpleasantness of dyspnea using a scale ranging from 0 (not noticeable/not unpleasant) to 10 (maximal imaginable intensity/maximal imaginable unpleasantness).

Physiological Measures

Subjects were seated in a comfortable office chair in a sound-and-light attenuated room. Electrocardiography (ECG) was recorded by placing two thoracic electrodes in a modified II lead configuration on the chest across the heart. Impedance pneumography (IPG) was collected using a 4-spot impedance electrode array as per recommendations found in the methodological guidelines for impedance cardiography (Sherwood et al., 1990). IPG measures changes in thoracic impedance due to respiration, from which estimates of respiration rate and tidal volume can be derived (de Geus, Willemsen, Klaver, & van Doornen, 1995; Ernst, Litvack, Lozano, Cacioppo, & Berntson, 1999; Houvteen, Groot, & de Geus, 2006). IPG and ECG were recorded using a BIOPAC MP100 system, and all raw signals were digitized at 1,000 Hz (BIOPAC Systems Inc., Goleta, CA).

Stimuli

Images from IAPS (18 pictures total) were presented for 5.5 s and were preceded by a 4.5-s black screen. The pictures were selected from six categories (adventure, erotica, family, food, nature, and sports), and were intended to provide a diverse and engaging display of positive emotion. Examples of each category are: an astronaut in outer space (adventure), a naked man and woman embracing in a bed (erotica), a man kissing a baby (family), a waterfall (nature), and a skier flying through the air (sports). The presented images were also chosen based upon valence ratings from a validation study of the IAPS using a normative sample of college students (Lang et al., 2008). The valence ratings of the images presented in the current study had an average rating of 6.89 ($SE = 0.14$) along a nine-point scale (1 = unpleasant, 9 = pleasant), indicating an overall positive valence.

Experimental Tasks

Subjects first filled out questionnaires and acclimated to the environment for approximately 15 min and then completed two paced breathing tasks in a counter-balanced order. The paced breathing tasks consisted of breathing at 6 breaths per min with a 4.5-s to 5.5-s inspiration to expiration ratio. Prolonged exhalation is common among CV resonance inductions (Lehrer et al., 2000; Vaschillo et al., 2006) and contributes larger beat-to-beat fluctuations in heart rate compared to relatively prolonged inhalation (Porges, 2007; Strauss-Blasche et al., 2000). Each paced breathing task lasted 3 min, was preceded by a 3-min baseline, and followed by a 3-min recovery period. The duration of the paced breathing is congruent with the recommendation of Lehrer and colleagues (2000) who recommend an epoch length of 2 min when assessing the resonant frequency. The following instructions were provided during the baseline period: "Now just relax as much as possible. Try not to move so as not to disrupt the recording." The major distinction between the two paced breathing tasks was the pacing stimulus itself (see below).

Paced breathing. In the first condition, subjects were instructed to breathe in phase with a moving bar graph ("inhale as the bar goes up, exhale as the bar goes down") and were provided with feedback of their heart rate and respiration activity on a computer screen. This biofeedback method was adopted to follow the most common and well-established method of using slow paced breathing to induce CV resonance, which typically includes a pacing stimulus and biofeedback (Lehrer et al., 2000; Vaschillo et al., 2006).

Paced picture breathing. In the second condition, the pacing stimulus consisted of a timed slideshow of pictures from the IAPS. Subjects were instructed to inhale when a black screen appeared on a computer screen and exhale when a picture appeared. The pictures also served as the source of the positive affect induction during this paced breathing condition. Biofeedback was not included in this condition so as to maximize attention to the emotional stimuli.

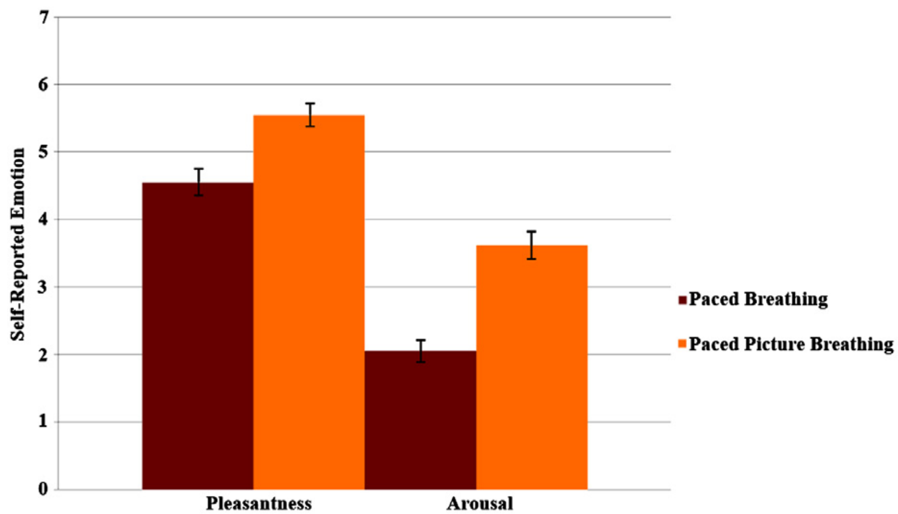

Figure 1. Mean SAM ratings of valence and arousal during paced breathing and picture paced breathing (1 = unpleasant/low arousal; 5 = neutral; 9 = pleasant/high arousal).

Data Reduction

Interbeat intervals were defined as the time in milliseconds between consecutive R spikes and were derived from the ECG using AcqKnowledge 4.1 software (BIOPAC Systems Inc.). Heart rate variability was also calculated to quantify large oscillations in heart rate (using Kubios HRV Analysis Software 2.0), which are one of the characteristics of CV resonance. The time series of interbeat intervals for each task was analyzed using autoregressive modeling (to quantify the natural log of the spectral power (ms^2) in the low frequency band (0.04–0.15 Hz) because respiration was paced within this frequency range. Changes in the band-passed filtered (0.05–0.50 Hz) thoracic impedance were classified as inspirations and expirations using the VU-AMS software for respiratory signals (AMSRES). Respiration rate was quantified as breaths per min (BPM = 60/the average respiratory cycle duration). Tidal volume was expressed as the natural log of the average absolute difference between the maximum and minimum change in impedance ($\Delta\Omega$) during each breathing cycle, which is indicative of the amount of air inhaled with each breath.

Data Analysis

Results are shown as means ± standard errors. Self-reported emotion and dyspnea ratings for each paced breathing task were compared using pairwise *t* tests. Physiological effects were examined with pairwise *t* tests of the mean difference between task and baseline values. Physiological differences between the two paced breathing tasks were examined by conducting pairwise *t* tests on the raw task scores from each task; raw task scores were used because none of the baseline values significantly differed between the two paced breathing tasks. All mean differences were also converted to effect size $d = (M_1 - M_2) \div [(SD_1 + SD_2) \div 2]$. Moderation of task differences was examined by conducting repeated measures analysis of variance (ANOVA) with the moderator as a covariate or between-subjects factor. Prior to data analysis, missing values resulting from technical errors (<2% of sample) were replaced using maximum likelihood estimates and regression imputation in AMOS 18.0.

Results

Emotion Ratings

As illustrated in Figure 1, emotion ratings differed significantly between the paced picture breathing and the paced breathing tasks in valence, $t(70) = 5.06$, $p < .001$, $d = .626$, and arousal, $t(70) = 6.46$, $p < .001$, $d = .972$. The paced picture breathing task was reported as both more pleasant (5.55 ± 1.76 vs. 4.55 ± .203) and arousing (3.62 ± .212 vs. 2.06 ± 1.70) than paced breathing.

Dyspnea Ratings

The paced picture breathing and the paced breathing tasks also significantly differed in terms of the intensity, $t(70) = 2.09$, $p = .041$, $d = .213$, and unpleasantness, $t(70) = 2.12$, $p = .038$, $d = .235$, of reported dyspnea (see Figure 2). The level of dyspnea reported during paced breathing was rated as both more intense (3.34 ± .289 vs. 2.85 ± .259) and unpleasant (3.70 ± .342 vs. 3.08 ± .284) than that reported during paced picture breathing. Furthermore, dyspnea and emotion ratings were correlated for both paced breathing tasks (see Table 1). For example, the more pleasant the paced picture breathing task was perceived, the less intense ($r(71) = -.33$, $p = .005$, $d = .70$) and less unpleasant ($r(71) = -.39$, $p = .001$, $d = .83$) dyspnea was rated. Difference scores (paced picture breathing—paced breathing) were calculated for emotion and dyspnea ratings to test if task differences in emotion were related to task differences in dyspnea (see Table 2). Indeed, the more positive the paced picture breathing task was rated relative to the paced breathing task, the less unpleasant the dyspnea was rated during the paced picture breathing ($r = -.31$, $p = .008$, $d = .66$).

Physiological Data

Heart rate variability in the low frequency band (0.04–0.15 Hz) significantly increased during both paced breathing, $t(70) = 19.34$, $p < .001$, $d = 1.886$, and paced picture breathing, $t(70) = 15.19$, $p < .001$, $d = 1.822$, indicating both paced breathing tasks successfully induced CV resonance (see Table 3 for means and standard errors). The two paced breathing tasks did not significantly differ in

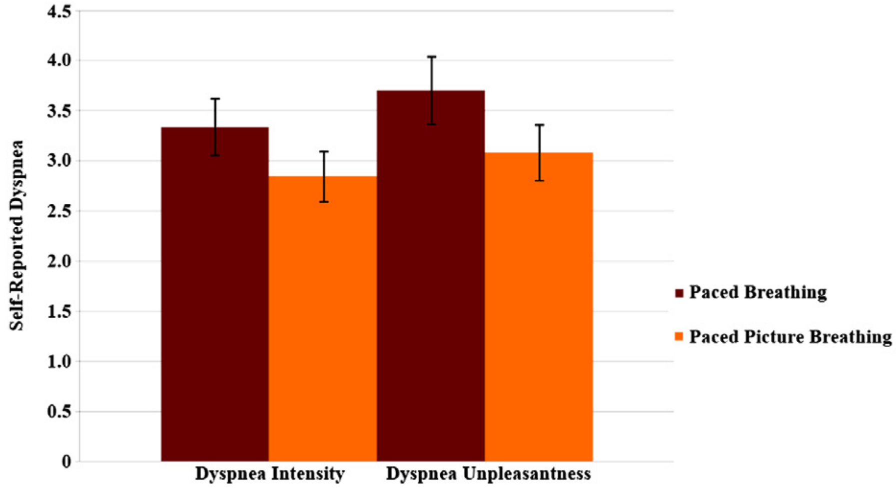

Figure 2. Mean dyspnea ratings of intensity and unpleasantness during paced breathing and picture paced breathing (0 = not noticeable/not unpleasant; 10 = maximal imaginable intensity/maximal imaginable unpleasantness).

the extent to which low frequency HRV increased, $t(70) = -0.22$, $p = .828$, $d = 0.016$. Tidal volume significantly increased during both paced breathing, $t(70) = 16.20$, $p < .001$, $d = 2.714$, and paced picture breathing, $t(70) = 17.38$, $p < .001$, $d = 2.841$. However, subjects breathed significantly deeper, $t(70) = 5.01$, $p < .001$, $d = 0.547$, during the paced breathing task (0.77 ± 0.26), compared to the paced picture breathing task (0.65 ± 0.18). Furthermore, analysis of difference scores (paced picture breathing—paced breathing) indicated that task differences in dyspnea found between the paced breathing conditions were not related to differences in tidal volume ($r = .079$, $p = .515$), but did correlate with differences in emotion in the expected direction ($r = -.313$, $p = .008$; see Table 2). Additionally, mean interbeat interval did not significantly change during the paced picture breathing task, $t(70) = 1.70$, $p = .093$, $d = 0.112$, or during the paced breathing task, $t(70) = 0.44$, $p > .066$, $d = 0.030$.

Table 1. *Correlations Between Emotion and Dyspnea Ratings During Paced Breathing*

	Paced breathing		Paced picture breathing	
	Valence	Arousal	Valence	Arousal
Dyspnea intensity	−0.257*	0.203	−0.327**	0.054
Dyspnea unpleasantness	−0.441**	0.046	−0.385**	−0.033

*p < .05. **p < .01.

Table 2. *Correlations Between Task Differences in Emotion and Dyspnea Ratings During Paced Breathing*

Differences between tasks (PPB—PB)	Valence	Arousal	Tidal volume
Dyspnea intensity	−0.112	0.024	0.031
Dyspnea unpleasantness	−0.313**	−0.142	0.079

Notes. PPB = paced picture breathing; PB = paced breathing.
**p < .01.

Discussion

The present study examined the effect of emotion on the perception of dyspnea during slow paced breathing by comparing subjective and physiological responses to a slow paced breathing task with and without a positive emotion induction. The results suggest that the presentation of positive stimuli may have buffered the aversive nature of breathing at a pace to which is much slower than people are typically accustomed. Specifically, arousal and positive affect were greater when slow paced breathing was combined with positive images from the IAPS. Of particular note is that these differences in emotional state were paralleled by a reduction in both the sensory and affective dimension of dyspnea reported during slow paced picture breathing. Although both paced breathing tasks resulted in similar cardiorespiratory profiles, tidal volume was slightly lower during slow paced picture breathing. However, the differences in tidal volume were not related to task differences in valence or dyspnea. Inasmuch that reduced tidal volume is associated with less dyspnea, perhaps the positive emotion induction fostered a more beneficial physiological state.

The present findings also concur with prior reports that show dyspnea is tied to emotion. For example, manipulation of emotional state during resistive load breathing in healthy volunteers has resulted in higher ratings of dyspnea with induced negative affect and lower ratings of dyspnea when positive affect was induced

Table 3. *Means (Standard Errors) of Physiological Variables During Baseline and Paced Breathing*

	Baseline	Paced breathing	Baseline	Paced picture breathing
IBI	855.81 (14.96)	859.37 (13.36)	860.68 (14.07)	873.78 (13.73)
TV	0.29 (0.01)	0.77 (0.03)	0.28 (0.01)	0.65 (0.02)
LF	7.16 (0.12)	8.88 (0.10)	7.22 (0.12)	8.90 (0.10)

Notes. IBI = interbeat intervals; TV = tidal volume; LF = low frequency heart rate variability.

(von Leupoldt et al., 2006). More intense respiratory discomfort has also been reported by patients with a respiratory tract infection who were high on trait negative affect compared to patients low on trait negative affect (Smith & Nicholson, 2001). Disorders of emotion, such as anxiety, contribute to higher dyspnea ratings as well. For example, patients with chronic obstructive pulmonary disorder (COPD) and comorbid panic disorder (PD) reported greater dyspnea during a resistive load breathing task compared to COPD patients without comorbid PD (Giardino et al., 2010). Furthermore, the relationship between perceived dyspnea and emotion are beginning to be explicated through fMRI research. Preliminary findings support an association between a greater unpleasantness in perceived dyspnea and heightened activity in both the right insular cortex and right amygdala (von Leupoldt et al., 2008). Conversely, patients with lesions to the right insular cortex report reduced dyspnea, and less unpleasant respiratory sensations in particular (Schön et al., 2008). Together, this body of literature and the present findings support the argument that emotional state and psychological factors must be considered when dyspnea-inducing therapies such as slow breathing or CV resonance biofeedback are implemented.

Several limitations on the current findings should be noted. One potential issue is the lack of experimental control over tidal volume, which renders the causal link between the positive emotion induction and reduced dyspnea ratings open to alternative explanations. For example, it is possible that differences in tidal volume resulted in less strain on respiratory muscles and caused the lower dyspnea ratings independent of the emotion induction itself. However, tidal volume dramatically increased in both conditions, the task differences in tidal volume were unrelated to valence or dyspnea, and our results are consistent with prior reports of reduced dyspnea with positive emotion (von Leupoldt et al., 2006).

A more concerning limitation is the issue of attention. Our experimental design fails to reconcile whether focusing attention on an image, regardless of valence, would reduce dyspnea and improve mood. Control over attention is a limiting factor in our study because the presence of biofeedback during only one of the paced breathing tasks leaves open the question as to whether feedback of respiratory and CV activity contributed to the differences found in physiology, emotion, and dyspnea. However, we know of no evidence in the literature that has examined attention load and dyspnea during cardiovascular resonance. Regardless, biofeedback was included with the paced breathing alone condition to mirror what is commonly used in clinical settings (Lehrer et al., 2000). Additionally, the authors thought it was important that subjects allocate as much visual attention as possible to the positive imagery during the emotion induction. As such, it seemed prudent not to compromise the potency of the affective manipulation with the distraction of biofeedback. Future research should examine how attention and emotion interact during inductions of cardiovascular resonance.

Finally, as noted above, we intentionally did not exclude subjects on the basis of physical or mental health status. Although these factors obviously can affect cardiorespiratory function, many of the previous CV resonance studies have been directed at treating disorders, and so we reasoned that a narrowly defined sample would have less generalizability to potential populations of interest. At any rate, the percentage of smokers in this study was generally low, and the BMI composition of the sample was unexceptional. The percentage of asthmatics in the study was higher than what might be expected, but controlling for this factor did not affect the results. Depression and stress levels were similar to a normative, nonclinical sample (Crawford et al., 2003). The average anxiety levels were slightly higher in the present sample compared to a recent study of a normative, nonclinical sample (Crawford & Henry, 2003), but controlling for mental health did not affect the results.

The present study provides some support for the use of a positive affect induction to ameliorate the dyspnea associated with slow paced breathing. Hence, the next step is to dissect these findings through systematic manipulation of attention while controlling for tidal volume. For example, a future study could include a positive and neutral image condition that entails paced picture breathing with an oscillating auditory tone to guide inhalation, exhalation, and tidal volume. Such a study would inform our understanding of whether positive emotion diminishes sensations of dyspnea, rather than the mere distraction from those sensations normally experienced during biofeedback. However, because dyspnea has been shown to be perceived as less unpleasant during positive affect inductions compared with neutral or negative inductions (von Leupoldt et al., 2006), it seems likely that the affective quality of the stimulus is a key component of benefits of the induction method.

In sum, a programmatic series of studies will help to further probe the implications of the present findings for the induced CV resonance paradigm. Research supports the application of this model in treating a wide range of mental and physical disorders. However, the technique is limited by the dyspnea associated with slow paced breathing, which can create problems with initial mastery and continued compliance with the regimen. The present findings provide some support for the power of positive emotion in reducing this dyspnea, and in doing so enhance the practicality and effectiveness of slow paced breathing for inducing CV resonance. However, future studies are needed to distinguish between the effects of positive emotion and the contribution of alterations in attention during perception of dyspnea. It is hoped that the current investigation will stimulate further research along these lines and in doing so promote continued exploration of induced CV resonance, a method that holds promise of benefits across many domains.

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