The Impact of an Emotional Self-Management Skills Course on Psychosocial Functioning and Autonomic Recovery to Stress in Middle School Children

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Abstract—Unmanaged emotional reactions to stress not only lead to behavior problems in young people but also create physiological conditions that inhibit learning and potentially increase the risk of disease later in life. For these reasons, the integration of emotional self-management skills training programs has become an increased priority in some schools. In this study, middle school students enrolled in a course in emotional competence skills learned techniques designed to intercept stressful responses during emotionally challenging situations. Behavioral outcomes were assessed using the Achievement Inventory Measure and autonomic function was measured by heart rate variability (HRV) analysis during and after a stressful interview. Following the program, students exhibited significant improvements in areas including stress and anger management, risky behavior, work management and focus, and relationships with family, peers and teachers. These improvements were sustained over the following six months. Students using the skills taught in the course to recover from acute emotional stress were also able to positively modulate their physiological stress responses. As compared to a control group, trained students demonstrated significantly increased HRV and more rhythmic, sine wave-like heart rhythm patterns during recovery. This response pattern reflects increased parasympathetic activity, heart rhythm coherence, and entrainment of other biological oscillatory systems to the primary heart rhythm frequency. Increased physiological coherence is associated with improved cognitive performance, emotional balance, mental clarity and health outcomes. These physiological shifts could promote the sustained psychological and behavioral improvements associated with the use of emotional management skills. It is suggested that learning emotional competence skills in childhood establishes healthier physiological response patterns which can benefit learning and long-term health. Results provide support for the integration in school curricula of courses designed to teach effective self-management skills to children.

Introduction

IT HAS BECOME increasingly clear in recent years that children and adolescents can no longer be considered exempt from the adverse effects of stress. Children at risk for behav-

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ioral, adjustment and psychiatric problems represent a large portion of contemporary youth (Seifer et al., 1992). Community-based epidemiological studies clearly demonstrate the deterioration of children's emotional health, showing clinically significant psychopathology in the range of 20 percent in both adolescent and pre-adolescent populations (Costello et al., 1988; Kashani et al., 1987). Numerous children are part of households where parents are rarely home and the responsibility of caring for themselves as well as younger siblings has become largely their own. Many find little more comfort or security at school, where they fear becoming victims of violence and worry about the intense pressures to engage in risky behaviors such as early sex and substance abuse.

The inability to effectively manage chronic stress and negative emotions can instill a sense of hopelessness in children, which has in turn been linked to impulsive, destructive and socially inappropriate behaviors (Kashani et al., 1997). The prevalence of undesirable and dangerous behaviors among youth can serve to perpetuate the emotional atmosphere of fear, hostility and violence that pervades many school environments. Increasing media reports of extreme episodes of violence in schools have recently increased popular awareness of children's deteriorating emotional health and underscored the need to find more than topical solutions to resolve these issues.

Stress and Physiological Responses

The stressful emotions children experience on a day-to-day basis also influence a host of complex and interacting physiological reactions, which affect nearly every organ system in the body. Emotional stress is known to stimulate the sympathetic nervous system and alter heart rhythm patterns, thus changing the pattern of activity in the afferent neurological information transmitted from the heart to the brain. In contrast, positive emotions promote increased coherence in heart rhythm patterns, and a shift in sympathovagal balance towards increased parasympathetic activity (McCraty et al., 1995; Tiller et al., 1996). For clarity, *coherence* is used here to describe the degree of rhythmicity in the heart rate tachogram. Used in this sense, the term denotes an ordered or constructive distribution of power content within a single waveform (autocoherence). By this definition, a perfect sine wave represents the maximum coherence possible. Thus, the more sine wave-like a heart rhythm pattern, the more coherent it is said to be.

As the pathogenesis of both coronary heart disease and essential hypertension has its origins in childhood (Berenson et al., 1982), the study of autonomic responses to stress in children may have important implications for the etiology and prevention of these diseases in adults (Jemerin and Boyce, 1990; Krantz and Manuck, 1984). A number of studies have shown that autonomically-mediated stress responses in children and adolescents can predict future cardiovascular functioning (Matthews et al., 1993; Parker et al., 1987; Treiber et al., 1996), and in some cases these responses have been linked to the subsequent development of hypertension (Falkner et al., 1981; Wood et al., 1984). Notably, children with significant sources of ongoing stress in their lives exhibit increased physiological activation in response to acute laboratory stressors (Matthews et al., 1997), and trait negative affect has been linked with elevated resting blood pressure levels in adolescents (Ewart and Kolodner, 1994). Further, a growing body of evidence suggests that exaggerated physiological responses to stress not only place children at increased risk for a variety of health problems during childhood, but are also associated with maladaptive behavior patterns (Jemerin and Boyce, 1990).

The cascade of physiological events induced by unmanaged responses to emotional stress also impairs cognitive processes involved in learning. Changes in patterns of autonomic and hormonal activity during emotional stress are reported to lead to the inhibition of higher brain centers that enable one to focus on complex intellectual tasks and behaviors, to inhibit inappropriate responses or distractions, to plan, organize and remember information effectively (Arnsten, 1998; Kirschbaum et al., 1996). Research suggests that during emotional stress, resulting changes in the patterns of activity in the afferent neurological input to the brain can alter brain activity and compromise mental clarity, reasoning and decision making capacities (Tiller et al., 1996; Sandman et al., 1982). Taken together, these findings provide a physiological basis for teachers' increasing complaints that children are coming to school literally too angry, hurt or scared to effectively focus on complex mental tasks and the intake of new information.

Physiological responses to behavioral stressors are critically dependent on the manner in which individuals perceive or interpret the stimuli presented to them, and these interpretive styles are generally developed early in childhood. Evidence suggests that the level of responsiveness of systems involved in the body's physiological stress response may be set early in life and influenced by the nature of early experience and relationships (Meaney et al., 1994). The emotional environment that becomes familiar to children early in life can be a powerful determinant of cognitive, emotional and behavioral outcomes throughout childhood and adolescence. For example, a positive emotional environment characterized by feelings of caring and connectedness at home and at school has been shown to significantly reduce the chance of adolescents engaging in high-risk behaviors such as smoking, drug or alcohol abuse, early sex, violence and suicide, regardless of factors such as race, family income, school type, or single- or dual-parent status (Resnick et al., 1997). Further evidence suggests that positive emotions and social interactions experienced early in life can also influence long-term health outcomes. For instance, individuals raised in a loving and caring home environment as children have been found to have a substantially lower incidence of major diseases in mid-adulthood (Russek and Schwartz, 1997).

The Importance of Emotional Self-Management

The growing body of evidence documenting the profound effect that our emotions have on behavior, cognitive processes and health has underscored the importance of learning practical emotional management skills at an early age. This focus is further supported by recent theories of "emotional intelligence" which challenge the traditional view of intelligence as a one-dimensional construct, and suggest that a person's overall success and wellness throughout life is determined to a greater extent by proficiency in areas such as emotional self-management, conflict resolution, communication and interpersonal skills than by intellectual capability alone (Bar-On, 1996; Goleman, 1995; Mayer and Salovey, 1995). However, these theories also recognize that these crucial self-management skills are not simply developed "automatically," but rather require learning and practice.

In the social and emotional environments in which many children are raised, the self-management skills required to effectively deal with stress and conflict are frequently not learned at all. Educational systems focus on honing children's cognitive skills from the moment they enter the classroom, but little emphasis is placed on educating children in the resolution of inner conflicts and disturbing emotions. To this end, some educational administrators have recently begun to integrate "social and emotional learning" programs into school curricula. These programs focus on building social and emotional competence skills such as self-awareness, control of impulsivity, working cooperatively, and caring about oneself and others (Elias et al., 1997). The experience of many educators suggests that these programs are not only effective in improving student's stress management abilities, interpersonal skills and comfort in the classroom environment, but also enhance learning, motivation, work management skills and academic performance (Elias et al., 1997). However, few formal research studies have been conducted to confirm these results, and the influence of these types of programs on children's physiological responses has not yet been examined.

Heart Rate Variability: A Window on Autonomic Function

It is well established that emotional stress leads to alterations in the activity of the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). Valuable insight into the dynamics of ANS function can be gained noninvasively through the analysis of heart rate variability (HRV), a measurement of the beat-to-beat changes in heart rate (Öri et al., 1992). HRV reflects the autonomic regulation of the heart and has proven to be sensitive to changes in autonomic function and balance induced by emotional stimuli. There is evidence that the degree of coherence in the heart rhythms also affects electrophysiological activity in the brain and is related to aspects of cognitive function and performance (McCraty and Atkinson, 1999; McCraty et al., 1996b)

Other relevant research has focused on the behavioral correlates of vagal tone, which is reflected in the high frequency band of HRV. Evidence suggests that measures of vagal tone may reflect attentional capacity, stress vulnerability and the capacity to interact effectively with one's environment (Porges, 1992). Short-term measures of HRV are well established as a reliable indicator of real-time changes in ANS function and balance. For these reasons, in this study we selected short-term HRV analysis as an indicator of autonomic responses to emotional stress.

Aims and Scope of This Investigation

The present study examined the impact of an emotional competence intervention on psychological, behavioral and physiological measures in middle school children. The study was conducted in two phases over two years. In the first year, psychological and behavioral changes were examined in children enrolled in a self-management skills course. In the second year the impact of the training on children's autonomic responses and recovery to an acute emotional stressor was assessed.

Subjects

The study was conducted at the Palm Springs Middle School, located in Hialeah, Florida, near Miami. School counselors had observed that many students were distracted at school by various social pressures, anxiety, and depression that diverted their attention from focused academic learning, even among students with high ability. A preliminary analysis indicated that a number of students were at risk for anxiety, school dropout, risky behavior problems, and negative peer influence, and many had difficult home lives.

Internal Review Board approval was obtained from Essex IRB. In addition, approval for the study was obtained from the school board, and each child's parents provided informed consent and permission for participation. As a prerequisite for students' enrollment in the Heart Smarts course, students' parents agreed to attend monthly evening group sessions to learn and practice the self-management techniques with their children. These sessions were largely facilitated by the children themselves. At the first session, all parents willingly signed a written contract agreeing to practice the techniques themselves and with their children throughout the course of the study.

In year one, an emotional self-management program was provided to thirty-two seventh grade students (age range 12–13 years, mean age 12.2 years, eighteen males and fourteen females, twenty-six Hispanic, and six Caucasian) through a total of sixteen hours of training conducted over two weeks. Fifteen of the students volunteered to participate in a cross-age mentoring program at a nearby elementary school, where they tutored fifty-five second and third graders in the emotional management tools and techniques. In the second year the training program was expanded into the middle school curriculum as a full-year elective course called Heart Smarts. This course was provided to sixty children (grades sixth through eighth, age range 12–14 years, mean age 13.2 years) in two separate classes. From this group of sixty, thirty children were randomly selected and formed the experimental group whose autonomic function was assessed during and after a stressful interview. An additional thirty children, randomly selected from classmates not enrolled in the training program, comprised the control group. The experimental group consisted of nineteen females and eleven males and the control group had twenty-one females and nine males. Overall, the trained group was slightly younger but stature features, including height, weight and body surface area were insignificantly different. Overall gender differences were present, with males being taller, heavier and having a greater body surface area.

Measures

Psychological and Behavioral Assessment

The Achievement Inventory Measurement (AIM) (Leaseburg, 1991; Leaseburg and Martin, 1996) was used to assess psychological and behavioral changes in the first phase of the study. This 189–item inventory consists of nineteen scales that incorporate the domains of school, peers, family, and internal self-talk. The scales are grouped in three general categories: "Achievement Aptitude," "Interpersonal Skills," and "Mental Attitudes." The test items include traits that differentiate achieving, fully functioning individuals from youth that function at marginal cognitive and social levels, and eighteen of the scales are highly correlated with students' academic achievement. The test has been normed and validated on a sample of 4,176 students from mixed demographic backgrounds.

Physiological Assessment

The aim of the second phase of the study was to: (1) determine if the application of the techniques taught in the intervention would improve ANS balance and heart rhythm coherence when used to recover from acute emotional stress; and (2) if physiological shifts were found, to determine if they were consistent with those previously observed in adult populations. Participants' autonomic function was assessed by the analysis of heart rate variability (HRV). Both time domain and power spectrum analyses were performed. The time domain measures employed in this study were mean heart rate and standard deviation of RR intervals.

The HRV power spectrum was divided into the standardized frequency ranges: very low frequency (VLF), 0.033 to 0.04 Hz; low frequency (LF), 0.04 to 0.15 Hz; and high frequency (HF), 0.15 to 0.4 Hz. The HF band is widely accepted as a measure of parasympathetic or vagal activity. The peak in this band corresponds to the heart rate variations related to the respiratory cycle, commonly referred to as respiratory sinus arrhythmia. The LF region can reflect both sympathetic and parasympathetic activity, especially in short-term recordings. Parasympathetic influences are particularly present when respiration rates are below seven breaths per minute (Tiller et al., 1996) or when an individual takes a deep breath. This region was previously called the "baroreceptor range," as it also reflects baroreceptor activity (Malliani, 1995) and blood pressure wave activity and resonance. We have observed that during the practice of the self-management interventions used in this study, respiration, blood pressure waves (Tiller et al., 1996) and sometimes, brain wave patterns in the slow potential region of the EEG (McCraty et al., 1996b) can all entrain with the heart rhythms at a frequency of approximately 0.1 Hz. When this entrainment phenomenon occurs, the HRV waveform becomes a sine wave-like signal and the HRV power spectrum shifts to a narrow-band, high-amplitude signal in the LF region. This reflects an increase in respiratory sinus arrhythmia and parasympathetic activity.

Because the frequency at which entertainment occurs falls in the center of the LF band, this shift could be misinterpreted as an increase in sympathetic activity. In reality, it is primarily due to an increase in parasympathetic activity and vascular resonance. Sophisticated modeling techniques have shown that in normal states, about 50 percent of the total power in the LF band is explained by neural signals impinging on the sinus node which are generated at a central level, and the majority of the remaining power is due to resonance in the arterial pressure regulation feedback loop (Baselli et al., 1994). This model is supported by our own findings which demonstrate that during periods of entrainment, as described above, blood pressure oscillations become rhythmic and synchronize to the entrainment frequency of ~0.1Hz (Tiller et al., 1996). While the sympathetic system does not appear to influence heart rhythms above 0.1 Hz, the parasympathetic can be observed to operate down to frequencies of 0.05 Hz. Thus, during periods of slow respiration rate, as commonly occur during sleep, states of deep relaxation, as well as during use of the techniques described below, parasympathetic activity modulates the heart rhythms at a frequency that falls within the LF band.

The VLF component of the HRV power spectrum has been proposed as a marker of sympathetic activity; however, the physiological mechanisms involved in the generation of this rhythm are less defined and somewhat controversial.

Intervention

The intervention aimed to reinforce resiliency skills and positive citizenship among students, while counteracting the negative effects of mental and emotional stress on learning. The program presented a series of tools and strategies to help students reduce stress, sustain academic focus, improve communication skills, and enhance relationships with peers, teachers and family. The course also included a cross-age mentoring component. In the second year the full-year course was called *Heart Smarts.*

The Heart Smarts course presents a series of practical techniques designed to help students neutralize or transform negative, reactive emotions and behaviors in the moment, allowing them to replace emotional imbalance with increased resilience and emotional stability. Previous applications of these techniques with children, adolescents and families include: facilitating improvements in reading skills in learning-disabled fifth and sixth graders; facilitating a substance abuse recovery program in teenagers; and helping migrant families better integrate into American culture, improve academic skills, reinforce family connectedness and cope with challenges such as violence, poverty, fear and isolation (Childre and Martin, 1999). The techniques are described in detail elsewhere (Childre, 1998; Childre and Martin, 1999; Childre, 1996) and only brief descriptions of three of the techniques are included here.

Freeze-Frame (Childre, 1998). Freeze-Frame enables individuals to intervene in the moment that stress or an emotional reaction is experienced. In essence, the technique instructs one to consciously disengage from negative mental and emotional reactions as they occur by shifting one's attention to the physical area around the heart, where many people subjectively feel positive emotions, and then self-generate a sincere positive feeling state such as appreciation, love or care. This prevents the normal destructive stress response and changes the bodily feedback sent to the brain, thus arresting physiological and psychological wear and tear. As a result of Freeze-Frame, one can think more objectively and clearly and often transform an inefficient, emotionally draining response to a proactive, creative one. With practice, this tool can be used effectively in less than one minute. An important feature of this approach is that the technique focuses on genuinely experiencing a positive emotion at the *feeling level*, and is thus differentiated from other stress management techniques that attempt to elicit an emotional response through mental visualization or emotion recall.

Heart Lock-In (Childre and Martin, 1999). The Heart Lock-In is taught as a companion tool to Freeze-Frame. With practice of this technique, individuals learn to establish and sustain positive emotional and physiologically coherent states for longer periods of time. Physiological coherence is associated with efficient cardiovascular function, reduced fatigue, and heightened inner peace, self-security, mental clarity and emotional balance (McCraty et al., 1998b). Students enrolled in the Heart Smarts course practiced the Heart Lock-In with specific music (Childre, 1991; Childre, 1995) which has been shown to promote mental clarity and emotional balance (McCraty et al., 1998a).

Intuitive Listening (Childre, 1996). The Intuitive Listening technique facilitates the sharing of ideas and information with greater sincerity and effectiveness. Students learn to communicate more openly and honestly and to stop internal dialog in order to listen to others more deeply, with greater focus and attention. This technique was a key skill that students applied in the cross-age mentoring component of the course.

The Heart Smarts course was divided into two main phases. The first half of the year was spent learning the emotional self-management tools and mentoring skills. This process was facilitated by participation in fun exercises, games and role playing activities specifically designed to reinforce the skills learned (Childre, 1996). The course also included a heart rhythm education component in which students were given the opportunity to see changes in their heart rhythm patterns in real time when they used the Freeze-Frame and Heart Lock-In techniques. During the second half of the year, students applied the skills they had learned through participation in a cross-age mentoring program with children in the first through fifth grades at nearby feeder elementary schools. The mentoring program encouraged students to further develop their listening and communication skills, and to truly internalize the self-management tools.

Methods

In the first phase of the study, students completed the AIM inventory one week before and one week after the completion of the self-management program. The subgroup of students who participated in the mentoring program was assessed again six months later to determine longer-term effects of the intervention.

In the second phase of the study, the students' HRV was assessed before, during and after a stressful interview. All testing was conducted at the school site during a twelve-day interval in May 1998; five students were assessed each day. The test sequence consisted of a preparatory interval and three test intervals: baseline, stress interview and recovery. Upon entry to the testing facility, students' height and weight were measured. Thereafter, electrodes were placed and connected to a bioimpedance apparatus (Minnesota Cardiograph, model 304) that was interfaced to a dedicated computer and used to record a 3–lead electrocardiogram (ECG) (Mayrovitz and Larsen, 1996).

The student then was seated at a small table facing the interviewer, whereupon the interviewer briefly described the next events to occur. After the student had been seated for about five minutes, baseline measurements were recorded for a four-minute period. Following this, the Social Competence Interview was conducted. The duration of the interview was approximately twelve minutes. The ECG was recorded continuously throughout the baseline, stress and recovery intervals. During the recovery period (approximately seven minutes), the trained children applied the Freeze-Frame technique, while the control group participants were asked to relax in any way they normally would.

The Social Competence Interview

A structured interview known as the Social Competence Interview (SCI) (Ewart and Kolodner, 1991) was selected as the stressor in this study. The purpose of the interview was to aid the participants in genuinely re-experiencing stressful emotions by reconstructing a real-life distressing experience in detail. The SCI was selected as the stressor based on its apparent ecologic validity and previous validation with youth of comparable age (Dobkin et al., 1998; Ewart et al., 1998; Ewart and Kolodner, 1993). Moreover, the test taps social stress, unlike contrived laboratory stressors. The participant discusses a recent socially stressful event from a list of problems reported frequently by urban adolescents concerning school, work, family, friends, money and neighborhood. The interviewer, in this case a female licensed psychologist, initiates discussion of the most problematic topic which represents a source of recurring conflict for the participant. The participant describes a specific occasion when the stressful experience occurred. The situation is reconstructed in detail, and the interviewer attempts to facilitate accurate and genuine re-experiencing of the event and the emotions associated with it through the use of guided imagery and reflective listening. At the end of the SCI, students were told that the main test was now completed and that they had done well.

Heart Rate Variability Analysis

Analysis of heart rate variability was performed from the students' electrocardiograms, sampled at 256 Hz; baseline, stress and recovery intervals were each analyzed separately. The short-term HRV signal was in the form of an RR interval tachogram. Power spectral density (PSD) was obtained from the analysis of successive discrete RR interval time series. Analyses of HRV, fast-Fourier transforms, PSD (calculated as ms^2/Hz) and time-domain measurements were computed using DADiSP/32 digital signal processing software (DSP Development Corporation, Cambridge, Massachusetts). The HRV power spectrum was divided into the three major frequency ranges in keeping with the International Task Force Report, which standardized the nomenclature, analysis methods and definitions of the physiological and pathological correlates of heart rate variability measures (Task Force Report, 1996).

Results

Psychological and Behavioral Assessment

A total of 32 seventh grade students completed the pre- and post-HeartMath training AIM assessments. The paired t test was utilized to compare the pre- and post-intervention scores. A p value of 0.05 was considered significant. The AIM responses are reported as percentile rankings based on norms established from analysis of an age- and sex-matched student population (Table 1).

The pre-test scores reinforced the need for the school to implement the emotional self-management program, indicating that this group of students was at risk for anxiety, school dropout, risky behavior problems and negative peer influence. The children's poor emotional health and psychosocial functioning was also reflected in their responses to individual test items. For example, before the intervention, only 24 percent of the students reported their minds being calm and quiet. "I often have headaches or an upset stomach" was reported as "yes" by 56 percent and "sometimes" by 32 percent. Only 44 percent of the students perceived that they had a chance to pass in school and had not given up hope. "I carry a weapon to feel safe at school" was reported as "yes" by 18 percent and "sometimes" by 8 percent of the students. "I feel so trapped and hopeless that I don't care what happens to me" was reported as "yes" by 47 percent of the children and "sometimes" by 24 percent. Before the intervention, the group's mean percentile ranking scores were well below the norm on nine of the 19 AIM scales (Motivated and Supported; Work Management/Focus; Energized vs. Defeated; Peer Influence; Risky Behavior; Family Support/Satisfaction; Locus of Control; Self-Reliance; and Teacher Comfort). The students' lowest percentile ranking was on the Teacher Comfort scale. Their scores were well above the norm only on the Idealistic vs. Realistic scale, while scores on the remaining eight scales fell within the average range.

As shown in Table 1, there were significant improvements in seventeen of the nineteen AIM scales following the intervention. After the training the children scored well above the average range on all nine scales on which they had previously scored below the norm. Further, their scores on some scales that had fallen within the average range prior to the training also rose to above average values after the intervention.

Six-month follow-up assessments were obtained for the fifteen students who participated in the cross-age mentoring program. Repeated measures ANOVA followed by Dunn-Sidak Post Hoc test for all pairwise comparisons was used to analyze the AIM scores at the three time points. At the six-month time point, students scored significantly higher than baseline on the following scales: Work Management/Focused ($p < .01$), Energized vs. Defeated ($p < .01$), Teacher Comfort ($p < .01$), School Attitude ($p < .05$), Motivated and Supported ($p < .05$), Peer Influence ($p < .05$), Assertive vs. Shy ($p < .05$), Locus of Control ($p < .01$), Stress Management ($p < .01$) and Self-Satisfaction ($p < .01$).

TABLE 1
Achievement Inventory Measure Scores Pre and Post HeartMath Program

	Percentile Rank		*Raw Score Means*							
	Pre	*Post*	*Pre*	±	*SD*	*Post*	±	*SD*	*t*	*p*<
Motivated & Supported	38.5	66.0	2.52	±	0.42	2.65	±	0.29	3.08	.01
Work Management/Focused	38.7	61.3	2.29	±	0.42	2.44	±	0.38	4.23	.001
Energized vs. Defeated	36.5	65.7	2.31	±	0.43	2.46	±	0.40	3.52	.001
Peer Influence	37.2	66.2	2.54	±	0.39	2.66	±	0.34	2.22	.05
Leadership Skills	50.0	59.0	2.23	±	0.30	2.27	±	0.35	0.96	NS
Risky Behavior	36.8	68.5	2.61	±	0.31	2.70	±	0.29	2.58	.05
Teacher Comfort	29.2	63.2	2.40	±	0.41	2.64	±	0.41	6.27	.001
Anger Management	43.9	68.0	2.51	±	0.38	2.65	±	0.34	2.89	.01
Assertive vs. Shy	43.0	60.5	2.25	±	0.38	2.34	±	0.41	2.61	.05
Peer Support/Satisfaction	43.0	60.9	2.50	±	0.37	2.58	±	0.34	2.05	.05
Peer Empathy/Outgoing	41.5	69.7	2.49	±	0.35	2.60	±	0.32	2.99	.01
Family Support/Satisfaction	38.6	68.7	2.55	±	0.37	2.71	±	0.26	3.05	.01
Family Compliance/Participation	53.6	74.6	2.52	±	0.41	2.65	±	0.29	2.18	.05
School Attitude	42.2	65.9	2.45	±	0.38	2.54	±	0.37	1.60	NS
Self-Satisfaction	56.7	60.6	2.13	±	0.47	2.24	±	0.46	2.10	.05
Locus of Control	31.0	67.0	2.50	±	0.33	2.61	±	0.30	3.03	.01
Self-Reliance	34.5	68.7	2.53	±	0.29	2.65	±	0.25	3.59	.001
Stress Management	43.6	61.5	2.27	±	0.39	2.42	±	0.30	3.12	.01
Idealistic vs. Realistic	73.8	71.8	1.90	±	0.41	2.02	±	0.42	2.15	.05

Paired Samples t Test, N=32.

Physiological Assessment

Analysis of covariance (ANCOVA) was used to compare HRV parameters for differences between groups during the stress and recovery intervals. In order to correct for skewness, the frequency domain HRV measures were logarithmically transformed and statistical analysis was performed on the resulting values. For comparisons of heart rate changes, statistical analysis was performed on inter-beat interval values. Heart rate equivalents in BPM are also provided. Table 2 presents means and standard deviations for each HRV parameter for each phase of the study protocol. The groups did not significantly differ at baseline or during the stress interval.

The groups exhibited significantly different responses during the recovery period. In the trained group, heart rate ($p < .05$), standard deviation of RR intervals ($p < .001$), total power ($p < .001$) and VLF power ($p < .01$) were higher than in the control group, indicating that the trained children had higher HRV during this phase. The trained group also had higher LF power than the control group during the recovery period ($p < .01$). This is consistent with increased heart rhythm coherence as described above, as the classic signature of coherence is a large rise in power in the low frequency range (Tiller et al., 1996).

The mean HRV power spectrum plots shown in Figure 1 compare the responses of the groups at each phase. The two groups exhibited a similar increase in VLF, LF and HF power during the stress interval. The significant difference between the groups during recovery is apparent in the mean power spectra. The increase in LF power in the group that used Freeze-Frame during the recovery period reflects a shift to increased heart rhythm coherence, which was also clearly visible in the individual heart rate tachograms.

The mean power spectrum plots shown in Figure 2 summarize the changes in HRV frequency domain measures that occurred within each group in the baseline, stress and recovery intervals. The increase in power across all frequency bands during Freeze-Frame is clearly visible, with the largest increase in the LF band.

Analysis of the individual heart rate tachograms of each participant revealed visible differences in the HRV patterns recorded from the trained group versus the control group during the recovery phase. In the trained group, close to half of the participants showed a clear shift in their heart rhythms to the more coherent state (a near-sine wave-like pattern). Representative examples of one trained participant's heart rate tachogram and HRV power spectra are shown in Figure 3. In the control group participants there were no obvious increases in heart rhythm coherence. Representative examples of a control group participant's heart rate tachogram and HRV power spectra are shown in Figure 4.

Discussion

The results of this study demonstrate that significant psychological, behavioral and physiological improvements can be achieved in middle school children through learning and practicing effective emotional self-management techniques. The psychological and behavioral data gained in the initial phase of the study indicated that after learning the HeartMath techniques, students felt more motivated at school, were more focused in their school work and better able to organize and manage their time, both at school and at home. Their leadership and communication skills improved, and risky or harmful behavior problems decreased. They felt more supported by their families and friends, more comfortable with their teachers and showed increased compassion with their peers. The children also felt more comfortable with themselves, were more assertive and independent in their

TABLE 2
Heart Rate Variability Means and Standard Deviations

	Baseline		Stress				Recovery			
	Trained Group	*Controls*	*Trained Group*	*Controls*			*Trained Group*	*Controls*		
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*F*	*p<*	*Mean ± SD*	*Mean ± SD*	*F*	*p<*
Heart Rate (BPM)	86.80 ± 10.24	85.01 ± 12.60	89.68 ± 9.21	87.89 ± 11.66	–	–	85.24 ± 8.24	81.44 ± 11.33	–	–
Inter-Beat Interval (ms)	705.87 ± 86.32	726.82 ± 116.92	682.65 ± 71.20	701.70 ± 97.88	.12	NS	717.42 ± 74.17	755.63 ± 108.76	4.71	.05
SD (ms)	58.57 ± 21.38	57.60 ± 28.63	66.38 ± 21.99	67.53 ± 30.49	.26	NS	69.09 ± 22.32	57.60 ± 25.41	11.45	.001
High Frequency (ms^2)	1029.78 ± 915.21	1143.30 ± 1113.15	1332.23 ± 771.58	1489.72 ± 1010.69	–	–	1329.13 ± 1068.05	1048.61 ± 876.51	–	–
Ln High Frequency	6.66 ± .74	6.58 ± 1.03	7.03 ± .60	7.13 ± .59	.93	NS	6.93 ± .72	6.68 ± .75	2.67	NS
Low Frequency (ms^2)	1215.75 ± 779.09	1125.76 ± 971.58	1767.38 ± 1042.25	1670.04 ± 1454.39	–	–	1881.53 ± 1344.82	1067.96 ± 889.29	–	–
Ln Low Frequency	6.91 ± .64	6.70 ± .84	7.31 ± .59	7.15 ± .71	.07	NS	7.26 ± .80	6.68 ± .79	9.01	.01
Very Low Frequency (ms^2)	997.24 ± 1013.71	915.13 ± 1472.32	1120.10 ± 1112.99	1219.67 ± 2430.14	–	–	1330.03 ± 918.43	920.40 ± 1216.85	–	–
Ln Very Low Frequency	6.46 ± 1.00	6.21 ± 1.08	6.63 ± .91	6.39 ± 1.02	.11	NS	6.88 ± .90	6.27 ± 1.02	9.13	.01
Total Power (ms^2)	3242.78 ± 2234.79	3184.19 ± 2829.55	4219.71 ± 2607.32	4379.44 ± 4581.43	–	–	4540.70 ± 2725.33	3036.97 ± 2579.87	–	–
Ln Total Power	7.87 ± .67	7.69 ± .90	8.16 ± .63	8.09 ± .70	.21	NS	8.22 ± .68	7.73 ± .76	12.73	.001

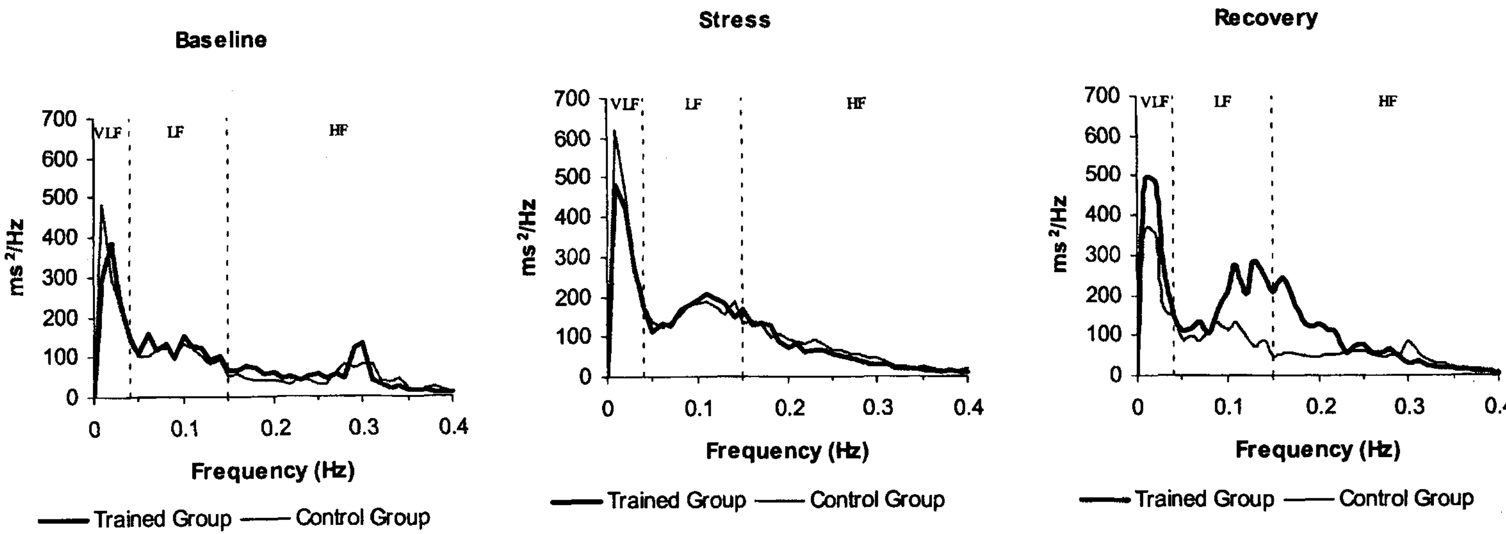

FIG. 1. Mean heart rate variability power spectra: Between-group effects. Mean heart rate variability (HRV) power spectra compare frequency domain HRV measures in the trained group (thick line) and the control group (thin line) during the baseline, stress and recovery intervals. Trained participants used the Freeze-Frame emotional self-management intervention during the recovery interval, while control group participants were asked to relax in any way they normally would. While there were no significant differences between the groups at baseline or during the stressful interview, the trained group had significantly higher VLF, LF and Total Power than the control group during the recovery period.

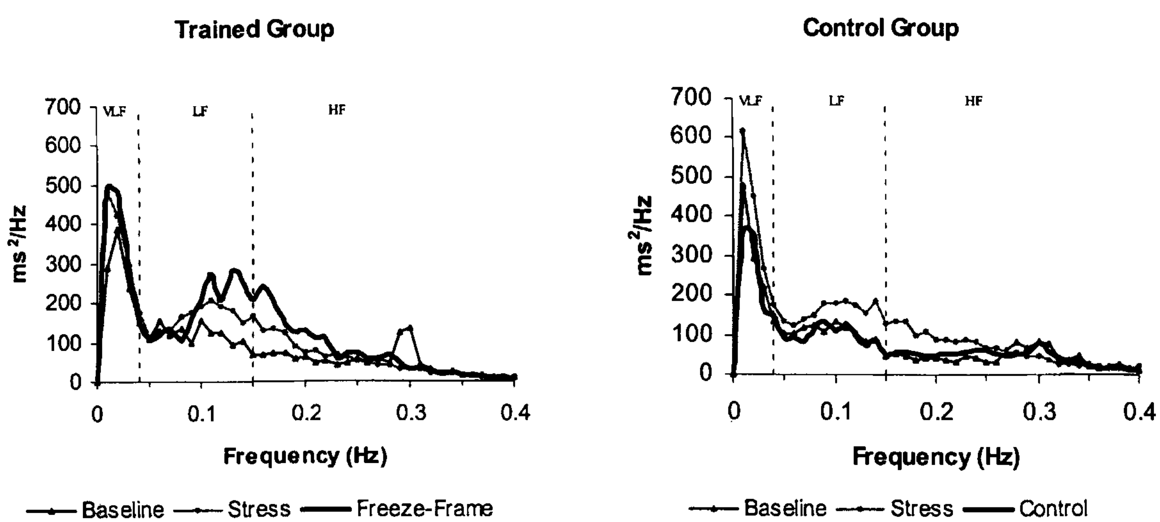

FIG. 2. Mean heart rate variability power spectra: Within-group effects. Mean heart rate variability (HRV) power spectra compare changes in frequency domain HRV measures from baseline to the stress and recovery intervals in the trained and control groups. Trained participants used the Freeze-Frame emotional self-management intervention during the recovery interval, while control group participants were asked to relax in any way they normally would. During the stressful interview, subjects in both groups exhibited a significant rise in LF, HF and Total Power. In the control group these measures returned to near baseline levels during recovery. In contrast, in the trained group HRV remained significantly elevated above baseline levels during the recovery period. Note the increase in power across all frequency bands during Freeze-Frame, with the largest increase in the LF band. This pattern reflects a shift to a state of increased physiological coherence (described in the text) with use of the intervention.

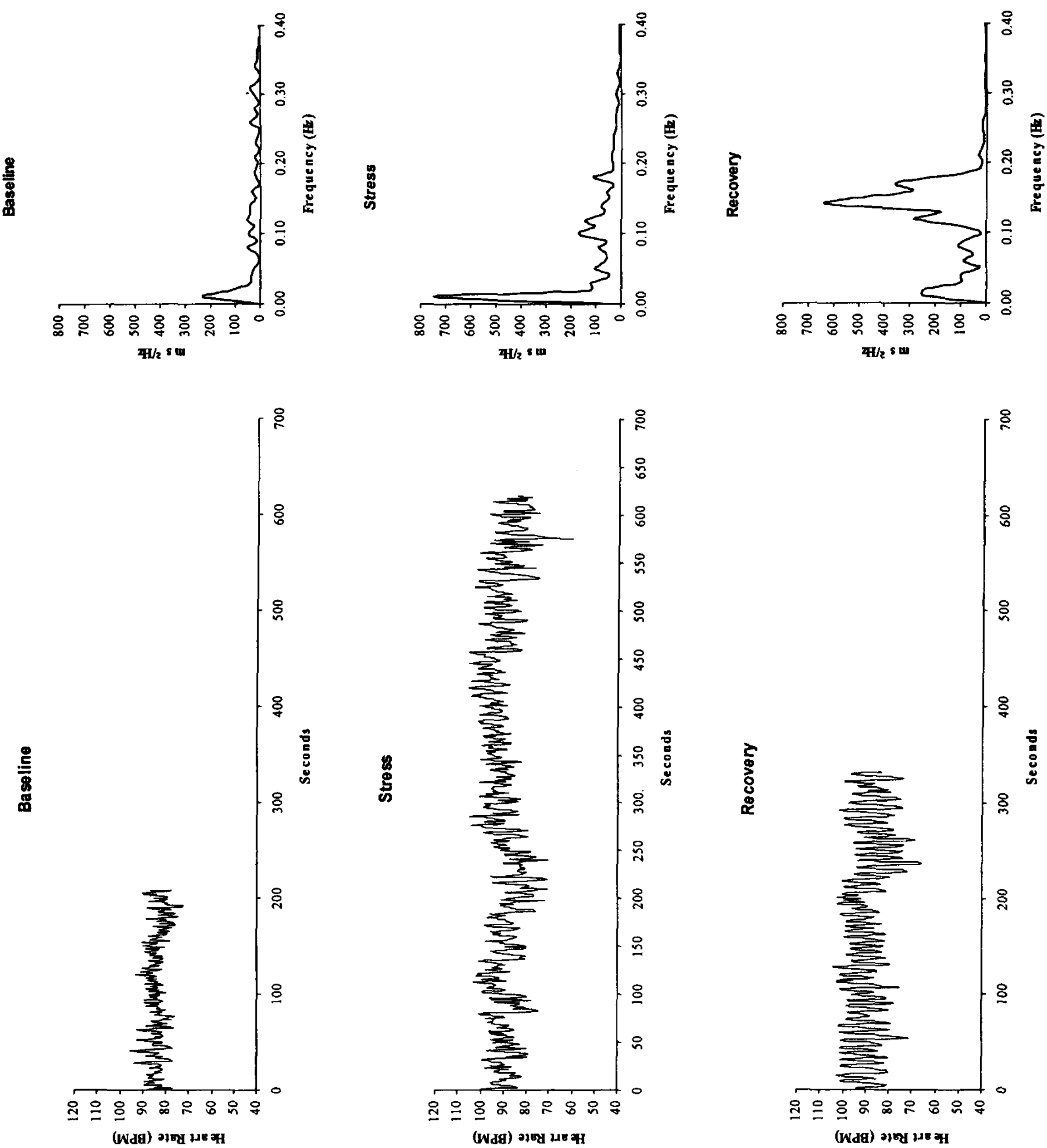

FIG. 3. Heart rate tachograms and heart rate variability power spectra: Example from a trained group participant. The tachograms and power spectra of one trained student show a representative example of the changes in heart rhythm patterns and autonomic balance that occurred in the trained group throughout the testing sequence. As this student used the Freeze-Frame intervention during the recovery interval, note the shift to a near sine wave-like pattern in the HRV trace, and the corresponding marked increase in the LF region of the power spectrum (large peak). This pattern reflects a state of increased heart rhythm coherence (described in the text).

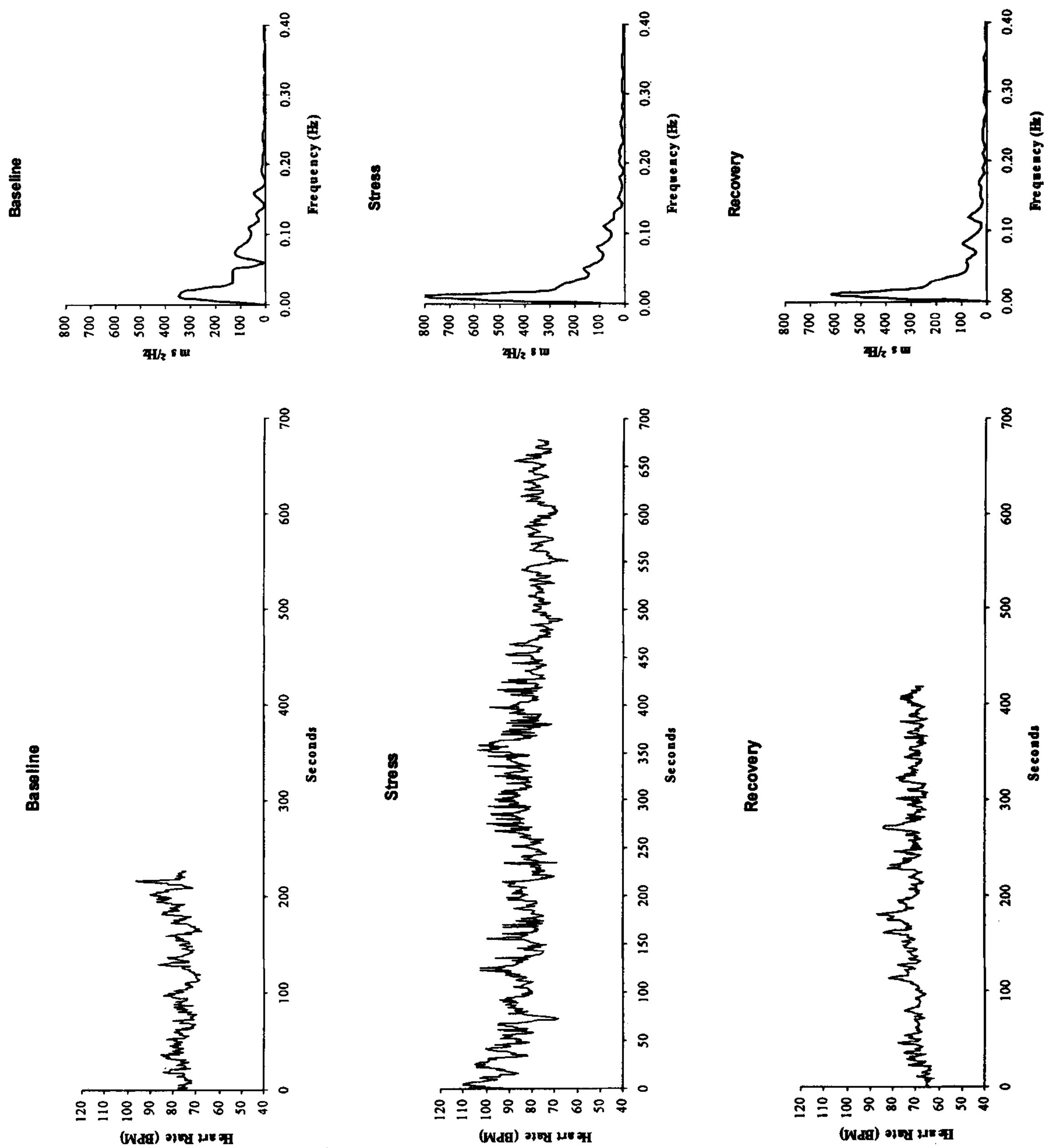

FIG. 4. Heart rate tachograms and heart rate variability power spectra: Example from a control group participant. The tachograms and power spectra of one control group participant show a representative example of the changes in heart rhythm patterns and autonomic balance that occurred in the control group throughout the testing sequence. No increases in heart rhythm coherence are evident in any of the test intervals.

decision making, more resistant to the demands of peer pressure, and better able to manage their stress, anger and negative internal self-talk. In essence, the children showed increased satisfaction and control over their lives while with friends, at school and around their families. Notably, these significant improvements occurred within a short period of time in an at-risk population with below-average levels of psychosocial functioning. Further, the follow-up analysis suggests that many of these changes were sustained over the following six months.

Physiological measurements revealed that middle school-aged children exhibit significant autonomic activation in response to an emotionally stressful event and that they are able to modulate aspects of this response using self-management techniques. In addition to providing basic information on the nature of autonomic responses to psychosocial stress in middle school-aged children, the results indicate that use of the techniques is associated with physiological changes similar to those observed in adult populations (McCraty et al., 1995; McCraty et al., 1998b; Tiller et al., 1996). As has been consistently observed in adults, there were clear increases in the children's heart rhythm coherence when they used the Freeze-Frame technique. It should also be underscored that the children in this study were able to achieve this physiological shift after an emotionally-charged event. We believe that the physiological changes associated with use of the Freeze-Frame technique were consistent with the psychological and behavioral improvements measured in Phase 1 of the study.

As anticipated, both groups exhibited significantly enhanced autonomic activation in response to the stressful interview, as evidenced by increases in heart rate and heart rate variability during the SCI. ANS activation is known to occur with emotional responses, as well as with talking and movement. The increase in mean heart rate and VLF power suggests that sympathetic activity was predominant during the stress interval, which is consistent with data indicating that stress and negative emotions such as anger, frustration or anxiety increase the ratio of sympathetic/parasympathetic activity (McCraty et al., 1995; Sloan et al., 1994; Thayer et al., 1996).

The main differences between the two groups were evident in the HRV changes during the recovery interval. The data suggest that students who used the Freeze-Frame technique after the stressful interview were able to increase parasympathetic activity and heart rhythm coherence. These differences can best be seen by comparing the heart rhythm patterns of individual students shown in Figures 3 (trained student) and 4 (untrained student). The heart rhythms of the children who used Freeze-Frame during the recovery period became substantially smoother and more sine wave-like relative to the stress and baseline intervals. This pattern reflects a slowed respiration rate, increased respiratory sinus arrhythmia and entrainment between respiration and the heart rhythm. The corresponding shift in the HRV power spectrum is easily seen in the example of a single trained student (Figure 3) and in the mean power spectra of the trained group as whole (Figure 1). These same physiological shifts have been previously associated with use of the Freeze-Frame and Heart Lock-In techniques in adult subjects (McCraty et al., 1998b; Tiller et al., 1996).

During the recovery interval, the trained subjects' overall heart rate variability, HF, LF and VLF power was increased relative to baseline, while these measures dropped back to near baseline values in the control group. Notably, heart rate dropped in both groups during the recovery phase; however, in the trained group, the HRV measures did not decrease. This response pattern indicates increased parasympathetic (vagal) activity in the trained children, as the parasympathetic nervous system is the primary mediator of large beat-to-beat changes in HRV. As explained above, in subjects who entered the *entrainment* mode, the increase in parasympathetic activity contributes to the large increase in power in the LF band of the HRV power spectrum, reflecting a marked slowing in breathing rate. In subjects who did not achieve full entrainment, the increase in vagal activity is manifested as an increase in power in the HF range. These results were consistent with the individual heart rate tachograms which showed that close to half of the trained participants made clear shifts to increased HRV coherence during the recovery phase, while most of the rest of the group showed a noticeable increase in patterns indicative of parasympathetic influence. The results are also in accordance with previous investigations in adults showing a group mean increase in both LF and HF power with use of the Freeze-Frame technique (McCraty et al., 1995).

There is evidence to suggest that increased ANS coherence is associated with improvements in cognitive performance (McCraty and Atkinson, 1999) as well as health-related outcomes, including enhanced humoral immunity (McCraty et al., 1996a; Rein et al., 1995), reduced cortisol and increased DHEA (McCraty et al., 1998b), and lowered blood pressure (Barros-Choplin et al, 1997; McCraty and Atkinson, 1999). Additionally, our experience with diverse populations indicates that as individuals learn to increase emotional self-management and generate periods of heart rhythm coherence with greater consistency, positive psychological improvements ensue, such as reduced hostility, anxiety and burnout, and enhanced emotional balance, feelings of inner peace, greater communication effectiveness and heightened mental clarity (Childre and Martin, 1999; McCraty et al., 1998b). These observations are consistent with the significant mental, emotional and behavioral improvements measured in the present study in children who used the techniques.

Based upon electrophysiological studies combined with findings from psychological assessments in numerous populations, we have proposed a model whereby the degree of coherence in the heart rhythms can influence perception and aspects of mental and emotional function, leading eventually to long-term changes in attitudes and behavior (McCraty and Atkinson, 2000). It is known that with every heartbeat, a burst of neural activity is communicated to the brain via the vagus nerve. These afferent signals are involved in the homeostatic regulation of autonomic outflow; however, they also affect brain centers involved in cognitive processing and emotional regulation (Frysinger and Harper, 1990; Koriath and Lindholm, 1986). Changes in the rhythmic beating pattern of the heart alter the afferent information the brain receives. Previous research has shown that during stress or negative emotions, heart rhythms become erratic or disordered (Tiller et al., 1996). This alters the pattern of activity in the neurological information transmitted from the heart to the brain. In this state, we experience a reduced ability to think and communicate clearly, and higher mental faculties such as decision making, problem solving and creativity are compromised. The term "cortical inhibition" is used to refer to this effect. In contrast, when heart rhythms become more coherent, as in positive emotional states, the coherence in the patterns of afferent information traveling from the heart to the higher brain centers also increases (Tiller et al., 1996). During these states mental clarity is augmented, positive feelings are facilitated and cortical function enhanced. This effect is termed "cortical facilitation" (McCraty and Atkinson, 2000).

Other research has also illuminated a link between heart rhythm patterns and cognitive processing. One recent study found that the heart rhythms of children with attention deficit hyperactivity disorder were significantly less coherent than those of normal children (Shibagaki and Furuya, 1997). In another investigation, disturbances in cognitive processing reflected by poor performance on a discrimination task were documented in children with congenital heart defects and altered cardiac patterns (O'Dougherty et al., 1988). Abnormal heart rhythm responses to stimuli have also been associated with an impaired attentional set and performance deficits in learning disabled children (Sroufe et al., 1973), while improvements in performance following stimulant medication have been associated with the normalization of cardiac response patterns (Porges et al., 1975; Sroufe et al., 1973).

In the present study, in addition to increasing heart rhythm coherence, children also increased parasympathetic (vagal) activity with use of the intervention. Increased vagal tone has been associated with increased physiological and behavioral flexibility, responsiveness to the environment, stress resiliency and emotion regulation ability (Porges, 1992; Porges et al., 1994). Evidence suggests that high vagal tone also enhances cognitive processes involved in learning, including attentional capacity (Porges, 1984; Richards, 1987) and verbal memory (Clark et al., 1999). These findings are supported by neurophysiological research which indicates that vagus nerve stimulation produces changes in the electrophysiological and metabolic profile of forebrain and brainstem structures involved in learning and memory (Ko et al., 1996; Naritoku et al., 1995). Finally, there is abundant data supporting the notion that greater vagal tone is associated with a more optimal physiological state while low vagal tone is related to illness and health risk. Low heart rate variability is found in individuals with a wide range of diseases and disorders and is considered a powerful predictor of future heart disease, increased risk of sudden death, as well as all-cause mortality (Dekker et al., 1997; Öri et al., 1992; Tsuji et al., 1994).

We suggest that learning effective emotional self-management techniques at a young age is a means of essentially conditioning one's system to respond to stress in a more coherent and healthy manner early in life. As these coherent response patterns become the norm in one's system, they promote a balanced internal environment that helps maintain health and protect against disease. Thus, providing emotional competence courses to school-aged children could be a valuable preventative measure, decreasing the long-term cumulative effects of stress, and promoting sustained physiological and psychological health throughout life. Although we believe that the physiological and behavioral changes observed with the use of self-management techniques are linked, this would of course be more definitively demonstrated in a study that measured these changes simultaneously in the same population.

Conclusions

The results of this study suggest that an emotional self-management intervention can significantly improve psychosocial functioning and substantially impact physiological responses to acute emotional stress in middle school-aged children. The ability to modulate autonomic function and balance at will is not generally recognized to be an easily obtained capacity. It is thus all the more significant to underscore this study's main finding that through a relatively straightforward intervention, middle school-aged children were able to self-generate positive shifts in autonomic balance and coherence. Further, these shifts were apparent even under the pressure of an acutely stressful situation. The results suggest that interventions which increase physiological coherence and vagal tone foster conditions conducive to emotional self-regulation and productive interaction with one's environment. This is consistent with the improvements in students' school-related performance, attitudes, emotions, key relationships and behavior reported here. It is proposed that shifts to states of increased physiological coherence could facilitate and help sustain positive psychological and behavioral shifts such as those observed in children who used the interventions. Future studies with larger sample sizes and appropriate controls should be designed to confirm psychological and behavioral results and to examine more directly the potential interrelationships between these parameters and physiological responses.

In summary, this study's results indicate that self-management skills can be effectively taught to middle school-aged children and provide support for the integration of emotional competence programs in school curricula. It is suggested that learning these skills in childhood instills healthy emotional and physiological response patterns. Evidence suggests that increased physiological coherence and improved autonomic balance not only enhance cognitive and emotional functioning, but may also positively impact long-term health outcomes.

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