The Scientific Role of the Heart in Learning and Performance

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The scientific, philosophical, and pedagogical foundation of the Institute of HeartMath's education initiative is based on leading-edge scientific research conducted during the past several decades on how stress and emotions impact learning and performance. It may be surprising to some to learn the critical role the heart plays in regulating the autonomic nervous system and in affecting our emotional experience. The following material provides a brief overview and explanation of these new scientific discoveries and some of their implications for education.

Overview

Throughout history, many cultures and spiritual traditions have shared a regard for the heart as a source of wisdom and positive emotions. Recent scientific discoveries suggest that these long-surviving associations may indeed be more than merely metaphorical. In particular, new understanding of the physiology of positive emotions and the key role played by the heart in the generation of emotional experience have exciting implications for higher-order thinking skills, learner readiness, decision making, and test-taking, as well as for social and emotional behavior. Based on this research, practical tools have been developed that enable students to self-regulate the physiological processes underlying effective learning and performance. Outcome studies show that use of these tools is associated with both academic and social-emotional improvements in students ranging from elementary to college level.

A new view of emotion

Research conducted throughout the past decade has challenged several longstanding assumptions about emotions. For example, psychologists once maintained that emotions were purely mental expressions generated by the brain alone. However, we now know that emotions have as much to do with the body as they do with the brain. Research has shown that neurological and hormonal signals flowing to the brain from many bodily organs and systems not only play a role in regulating physiological functions, but also influence higher brain centers involved in perception and emotional processing.[1-4] Furthermore, it appears that pertinent information is transmitted not only in the amplitude (strength or amount) of these bodily signals, but also in their *rhythm* and *pattern*.[1, 5-7]

The role of the heart

Although input originating from many different bodily organs and systems is involved in determining our emotional experience, recent research provides evidence that input from the heart may play a particularly important role.[3] As a primary and consistent generator of rhythmic information patterns in the human body, and possessing a far more extensive communication system with the brain than do other major organs, the heart exerts a unique and far-reaching influence on the brain and the entire body. It is now well-established that the

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heart is far more than a simple pump. It also functions as a hormonal gland, a sensory organ, and an information encoding and processing center, with an extensive intrinsic nervous system sufficiently sophisticated to qualify as a "heart brain." Its neural circuitry effectively enables it to learn, remember, and make functional decisions independent of the cranial brain.[8] With every beat, the heart transmits to the brain and throughout the body complex patterns of neurological, hormonal, pressure, and electromagnetic information, which form a major component of the physiological backdrop that ultimately determines our emotional experience.

Emotions are reflected in the heart's rhythms

One research tool that has proven particularly valuable in examining the interactions between the heart and brain is the analysis of heart rate variability. Contrary to many people's beliefs, the rhythmic beat of the heart is not monotonously regular, but rather varies dynamically from moment to moment. The term *heart rate variability* (HRV) is used to refer to these naturally-occurring, beat-to-beat changes in heart rate, which are reflective of heart-brain interactions and autonomic nervous system dynamics. Recent research has revealed that heart rate variability patterns, or *heart rhythms*, are remarkably responsive to changes in emotional states.[9-12] Specifically, during the experience of stress and negative emotions such as anger, frustration, or anxiety, heart rhythms become more erratic and disordered, indicating desynchonization in the reciprocal action between the parasympathetic and sympathetic branches of the autonomic nervous system (Figure 1). In simple terms, feeling stressed causes our system to get "out of sync"—not only mentally and emotionally, but also physiologically. When the two branches of the autonomic nervous system are out of sync with each other, it is similar to driving a car with one foot on the accelerator (the sympathetic nervous system) and the other on the brake (the parasympathetic nervous system) at the same time. The result is incoherence, increased energy consumption, and added wear and tear on the entire system.

In contrast, sustained positive emotions, such as appreciation, love, and compassion, are associated with highly ordered or *coherent* patterns in the heart rhythms, reflecting greater synchronization between the two branches of the autonomic nervous system and increased physiological efficiency[9-12] (Figure 1). Thus, sincerely experiencing positive feelings helps us get (and stay) "in sync."

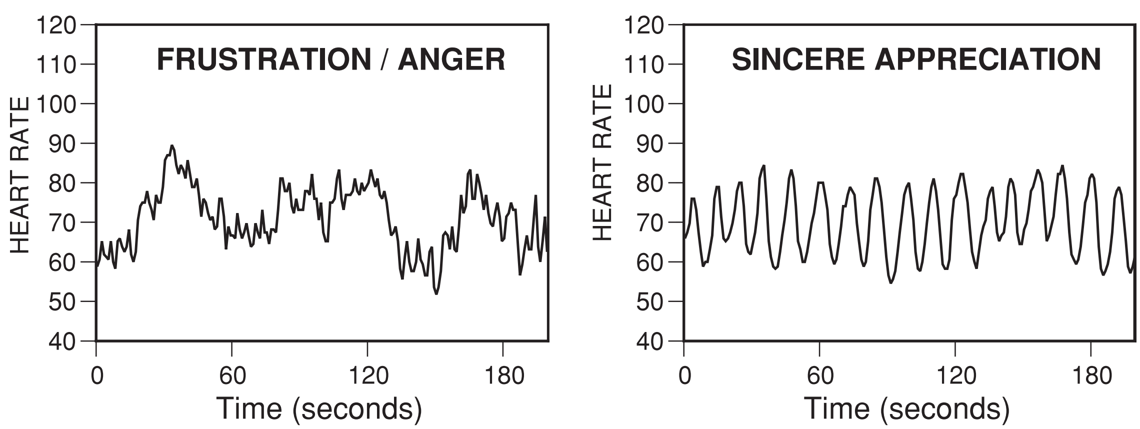

Figure 1. The heart rate variability pattern shown in the left graph, characterized by its random, jerky form, is typical of feelings of anger or frustration. This reflects a desynchronization in the activity between the two branches of the autonomic nervous system. Sincere positive feeling states like appreciation (right) can result in highly ordered and coherent HRV patterns, generally associated with enhanced cognitive performance and emotional stability. These patterns also reflect increased synchronized activity between the two branches of the autonomic nervous system.

Different patterns in the heart's rhythms and nervous system activity also affect the synchronized activity in the brain, which is the very basis of perception and cognition, including higher-order thinking skills. During emotional stress, when the heart transmits a disordered signal to the brain and activity in the nervous system is chaotic or desynchronized, higher cognitive functions are inhibited—limiting our ability to think clearly, focus, remember, learn, and reason. (This can help explain why we often can't think clearly, make careless mistakes, and have trouble retrieving information from memory when under stress.) In contrast, during positive feeling states, when the heart transmits an ordered, coherent signal to the brain and nervous system activity is harmonious and synchronized, our higher cognitive abilities are facilitated—often resulting in enhanced focus, memory recall, comprehension, and creativity.

Physiological coherence: Increasing nervous system harmony and emotional stability

Our research on the heart's rhythms and emotions has led us to identify a distinct mode of physiological functioning that is associated with the experience of heartfelt positive emotions. We have introduced the term *physiological coherence* to describe this mode. Correlates of physiological coherence include a smooth, sine wave-like pattern in the heart rhythms, decreased sympathetic nervous system activation and increased parasympathetic activity, increased heart-brain synchronization (the brain's alpha rhythms become more synchronized to the heartbeat), increased vascular resonance, and entrainment among diverse physiological oscillatory systems.[5-7, 10] These physiological changes result in a highly efficient state in which the body, brain, and nervous system function with increased synchronization and harmony—in other words, creating a state of being highly "in sync." The practice of techniques that increase physiological coherence has been associated with favorable health-related outcomes in both healthy and various clinical populations.[11, 13-16] Moreover, data suggest that the physiological coherence mode is also associated with greater emotional stability, a reduction in the perception of stress and negative emotions, and an increase in the experience of sustained positive emotions.[11-13]

Physiological coherence improves cognitive performance

Intriguingly, recent experiments conducted at the Institute of HeartMath provide evidence that increasing physiological coherence also improves cognitive performance.[7, 17] In these investigations, participants' performance on a cognitive task requiring focus and attention, discrimination, and a quick and accurate reaction was compared before and after they used a positive emotion-refocusing technique to increase physiological coherence. Results were compared with those of a control group who performed the same cognitive task before and after a relaxation period. Results showed that participants who increased heart rhythm coherence demonstrated a significant improvement in cognitive performance. In contrast, the control group showed no increase in heart rhythm coherence or improvement in performance after they engaged in a relaxation exercise (Figure 2). In addition, a significant correlation was found between the degree of heart rhythm coherence and performance across all subjects during all tasks—illustrating, in essence, that the more coherent or in sync we are, the better our cognitive performance. The results of this study suggest that the generation of the coherent mode may lead to changes in the brain's information-processing capabilities that can result in measurable improvements in performance on tasks requiring cognitive abilities such as focus, attention, and discrimination.[7]

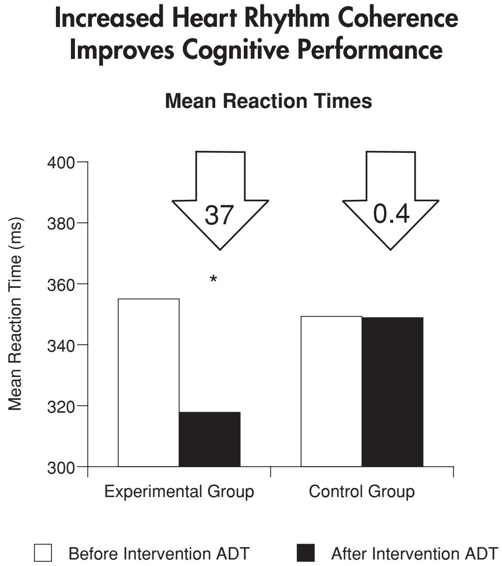

Figure 2. Mean reaction times for the experimental versus control group during the first (pre-intervention) and second (post-intervention) auditory discrimination tasks (ADT). Auditory discrimination tasks are well-established tests of cognitive performance that measure the participants' ability to focus and pay attention, discriminate subtle differences, and quickly and accurately react. By using HeartMath techniques to generate a state of increased heart rhythm coherence, the experimental group achieved a significant reduction in mean reaction time, indicative of improved cognitive performance. Note that control group participants, who simply relaxed during the interval between tests, showed no change in mean reaction time from the first to the second discrimination task.

Tools to increase physiological coherence

Based on the research described above, the Institute of HeartMath has developed new, positive emotion-focused tools and technologies that enable students to systematically increase physiological coherence and emotional stability, thereby improving both academic and social-emotional outcomes.[18-20] Collectively known as the HeartMath system, these techniques utilize the heart as a point of entry into the psychophysiological networks that underlie emotional experience.[19, 21] As discussed, because the heart is a primary generator of rhythmic patterns in the body—influencing brain processes that control the autonomic nervous system, cognitive function and emotion—it provides an access point from which system-wide dynamics can be quickly and profoundly affected.[7]

In brief, HeartMath techniques combine a shift in the focus of attention to the area around the heart (where many people subjectively feel positive emotions) with the intentional self-induction of a sincere positive emotional state, such as appreciation. Such a shift in focus and feeling serves to increase heart rhythm coherence and nervous system harmony, which results in a change in the pattern of neurological signals sent to the cognitive and emotional centers in the brain. This, in turn, facilitates higher cognitive faculties and emotion regulation abilities that are normally compromised during stress or negative emotional states, thus sharpening one’s discernment abilities, increasing resourcefulness, and often enabling problematic issues, interactions, or decisions to be assessed and dealt with from a broader, more emotionally balanced perspective.

Positive emotion-focused, coherence-building techniques are effective in helping to stabilize nervous system dynamics in real time—for example, when used in the midst of a potentially stressful situation that otherwise might have drained both physical and mental resources. However, the use of such techniques is also associated with benefits that extend well beyond the present moment. Research studies have shown that people of all ages who regularly use HeartMath techniques experience enduring improvements in many aspects of their lives, including health, emotional well-being, attitudes, behaviors and relationships.[11-13, 16] Research suggests that these enduring benefits stem from the fact that as people learn to generate physiological coherence with increasing consistency*, a system-wide repatterning process occurs*, whereby the associated synchronized, harmonious patterns of activity become ever more familiar to the brain and nervous system. These patterns thus become established in the neural architecture as a new, stable baseline or norm, which the system then strives to maintain. The result is that unhealthy or maladaptive patterns are progressively replaced with ones that foster increased physiological efficiency, mental acuity, and emotional stability. Moreover, even when one experiences stress, challenge, or emotional instability, the familiar, coherent, stable state is more quickly and easily accessible.

At the physiological level, the occurrence of such a repatterning process is supported by data showing that individuals well-practiced in coherence-building techniques often enter and sustain this mode spontaneously during their day-to-day activities, without conscious application of the techniques. We propose that the progressive establishment of new, healthier patterns in the neural architecture is what permits the practice of coherence-building techniques to produce the long-term improvements in emotion regulation abilities, behaviors, and health that have been documented by research studies in diverse populations.

HeartMath tools include positive emotion-refocusing techniques such as Freeze-Frame,[22] which enable individuals to modify their responses to stress in real time, and emotional restructuring techniques such as Attitude Breathing and Heart Lock-In,[20, 23] which build the capacity to sustain positive emotions and physiological coherence for longer periods. These tools are designed as simple, easy-to-use, low-cost interventions that can be adapted to virtually any culture or sub-culture, age group, or educational context. In addition, these and other HeartMath tools have recently been incorporated in an educational curriculum known as TestEdge,[18] which focuses specifically on reducing test anxiety and improving test performance in order to empower students to survive and even thrive in the stress-ridden environments of standards-based education and violent communities.

Heart rhythm coherence feedback training

Heart rhythm feedback training is a powerful tool to assist students in using positive emotion-focused techniques effectively and learning to self-generate increased physiological coherence.[24] Physiological coherence can be noninvasively monitored, quantified, and facilitated using practical technologies adaptable for classroom and counseling settings. One such device is the Freeze-Framer® heart rhythm-monitoring and coherence-building system (HeartMath LLC, Boulder Creek, CA). This interactive hardware/software system monitors and displays individuals' heart rate variability patterns in real time as they practice the positive emotion-focused techniques taught in an included tutorial program. Using a fingertip sensor to record the pulse wave, the Freeze-Framer plots changes in heart rate on a beat-to-beat basis. As students practice the techniques, they can readily see and experience the changes in their heart rhythm patterns, which generally become more ordered, smoother, and more sine wave-like as they feel appreciation and other positive emotions (see Figure 1). This process reinforces the natural association between the physiological coherence mode and positive feelings. The real-time physiological feedback also essentially takes the guesswork and randomness out of the process of self-inducing a positive emotional state, resulting in greater consistency, focus, and effectiveness in practicing emotional shifts.

The software also analyzes the heart rhythm patterns for coherence, which data is fed back to the user as an accumulated score or success in playing one of three enjoyable on-screen games designed to reinforce the emotion-refocusing skills. Finally, the software includes a multi-user database to store results and track users' progress.

Educational outcomes

Programs incorporating HeartMath tools and the Freeze-Framer coherence-building technology have been introduced at the elementary, middle school, high school, and college levels across the U.S. and have been demonstrated to improve emotional well-being, classroom behaviors, learning, and academic performance.[13] One collaborative research study by the Institute of HeartMath and the Miami Heart Research Institute was conducted in a Miami area middle school with sixth, seventh, and eighth grade students. In this study, a HeartMath program was incorporated in the middle school curriculum, first as a two-week in-class program and subsequently as a full-year elective course. The program was designed to reinforce resiliency skills and positive citizenship among students, while counteracting the negative effects of mental and emotional stress on learning. Application of the HeartMath tools was reinforced through a variety of fun, experiential games and activities, including participation in a cross-age mentoring program with elementary school students. The course also included an emotional physiology education component, using HeartMath's interactive Freeze-Framer system, in which students were given the opportunity to see changes in their heart rhythm patterns in real time as they practiced the Freeze-Frame and Heart Lock-In techniques. The Achievement Inventory Measure (AIM) was used to assess changes in psychosocial functioning, including measures of students' achievement aptitude, mental attitudes, and interpersonal skills.

Results showed that students who learned and practiced the HeartMath tools exhibited significant improvements in nearly all areas of psychosocial functioning assessed, including stress and anger management, self-reliance, risky behavior, work management and focus, and relationships with teachers, family and peers (Figure 3). Further, a follow-up analysis indicated that many of these improvements were sustained over the following six months.[12]

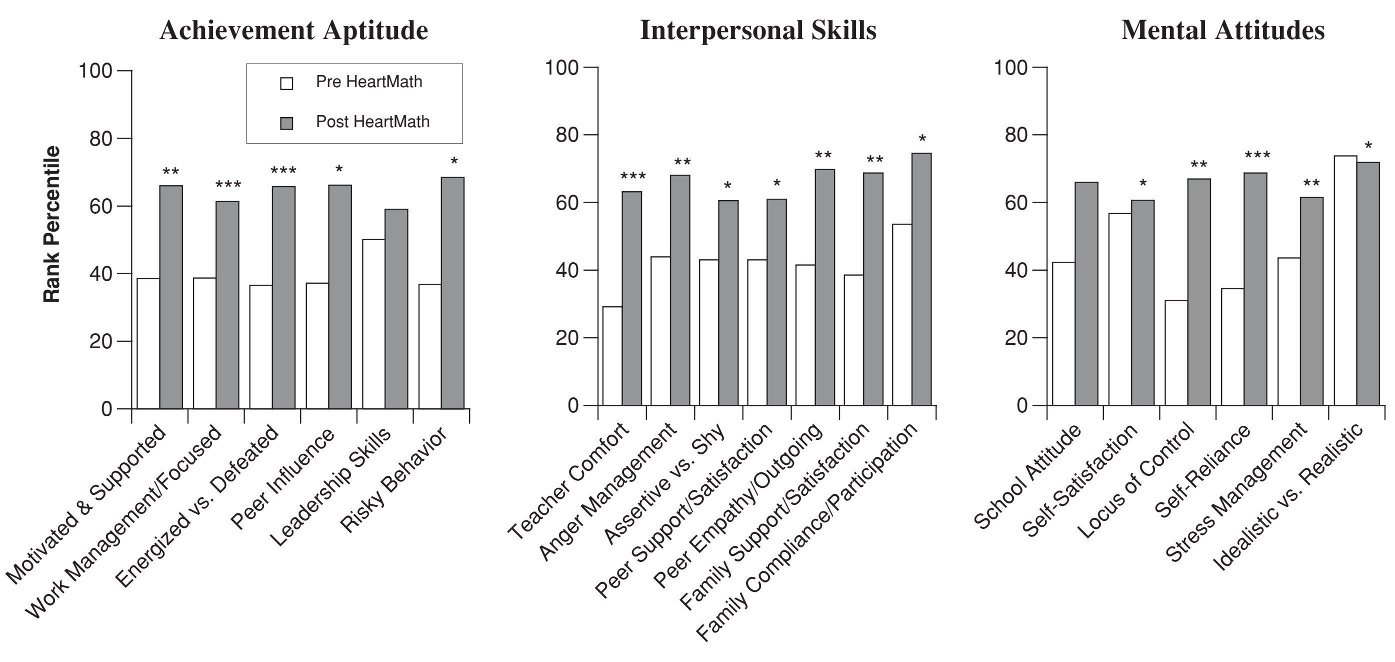

Figure 3. Psychological and behavioral improvements in at-risk seventh grade students after learning HeartMath tools and techniques.

A second phase of the study examined the impact of the HeartMath techniques on children's physiological responses to stress. Students' heart rate variability, as a measure of cardiovascular and nervous system dynamics, was assessed immediately prior to, during, and following a structured interview designed to elicit emotional responses to real-life stressful issues. Results showed that children who used the Freeze-Frame technique to recover from acute emotional stress were able to favorably modulate their physiological stress responses in real time, thus demonstrating increased stress resiliency in relation to a control group that did not learn the technique.[12]

Passing Rates for High School Seniors: HeartMath Group vs. District Average
(Minnesota Basic Standards Tests)

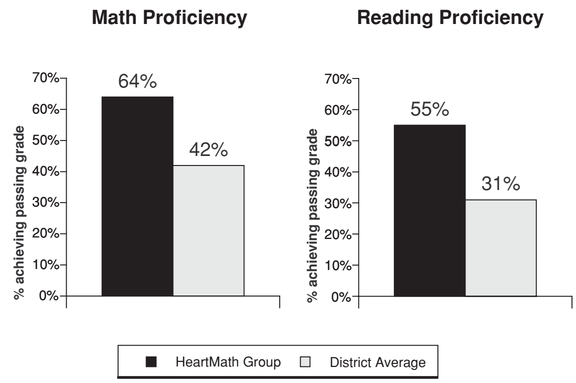

Figure 4. Percentage of HeartMath-trained students passing the Minnesota Basic Standards Tests in math and reading, as compared to the district average passing rate for all seniors re-taking the tests at that same time.

Another study conducted by clinical psychologist Dr. Pam Aasen, reading curriculum specialist Stephanie Thurik, and the Minneapolis Public School District examined the impact of HeartMath tools and technology on reducing test-taking anxiety and improving test scores in high school students. Twenty high school seniors, all of whom had previously failed their state-required exit exams and who needed to re-take the tests in order to graduate, participated in a three-week intensive test preparation program. In addition to academic material in reading and math, the course included approximately eight hours of instruction in HeartMath tools, with an emphasis on reducing test-related anxiety and instilling greater emotional stability and self-confidence. Students received heart rhythm feedback training with the Freeze-Framer to help them learn how to self-generate physiological coherence and increase nervous system harmony.

Psychological Improvements in High School Seniors Following HeartMath Training

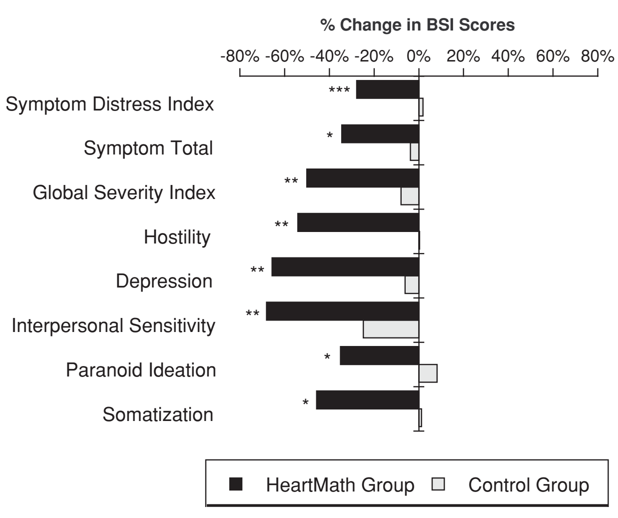

*Figure 5. Significant reductions in symptoms of psychological distress (Brief Symptom Inventory) experienced by HeartMath-trained students from pre to post-training, as compared to students in an untrained control group. Asterisks denote significant differences between the two groups in raw score means from time one to time two. *p< .05, **p< .01, ***p< .001.*

After the program, the students showed improvements in test-taking performance that greatly exceeded those achieved through standard academic preparation alone. The HeartMath group demonstrated a mean increase of 35% in math scores and a 14% increase in reading scores on the Minnesota Basic Standards Tests—gains that represented one to two years' growth in academic skills. Students' passing rates on the exams also improved substantially after the three-week program. Of the trained students re-taking the math test, 64% passed, as compared to the district average of 42% for all seniors re-taking the test at that time. For reading, the trained group's passing rate was 55%, as compared to the district average of 31% (Figure 4). As compared to a control group, the HeartMath-trained students also demonstrated significant improve-

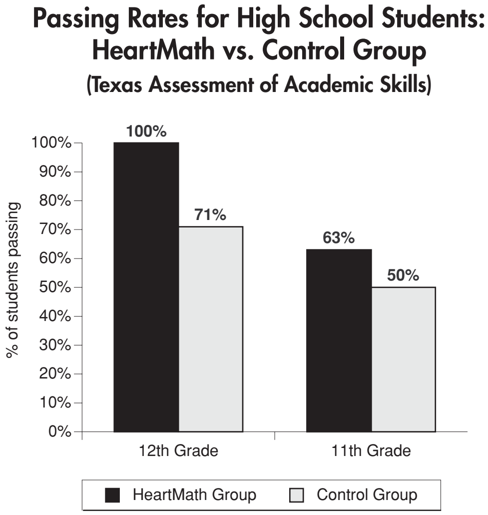

Figure 6. Percentage of HeartMath-trained students passing the Texas Assessment of Academic Skills Test, as compared to a control group.

ments in emotional well-being following the program, as measured by the Brief Symptom Inventory. These included reductions in hostility, depression, interpersonal sensitivity (feelings of personal inadequacy, inferiority and self-doubt), paranoid ideation (fearfulness, suspiciousness and mistrust), somatization (physical symptoms due to stress), and global indices of distress[25] (Figure 5).

The success of the Minneapolis pilot program led to a subsequent study in Houston, which substantiated the positive impact of the HeartMath program on test-taking. As part of their preparation for the Exit Level Texas Assessment of Academic Skills (TAAS) test, a group of high school juniors and seniors practiced the HeartMath coherence-building skills while studying the TAAS preparation materials to help raise their test scores. The students began their actual testing session with the Heart Lock-In technique to assist them in reaching a state of physiological coherence before beginning the TAAS Test, and they were also encouraged to use the Freeze-Frame technique while answering test questions to facilitate the retrieval of information. One hundred percent of the seniors in the program passed the TAAS Test, compared with 71% of seniors in a control group that received standard test preparation alone. Of the junior program participants, 63% passed the test as compared to 50% of the junior control group participants (Figure 6). After completion of the program, the trained students' scores on the Brief Symptom Inventory also indicated significant reductions in anxiety, hostility, and general psychological distress, as compared to the control group.

HeartMath tools and technology have also been successfully implemented in many elementary school classrooms across the nation. One independent study conducted at an inner city Phoenix elementary school examined the impact of the HeartMath tools on a small group of fifth and sixth grade Special Education students with learning disabilities. Most of the students suffered from a high level of emotional stress and had significant behavior and academic problems. In their regular classes, the students had already practiced a variety of learning methodologies for years, with very minimal improvement, and their self-esteem was extremely low. The students took part in a three-week summer course designed to improve reading skills and thereby allow the children to be promoted to the next grade. The class met for 1.25 hours each day for a total of 14 days within a three-week period. Given the short time period available and the instructor's perception of the children's true needs, the course focused primarily on teaching the students the HeartMath tools and provided very little

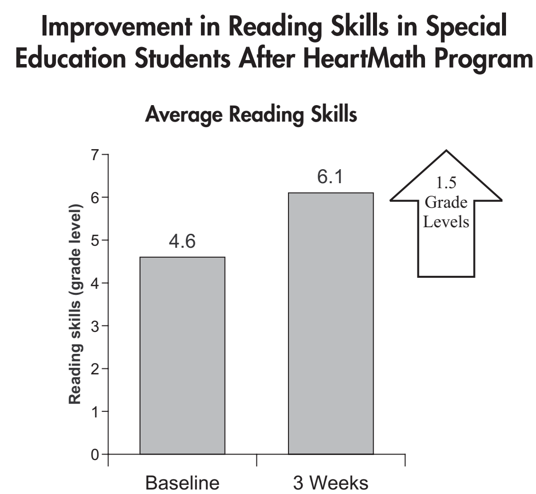

Figure 7. Average improvement in reading skills in fifth and sixth grade students with learning disabilities after the children practiced HeartMath techniques for three weeks. Reading skills were measured by the Wide Range Achievement Test test before and after the program, and scores shown represent average reading grade level. These Special Education students demonstrated an average improvement of 1.5 years' growth in reading proficiency over the three-week period.

traditional reading instruction. Pre- and post-intervention evaluations of students' reading proficiency were conducted using the Wide Range Achievement Test (WRAT). Additionally, changes in classroom behaviors were assessed by observational methods.

By the end of the three weeks, tremendous improvements in children's attitudes and behavior were readily apparent. Moreover, all of the students' reading scores improved dramatically, ranging from a two-month jump in reading proficiency for a bilingual student to over three years' growth for the highest performers (average growth of 1.5 years in grade level)[13] (Figure 7). The instructor's conclusion: "When techniques are presented that children are able to internalize and use to reduce stress, reduce the emotional pain of perceived failure, develop more sensitive communication, and relax, they are able to access what they have already learned."

Summary and Conclusions

In summary, research suggests that by learning to increase physiological coherence, students can increase nervous system harmony, thereby improving emotional stability, cognitive functioning, and academic performance. Physiological coherence can be noninvasively measured and facilitated in school settings using heart-based, positive emotion-focused techniques in combination with heart rhythm feedback technologies. Such approaches have been associated with improvements in standardized test scores, classroom behaviors, and social-emotional outcomes within a relatively brief time frame in studies conducted in diverse student populations. Collectively, results suggest that the integration of heart-based tools and technologies in educational curricula may be an efficient and effective means to facilitate both the academic and emotional development of our students.

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