Applied Psychophysiology and Biofeedback, Vol. 25, No. 3, 2000

Resonant Frequency Biofeedback Training to Increase Cardiac Variability: Rationale and Manual for Training

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Heart rate and blood pressure, as well as other physiological systems, among healthy people, show a complex pattern of variability, characterized by multifrequency oscillations. There is evidence that these oscillations reflect the activity of homeostatic reflexes. Biofeedback training to increase the amplitude of respiratory sinus arrhythmia (RSA) maximally increases the amplitude of heart rate oscillations only at approximately 0.1 Hz. To perform this task people slow their breathing to this rate to a point where resonance occurs between respiratory-induced oscillations (RSA) and oscillations that naturally occur at this rate, probably triggered in part by baroreflex activity. We hypothesize that this type of biofeedback exercises the baroreflexes, and renders them more efficient. A manual is presented for carrying out this method. Supporting data are provided in Lehrer, Smetankin, and Potapova (2000) in this issue.

KEY WORDS: respiratory sinus arrhythmia; cardiac variability; baroreflexes; biofeedback; homeostasis.

NATURE AND PURPOSE

Respiratory sinus arrhythmia (RSA) is the variation in heart rate that accompanies breathing. Heart rate increases during inhalation and decreases during exhalation. It is one of several identified oscillatory mechanisms in heart rhythm. These oscillations usually are superimposed upon each other, and yield a very complex pattern of natural rhythmicity. RSA is sometimes used as index of parasympathetic tone (Porges, 1986). Respiratory-linked variations in heart rate usually occur in the frequency range of 0.15–0.4 Hz (9–24 breaths/minute) in the healthy human adult. Heart rate oscillations in this range are often referred to as "high frequency" heart rate oscillations. There also appears to be a high-amplitude oscillation within the frequency band of 0.05–0.15 Hz (3–9 times/minute). Heart rate oscillations within this range are unrelated to respiration, unless the person breathes very slowly, within this frequency range. Activity in this frequency band is denoted as "low frequency" heart rate variability, and is affected by both the sympathetic and parasympathetic systems (Berntson et al., 1997). It is more closely related to baroreflex activity than heart rate

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variability within other ranges (Bernardi et al., 1994).[3] Activity within a still lower frequency range, 0.005–0.05 Hz, is sympathetically mediated, and appears to reflect regulation of vascular tone and body temperature.

The various frequencies of heart rate variability are related to particular sources of autonomic control, and, in psychophysiology, the relative amplitudes of heart rate variability in these frequency ranges are sometimes are used to reflect the weight of sympathetic versus parasympathetic autonomic balance.

This use may not be entirely valid, however. Oscillatory activity in each of these ranges appears to reflect autonomically mediated *modulatory* processes; but these are not always the same as *tonic* autonomic output. Porges (1995) has pointed out situations where RSA and tonic vagal stimulation of the heart are systematically and regularly decoupled. One such instance is the orienting reflex, where the organism responds to a novel stimulus by looking at it and "taking in" information. In the orienting reflex, a vagally-mediated heart rate deceleration occurs, but is systematically associated with a *cessation* in RSA. (These reflexes occur in all mammals, and cardiac decelerations are often used by cognitive psychologists to measure whether a particular stimulus produces an attentional response.)

Thus, in the orienting reflex two vagally-mediated influences on the heart simultaneously move in opposite directions. Porges has developed a "polyvagal theory" to describe this phenomenon. He theorizes that cardiac decelerations during the orienting reflex may be partially *mediated* by cessation in RSA, because RSA reflects the process by which vagal influence on the heart is modulated. During the orienting reflex, this modulation is absent, so vagal influence on tonic heart rate increases and produces the heart rate deceleration. He theorizes that RSA and tonic vagal control over the heart are controlled by different centers in the brain stem: the nucleus ambiguus and the dorsomotor nucleus, respectively.

Porges (1995) further points out that only warm-blooded animals have RSA, as further evidence that RSA is related to self-regulation. Cold-blooded animals move in and out of the sun in order to self-regulate, while warm-blooded animals require internal regulatory processes. These processes, he suggests, are reflected in psychophysiological oscillatory activity.

Such oscillations are found in almost all regulated physiological systems. Blood pressure and finger pulse volume both show oscillations within the same frequency range as heart rate, although here the baroreflex effects appear to be reflected in very low frequency activity (0.005–0.05 Hz) rather than in low frequency activity (Vaschillo, Lehrer, Rische, & Konstantinov, submitted for publication). Vaschillo has suggested that the well-known 0.1 Hz frequency peak rate oscillations (i.e., oscillations with a period of 10 sec, the midpoint of the low-frequency spectrum, and the approximate point at which the highest amplitude of oscillations occurs within the low-frequency spectrum in most human adults) reflect a 5-second delay in baroreflex influence on increasing and decreasing blood pressure. This delay is caused by elasticity of the vasculature. Vaschillo further theorizes that the baroreflex system is sensitive only to these oscillatory changes in blood pressure, rather than to tonic levels of it.

[3]The baroreflexes are triggered by changes in blood pressure in the large blood vessels (principally the aorta and the carotid artery). When pressure increases or decreases, pressure receptors ("baroreceptors") detect the changes, and convey this information to hypothalamic centers, which trigger homeostatic reflexes. Increases in blood pressure then trigger a parasympathetic response (and perhaps sympathetic withdrawal), while decreases in blood pressure trigger the opposite.

There is considerable clinical validation for the notion that cardiac oscillations reflect homeostatic activity (Hyundman, 1973). When these rhythms are absent, attenuated, and/or less complex, the individual appears to be at greater cardiovascular risk from several cardiovascular disorders, including hypertension, particularly when accompanied by left ventricular hypertrophy (Mancia, Giannattasio, Turrini, Grassi, & Omboni, 1995), sudden cardiac death (Goldberger, 1991), ventricular arrhythmia (Rosenbaum et al., 1994), and severe heart disease (Peng et al., 1996). Heart rate variability also has been used to predict mortality after myocardial infarction (Kleiger, Miller, Bigger, & Moss, 1987) as well as the risk of rejection after cardiac transplantation (Binder et al., 1992), and it correlates with angiographic findings (Rich et al., 1988). Amplitude of RSA waves also tends to be depressed in emotional disorders involving anxiety or depression (Asmundson & Stein, 1994; Rechlin et al., 1994). It is negatively correlated with age in an adult population (De Meersman, 1993), perhaps reflecting decline in homeostatic adaptability. We have recently suggested that the occurrence and complexity of these rhythms is related to the number of "back-up" systems that are functional for maintaining cardiovascular stability and adaptiveness to physiological and environmental demand (Giardino, Lehrer, & Feldman, 2000). More such systems should predict greater stability and less vulnerability to dysregulation.

Resonance in the Cardiovascular System, the "Two Closed-Loop" Theory of Baroreflex Function, and Biofeedback for Respiratory Sinus Arrhythmia

Russian research has shown that people are capable of voluntarily producing very large increases in respiratory sinus arrhythmia using biofeedback techniques (Chernigovskaya, Vaschillo, Rusanovsky, & Kashkarova, 1990). Also, there have been several Russian reports that biofeedback training can be helpful in treating a variety of diseases in which autonomic factors play a role, including asthma, hypertension, and various anxiety disorders. Vaschillo (1984) found that RSA biofeedback causes people to breathe at rates at which resonance occurs between cardiac rhythms associated with respiration (i.e., high-frequency oscillations, or RSA) and those caused by baroreflex activity (low-frequency oscillations). When people breathe at rates corresponding to baroreflex effects, resonance occurs between these two sources of heart rate oscillations, which greatly increases the amplitude of these oscillations. In turn, Vaschillo theorizes, the increased amplitude of baroreflex stimulation (caused by higher-amplitude oscillations in blood pressure as well as heart rate) produce greater exercise of the baroreflexes, ultimately yielding greater reflex efficiency, and, hence, greater modulation of autonomic activity.

There also is evidence that voluntarily increasing RSA amplitude, through RSA biofeedback, forces the individual to breathe within the low-frequency range—at approximately 6 times/minute (Lehrer et al., 1997). These data also suggest that resonance is the mechanism by which people learn to increase RSA amplitude during biofeedback training. Vaschillo (1984) noted that people can produce the highest oscillation amplitudes only at specific target frequencies within this range, centering at approximately 0.1 Hz (6 oscillations/min). Reliably high amplitudes of RSA can be triggered by breathing at rates within this range: a task that most people can perform with little training. He notes that the highest amplitudes achievable by biofeedback in blood pressure oscillations tends to occur within the very low frequency range, however. On this basis, he has modeled baroreflex activity as a "two closed-loop" system.

Vaschillo's experimental paradigm has been to display a computer-produced oscillation on a cathode-ray screen, and to instruct subjects (six male cosmonauts) to replicate this oscillation with their own physiological activity. The subject's heart rate is displayed elsewhere on the screen, and the subject is instructed to try to replicate the computer-generated sinus wave with his own self-generated activity. Vaschillo varied the frequency of the target stimuli within the very low and low frequency heart rate bands. All subjects showed the highest-amplitude and best-formed target-frequency heart rate oscillations within the low-frequency range. He also measured blood pressure oscillations in these subjects, although no direct biofeedback was given for this measure. Here the highest-amplitude target-frequency oscillations occurred within the very low frequency range. Vaschillo labeled the particular frequency with highest amplitude of oscillations as that individual's resonant frequency.

Consistent with his theory of resonance, Vaschillo et al. also found systematic phase relationships between blood pressure and heart rate oscillations at particular frequencies (Vaschillo, Lehrer, Rishe, & Konstantinov, submitted for publication). At the resonant frequency for heart rate (i.e., the peak-amplitude frequency for that measure, occurring within the low-frequency range), blood pressure and heart rate oscillations were 180° out of phase with each other. Thus, simultaneously, in each cycle, as biofeedback-related processes produced increases (or decreases) in heart rate, baroreflex effects produced further increases (or, respectively, decreases). At the resonant frequency for blood pressure oscillations (which occurred within the very low frequency range) heart rate and blood pressure oscillated in phase with each other (0° phase relationship). At this frequency, baroreflex effects inhibit the effects of biofeedback on heart rate, but appear to facilitate blood pressure oscillations, which are at a maximum, perhaps because of the influence of vascular tone on the baroreflex. (This latter relationship was not systematically studied, however.) Vaschillo theorizes that the different resonant frequencies for heart rate and blood pressure reflect separate baroreflex effects on heart rate and vascular tone. Further validation of his "two-closed-loop theory" of baroreflex activity would require studies of biofeedback training to increase blood pressure oscillations, direct measurement of vascular tone, and further validation on a larger number of individuals.

Our Procedure for RSA Biofeedback Training

In our procedure, the trainee is first taught to breathe at his/her resonant frequency, as a first step to training the individual how to produce maximal increases in amplitude of RSA. In the first session, we measure heart rate oscillation amplitudes while the individual breathes at specific frequencies, ranging between 4 and 7 breaths/minute, while trying to keep depth of respiration (and end-tidal CO_2, if measured) approximately constant. We provide a "pacing stimulus" for this purpose: a light display that moves up and down on the computer screen at the target respiratory rate, while a measure of the individual's response, taken from a strain gauge, is simultaneously displayed. The trainee is instructed to breathe at the rate of that stimulus. A pacing stimulus is presented on a computer display screen, instructing the patient when to inhale and exhale. In subsequent sessions, the individual is given biofeedback. The patient is instructed to practice breathing at his/her own resonant frequency for 20-minute periods twice daily for the next week. (Throughout training the individual is cautioned to breathe shallowly and naturally, in order to avoid hyperventilation.)

At the next session, the patient is directly given biofeedback for cardiac variability, and is instructed to increase the amplitude of heart rate fluctuations that occur in conjunction with respiration. The feedback takes several forms. One uses a beat-to-beat cardiotachometer, superimposed on a measure of respiratory activity. The patient is instructed to breathe approximately in phase with heart rate changes, with the goal of maximally increasing amplitude of RSA. In another display, the patient is shown a moving frequency analysis of heart rate, within the band of 0.005–0.4 Hz. The display is updated approximately every second, and reflects the frequency of heart rate fluctuations within the past minute. The patient is instructed to increase the spectral power peak that occurs at approximately resonant frequency. A light-bar display also can be used, whose height is proportional to the amplitude of RSA with each breath. The heart rate reflected in the top and bottom of the light bar must be set for each individual, and adjusted over time, depending on the peaks and troughs in the individual's heart rate. The sensitivity is set such that a full-screen excursion represents an amplitude that is approximately double that found at baseline. The patient often purchases, borrows or rents one of these devices for daily home use.

Clinical Applications of RSA Biofeedback

The theory for the clinical efficacy of RSA biofeedback is that frequent high-amplitude stimulation of the baroreflexes by breathing at resonant frequencies will exercise these reflexes and render them more efficient. Clinical demonstrations have been published in Russia, applying this method for treating asthma, hypertension, and various neurotic disorders (Chernigovskaya et al., 1990). We have reported an improvement in asthma using this technique in one report of 20 consecutive clinical cases from a Russian rehabilitation center (Lehrer et al., 2000, this issue). None of these studies included control groups, however, so it is possible that at least some of the observed effects reflected subject selection bias, regression to the mean, or expectancy (placebo) effects. We have reported the results of one controlled study (Lehrer et al., 1997) showing that RSA biofeedback produces large within-session decreases in respiratory impedance among adults with asthma. However, the number of patients in this study was small, and the effect of this training on general clinical improvement was not assessed. Thus, although this method shows great promise for treating a variety of conditions characterized by autonomic dysregulation, the controlled research necessary to prove its effectiveness still remains to be done.

Biofeedback versus Paced Breathing

Why is there a need for special biofeedback technology, rather than simply telling people to breathe at six breaths/minute? Vaschillo (1984) found that the exact cardiac resonant frequency differs from person to person (hence the need for a biofeedback technique to determine the precise rate of breathing required for each individual), and also can change over time within individuals. In our clinical experience, the rate of maximum amplitude fluctuation may decrease over time during training, so that some individuals may achieve maximum fluctuations in heart rate at closer to four breaths/minute. Some people may have difficulty breathing so slowly. Training must therefore occur gradually. The biofeedback technique allows each individual to breathe at a rate that is specifically adapted to the rhythms of his or her own body, and which will adapt over time as respiratory and baroreflex function improve.

Similarities to Eastern Breathing Disciplines

The Eastern disciplines of Yoga, QiGong, and Zen all involve slow breathing. Masters of these techniques tend to teach people to modulate their respiration rate to the needs and pace of their own bodies. These Eastern disciplines may, in fact, have similar effects to RSA biofeedback, to the extent that they induce people to breathe at their cardiovascular resonant frequencies. In a recent study of Zen monks during zazen meditative exercises, Lehrer et al. (1999) found that these individuals did indeed breathe within the low or very low frequency ranges (of heart rate variability) while practicing zazen. All of the Zen practitioners showed increased RSA amplitude at their slow respiratory frequencies. One Zen master breathed at the rate of once/minute, and produced particularly high-amplitude oscillations in heart rate at that frequency. Consistent with the theory that this frequency range reflects thermal regulation and is mediated sympathetically, this individual also showed an increase in heart rate and reported feeling warm, even though he was performing the exercises under subfreezing conditions.

Because these other disciplines have been used for a very long time, it is reasonable to ask about any possible advantages of using RSA biofeedback. This is an empirical question, upon which, of course, no data have yet been gathered. We believe, however, that it is worthwhile to investigate the effects of this biofeedback technique for a number of reasons. Most importantly, these Eastern disciplines are not well standardized, and the methods are taught quite differently by various instructors. They also are rather complex, and not all of their many components may be effective in controlling particular physiological systems or treating specific diseases. The method of RSA biofeedback is simple, replicable, and standardized, targeted to specific physiological changes, and can be learned quickly and easily by most individuals.

Indications and Contra-Indications

Because this method is so new, there is as yet little well-controlled experimental literature on the effect of this method on any clinical problem. Our preliminary research (Lehrer et al., 1997, 2000) suggests that it may be helpful for treating asthma.

There also is suggestive evidence that this method may be useful for treating hypertension, particularly where the problem is caused, in part, by baroreflex dysfunction. Baroreflex dysfunction is often present among people with labile hypertension, where blood pressure often is normal, but where clinically significant elevations periodically occur. Although no clinical studies have been reported relating labile ambulatory BP to baroreflex function, much indirect evidence exists. High amplitudes of HR oscillations tend to inhibit BP oscillations during challenge, but not at rest (Taylor & Eckberg, 1996). In a population of healthy individuals, Laitinen et al. (1999) found that baroreflex sensitivity correlated negatively with blood pressure variability in a testing situation. Baroreflex dysfunction may also be a contributing cause to some cases of tonic hypertension (Pitzalis et al., 1999). This suggests that RSA biofeedback may be beneficial to some chronically hypertensive individuals. Russian research suggests that it also may be applicable to treating hypertension (Chernigovskaya et al., 1990).

RSA biofeedback also may be helpful to some people with tonic *hypo*tension. Several researchers have theorized that individuals with initially *low* BP also may suffer from baroreflex dysregulation (Vein, Oknin, Khaspekova, & Fedotova, 1998). Russian research suggests that biofeedback training to increase amplitude of HR variability may *raise* BP where it initially is too low, but decrease it when it is elevated (Zingerman, Nikitina, & Nikiforova, 1994).

As mentioned above, RSA biofeedback also has been used in Russia to treat asthma (Lehrer et al., 2000, this issue), in a method proposed by A. Smetankin in St. Petersburg. This method combines RSA biofeedback with instructions to breathe abdominally, to inhale through the nose, and to exhale through pursed lips. Also patients are encouraged to exhale for a longer time than they inhale. Although increased baroreflex modulation is the hypothesized mechanism for the effects of this method, other mechanisms also may be involved. For example, slow pursed lips breathing may decrease airway turbulence during exhalation, and it may mechanically dilate the airways. It has been found to be useful among patients with various chronic obstructive respiratory diseases (Bai, 1991).

Also, because autonomic hyperreactivity tends to characterize many patients suffering from anxiety, RSA biofeedback also may be useful as a treatment component for patients suffering from various anxiety disorders. This application has been tried in Russia, as described by Chernigovskaya et al. (1990), who also described its use for treating other disorders that can be exacerbated by stress or autonomic nevous system dysregulation.

Intake Evaluation and Assessment

Because this method is not yet standardized for clinical use, there are as yet no standard methods for evaluation and assessment. When we use the method for treating asthma, we do spirometry before and after each session, and forced oscillation pneumography during biofeedback in four of the sessions. When treating hypertension we similarly blood pressure measures before, during, and after each biofeedback session.

In order to determine whether the feedback signal is a “true” signal, not subject to noise, we display a raw EKG signal on the screen simultaneously with the biofeedback signal. Also, before beginning treatment, we assess the individual for irregularities in the EKG wave or frequent extra-systolic beats. Either of these would create difficulties for the biofeedback process.

MANUAL FOR A 10–SESSION PROGRAM FOR RESPIRATORY SINUS ARRHYTHMIA BIOFEEDBACK

This manual is designed for use with two kinds of instruments, for office and home use, respectively, having the following characteristics. We mention the names of the particular instruments with which we are familiar. By the time that this paper is published other suitable models also may be available. Also, the reader should note that this is an experimental protocol. It has not been fully tested. It is currently undergoing further evaluation.

Instrumentation

1. *Office instrument*. This protocol requires a computerized instrument with display of heart rate and respiration, preferably superimposed on the same axes. An on-line moving display of heart rate variability frequencies also can be helpful. A pacing signal also is necessary, that the subject can match with breathing, to prompt the trainee to breathe at a particular rate. Commercial products with these characteristics now include the C-2 and DSP-12 biofeedback units [J&J Engineering, Poulsbo, Washington, USA] with HRDFT software and the Procomp [Thought Technology, Montreal, Quebec, Canada] with Cardiopro software.
2. *Home trainer*. A unit suitable for use as a home trainer is the Cardiosignalizer [Biosvyaz Corp, St. Petersburg, Russia].
3. *Combined use*. The HeartScanner and HeartTracker [Biocom Technologies, Poulsbo, WA] may be suitable for both purposes.

Session 1: Introduction to the Method and Obtaining Initial Estimate of Resonant Frequency

THERAPIST'S INSTRUCTIONS:

Your heart rate goes up and down with your breathing. When you breathe in, your heart rate tends to go up. When you breathe out, your heart rate tends to go down. These changes in heart rate are called "respiratory sinus arrhythmia," or RSA. RSA triggers very powerful reflexes in the body that help it to control the whole autonomic nervous system (including your heart rate, blood pressure, and breathing). We will train you to increase the size of these heart rate changes. Increasing the size of the heart rate changes will exercise these important reflexes, and help them to control your body more efficiently. As part of this treatment we will measure your RSA and give you information about the swings in heart rate that accompany breathing. That will be the RSA biofeedback. You will use this information, to teach yourself to increase your RSA. If you practice the technique regularly at home, you will strengthen the reflexes that regulate the autonomic nervous system. This should help improve your health and ability to manage everyday stress.

There is evidence that training these reflexes will help you to cope with various somatic and emotional problems (elevated blood pressure, anxiety attacks, hyperventilation, asthma, some digestive problems). Do you have any questions?

The therapist attaches electrodes for the computerized biofeedback device, and sets the pacer stimulus to 6 breaths/min.

THERAPIST'S INSTRUCTIONS:

Breathe at the rate of this bar, moving up and down. Breathe in as the bar goes up and out as it goes down. Try it. (Give feedback about whether the trainee is accurately following instructions.) Now continue to breathe at this rate. Do not breathe too deeply or you will hyperventilate. If this happens you may experience some lightheadedness or dizziness. If lightheadedness or dizziness occurs, breathe more shallowly.

Now try to breathe out longer than you breathe in. [If the pacing stimulus can only show equal inhalation and exhalation times, instruct the subject to begin exhaling at some point toward the end of each stimulus to inhale.]

The therapist points to the pacer, and demonstrates where inhalation and exhalation should begin and end, to allow longer exhalation than inhalation.

In all breathing instructions exercises we will teach you here, the most important thing is to breathe in a relaxed way. Breathe easily and comfortably. Do not try too hard.

The therapist demonstrates longer exhalation than inhalation, using the pacer bar, and tries to find the ratio that increases RSA the most. It should also be a comfortable ratio. The pacer is initally set for six breaths/min. The trainee breathe at this rate. The therapist points out increases in RSA on screen, and, if a frequency display is available, the frequency peak at 0.1 Hz.

Resonant Frequency Determination

THERAPIST'S INSTRUCTIONS:

> We will now find your "resonant frequency"—the speed of breathing at which your RSA is the highest. In this procedure we will ask you to breathe at various rates for periods of about 2 minutes each. You should not find this task difficult. Breathe easily and comfortably. Do not try too hard. Do you have any questions?

Have the trainee breathe for three minutes at each of several frequencies in the neighborhood of 0.1 Hz (e.g., 6.5, 6, 5.5, 5, 4.5 breaths/minute), as prompted. Set a pacing stimulus for each frequency. Ask the trainee to breathe at each frequency for 2 minutes (to allow computation of frequency spectra from at least ten breaths at each frequency). Do not begin this count until the trainee is breathing at the prescribed rate.

After this procedure, inform the trainee of his (her) resonant frequency (i.e., the frequency at which maximum amplitude of RSA is achieved). If a capnometer is available, the therapist should monitor end-tidal CO_2 values and instruct the trainee to breathe less deeply if values fall below initial CO_2 levels.

Home Practice

The trainee is reminded to practice breathing easily and comfortably at his/her resonant frequency, with longer exhalation than inhalation for two 20-minute periods. The trainee is told how long (in seconds) each breath should be (60 divided by the resonant frequency in breaths per minute). The trainee should use the second-hand of a watch to time the breathing cycle.

Session 2: Beginning of RSA Biofeedback

The therapist first reviews the trainee's understanding and practice of breathing at resonant frequency with longer exhalation than inhalation. The trainee is reminded not to breathe too deeply, to avoid hyperventilation symptoms (lightheadedness or dizziness). The trainee is reminded to breathe easily and comfortably, and not to "try" too hard.

Then the trainee is instructed to maximize RSA using the cardiotachometer display as biofeedback. The trainee is instructed to breathe in phase with HR changes, and trying to maximize the increases and decreases in heart rate that accompany breathing.

THERAPIST'S INSTRUCTIONS:

Now breathe at your resonant frequency for about 2 minutes, following the pacing stimulus. Then shift to following your heart rate. Look at this line (*point to the cardiotachometer tracing*). When your heart rate goes up, this line goes up. When it goes down, the line goes down. Breathe in phase with your heart rate. When your heart rate goes up, breathe in. When your heart rate goes down, breathe out. But first, just continue breathing at your resonant frequency. Follow the bar.

Using Biofeedback Without Pacing Stimulus

After several minutes (depending on how well the trainee is doing the task), prompt the trainee when to shift to following his/her heart rate. Turn the pacing signal off.

THERAPIST'S INSTRUCTIONS:

Breathe in phase with your heart rate. When your heart rate goes up, inhale. When it goes down, exhale. Make your heart rate go up as far as possible and down as far as possible. When your heart rate starts to go up, begin inhaling. When it begins to go down, begin exhaling. Breathe so that the changes in heart rate with each breath are as big as possible. Breathe easily, without tension. Breathe naturally. Do not try too hard. Breathing should just flow almost automatically. Don't think too much about how to do it. Maybe it won't work right away. It will improve with time.

Abdominal Breathing Instructions

THERAPIST'S INSTRUCTIONS:

One of the things you will learn to do in this method is relaxed breathing. 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. The chest should not move. Let me show you what I mean.

The therapist demonstrates, placing one hand on his/her own chest and the other on the abdomen, and demonstrates abdominal breathing:

THERAPIST'S INSTRUCTIONS:

When you breathe, your diaphragm moves down and pushes out your abdomen, so it seems like you are breathing from below your navel. When your diaphragm moves down, a partial vacuum is created in your lungs, so your lungs fill up. Your lungs do not *do* anything during breathing. They are passive, like balloons. Movement of the diaphragm makes them fill, just like blowing into the balloons. So your chest doesn't do anything in relaxed breathing. Your diaphragm does all the work. Your diaphragm is located here:

The therapist points to the position of the diaphragm in his or her own body. The therapist then places one hand on his/her own chest and the other on the abdomen, near the navel.

THERAPIST'S INSTRUCTIONS:

In relaxed breathing, as I inhale and exhale the bottom hand moves up and down, and the top hand doesn't move much at all.

The therapist demonstrates with two or three inhalations.

THERAPIST'S INSTRUCTIONS:

Do you see that? Why don't you try, just to get the feel of it? Relax and place one hand on your chest and the other on your abdomen. Now breathe so that just your abdomen moves in and out, while your chest stays still.

The therapist continues to model for the trainee. If it is helpful, the therapist can give the trainee greater tactile feedback by placing books on the trainee's abdomen and chest as prompts, particularly if the subject reclines or sits in a semi-reclining position.

Imagine almost that you are breathing through your feet, so that the work of breathing never even gets close to your chest.

The therapist continues to model while the trainee tries to do abdominal breathing. If the trainee finds abdominal breathing too difficult, however, the method is temporarily abandoned until the next session, and the trainee is told to continue practicing slow relaxed breathing.

THERAPIST'S INSTRUCTIONS:

Practice abdominal breathing at home for about 20 minutes each day. First try it lying down or standing in front of a mirror. You may find this easier than sitting. Then try doing it while sitting. Eventually you should be able to do abdominal breathing in all positions. Do it at the same time as you are practicing resonant frequency breathing.

Instruction in Pursed Lips Breathing

THERAPIST'S INSTRUCTIONS:

Now breathe in through your nose with your mouth closed. Good. And now breath out through pursed lips, like this. Okay, good.

The therapist demonstrates and gives feedback to the trainee. The trainee is praised for doing the task properly.

Now do all three components together: abdominal breathing, pursed lips breathing, and longer exhalation than inhalation. Combine abdominal and pursed lips breathing out longer than you breathe in. Remember: If you feel dizzy or lightheaded, you are breathing too deeply. You are hyperventilating. Breathe more shallowly and naturally. You will get the hang of it soon. Breathe easily and comfortably. Do not try too hard or too deeply. Watch out for hyperventilation symptoms. Do you have any questions?

The therapist answers questions about the procedure and gives feedback about the trainee's abdominal, pursed lips breathing, with prolonged exhalation. The trainee is reminded not to breathe too deeply. The therapist notes the phase relationship between RSA and breathing, and from it, prompts the trainee to breathe faster or slower, so the two are in phase, as long as RSA remains at its maximum. If the trainee's resonant frequency changes, the trainee is informed about the new frequency (seconds/breath).

Home Practice:

The trainee is reminded to continue practicing slow, relaxed, abdominal, pursed-lips, prolonged exhalation breathing for two 20-minute sessions each day until the technique is *mastered. Also, the trainee is told to breathe at his/her new resonant frequency in each of these sessions.*

Session 3 Instructions: Review of Pursed Lips Abdominal Breathing with Slow Exhalation, and Introduction to Home Training Biofeedback Unit

Note: These home trainer instructions are specifically designed for use with the Cardiosignalizer [Biosvyaz Corp, St. Petersburg]. They should be modified according to the display and operating characteristics of the particular instrument used.

THERAPIST'S INSTRUCTIONS:

> The most important thing is to breathe in a relaxed way. Breathe easily and comfortably. Do not try too hard. Remember: 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 [*The therapist demonstrates this*.] Now you try it. Breathe so that just your abdomen moves in and out, while your chest stays still. Imagine that you are breathing through your feet. The work of breathing never involves your chest. Now inhale through the nose and exhale through pursed lips, like this.

The trainee tries each of these instructions a few times while the therapist continues to model. The therapist gives feedback to the trainee and praises the trainee for doing the method properly. If the trainee finds abdominal breathing too difficult, however, the method is abandoned for this session, and the trainee is told to continue breathing slowly. The trainee is instructed to practice at home, about 20 minutes two times per day, lying down or standing in front of a mirror, using pursed lips abdominal breathing.

THERAPIST'S INSTRUCTIONS:

> Combine abdominal and pursed lips breathing. Remember to breathe out longer than you breathe in. Continue to do pursed lips breathing when you exhale. Breathe abdominally. Combine all three styles of breathing, like this.

The therapist demonstrates, gives feedback, and praises the trainee for good attempts. Biofeedback is given using the cardiotachometer and respiration channels on the computerized machine, with the same biofeedback instructions as in Session 2. The pacing stimulus is used for 2 minutes at the trainee's resonant frequency and then is turned off. The trainee is then told to maximize RSA, in phase with breathing. Twenty minutes of biofeedback is given using the home training unit along with the computerized biofeedback signal. The trainee is told that (s)he will be lent a home training biofeedback machine. Instructions on how to use this machine at home are now given.

Home Training Unit (Cardiosignalizer) Instructions

a. Turn on the biofeedback unit. Set upper and lower HR limits to twice the trainee's resting RSA amplitude.
b. Show the trainee how to adjust the sensitivity of the biofeedback signal so that RSA amplitude fills approximately 50% of the range of the screen or light bar. Once the trainee has been able to maintain 50% of preset criteria levels for RSA amplitude for a few minutes, shape the trainee's response by increasing the range

on the biofeedback unit. Show the trainee how to adjust the instrument to shape RSA amplitude.

c. Ask the trainee to inhale and exhale in synchrony with the biofeedback signal: inhale as the lights go up and exhale as the lights go down. For example, if the lights begin to descend while he/she is inhaling, the trainee should continue to inhale instead of trying to "catch up" with the lights. The trainee should exhale through pursed lips. Tell the trainee that together the inhalation and exhalation should last approximately the length of resonant frequency. (The trainee is reminded of his/her resonant frequency.)
d. Instruct the trainee not to "try too hard."
e. Remind the trainee that the most important thing is to continue to breathe slowly and regularly and establish a comfortable breathing pace. This will allow the trainee gradually to begin breathing in synchrony with the monitor.
f. Again, tell the trainee that if he/she feels lightheaded, it may be the result of hyperventilation and to breathe less deeply.

Sessions 4–10 Acquiring Further Experience with the Technique
Biofeedback Instructions

The trainee is instructed to maximize RSA using the cardiotachometer as biofeedback. This is done by breathing in phase with HR changes. The trainee is reminded not to breathe too deeply, particularly if experiencing dizziness or lightheadedness. If breathing is not in synchrony with RSA, the therapist instructs the patient to adjust respiration rate to see if that causes an increase in the amplitude of RSA. This will determine the trainee's new resonant frequency, and the trainee should be informed of this new frequency.

After approximately 2 minutes (depending on how well the trainee is doing the task), the therapist prompts the trainee to shift to following his/her heart rate, and turns the pacing signal off.

THERAPIST'S INSTRUCTIONS:

First breathe at your resonant frequency for a few minutes. Follow the bar. Then shift to following your heart rate. Look at this line (*point to cardiotachometer tracing*). When your heart rate goes up, this line goes up. When it goes down, the line goes down. Try to breathe in phase with your heart rate. When your heart rate goes up, breathe in. When your heart rate goes down, breathe out.

Make your heart rate go up as far as possible and down as far as possible. Breathe easily, without tension. Breathe naturally. Don't try too hard. It should just flow almost automatically. Don't think too much about how to do it. Maybe it won't work right away. It will improve with time.

The therapist reviews pursed-lips abdominal breathing, exhaling longer than inhaling.

Home practice: *Same as in Session 3.*

ACKNOWLEDGMENTS

This work was supported in part by Grant #R01 HL58805 from the Heart, Lung and Blood Institute, National Institutes of Health. Some of the material from this paper is being

published in Chinese in Zheng, Yan-Ping (Ed.), *The Practice of Biofeedback*, Beijing: Higher Education Press.

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