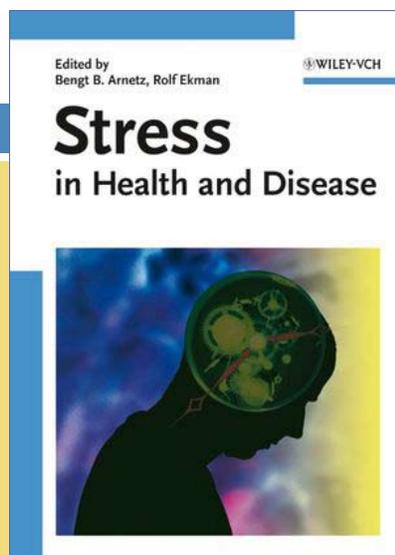


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From the Book
Stress in Health and Disease

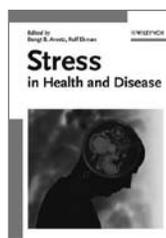
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Emotional Stress, Positive Emotions and Psychophysiological Coherence

Rollin McCraty, Ph.D. and Dana Tomasino

Chris, a 45-year-old business executive, had a family history of heart disease and was feeling extremely stressed, fatigued and generally in poor emotional health. A 24-hour heart-rate-variability analysis¹ revealed abnormally depressed activity in both branches of his autonomic nervous system, suggesting autonomic exhaustion ensuing from maladaptation to high stress levels. His heart-rate variability was far lower than would be expected for his age and was below the clinical cutoff level for significantly increased risk of sudden cardiac death. In addition, Chris's average heart rate was abnormally high, at 102 beats per minute, and his heart rate did not drop at night as it should.

Upon reviewing these results, his physician concluded that it was imperative that Chris take measures to reduce his stress. He recommended that Chris begin practicing a set of emotion-restructuring techniques that had been developed by the Institute of HeartMath. These positive emotion-focused techniques help individuals learn to self-generate and sustain a beneficial functional mode known as psychophysiological coherence, characterized increased emotional stability and increased synchronization and harmony in the functioning of physiological systems.

Concerned about his deteriorating health, Chris complied with his physician's recommendation. Each morning during his daily train commute to work, he practiced the Heart Lock-In Technique, and he would use the Freeze-Frame Technique in situations in which he felt his stress level rise.²

At first Chris was not aware of the transformation that was occurring. His wife was the first to notice the change and to remark about how differently he was behaving and how much better he looked. Then his

¹ The analysis of heart-rate variability (HRV), a measure of the naturally occurring beat-to-beat changes in heart rate, provides an indicator of neurocardiac fitness and autonomic nervous system function. Abnormally low 24-hour HRV is predictive of increased risk of heart disease and premature mortality. HRV is also highly reflective of stress and emotions.

² The Heart Lock-In Technique is an emotion-restructuring tool, generally practiced for 5 to 15 minutes, that helps build the capacity to sustain the psychophysiological coherence mode for extended periods of time. The Freeze-Frame Technique is a 1-minute positive emotion refocusing exercise used in the moment that stress is experienced to change perception and modify the psychophysiological stress response. The steps of these techniques are presented later in this chapter.

co-workers, staff and friends began to comment on how much less stressed he appeared in responding to situations at work and how much more poise and emotional balance he had. A second autonomic nervous system assessment, performed six weeks after the initial one, showed that Chris's average heart rate had decreased to 85 beats per minute and now lowered at night, as it should. Significant increases were also apparent in his heart-rate variability, which had more than doubled. These results surprised Chris's physician, because 24-hour heart-rate variability is typically very stable from week to week, and it is generally quite difficult to recover from autonomic nervous system depletion, which usually requires much longer than six weeks.

In reflecting on his experience, Chris started to see how profoundly his health and his life had been transformed. He was getting along with his family, colleagues and staff better than he could ever remember, and he felt much more clearheaded and in command of his life. His life seemed more harmonious, and the difficulties that came up at work and in his personal relationships no longer created the same level of distress; he now found himself able to approach them more smoothly and proactively, and often with a broader perspective.

This true story of Chris' transformation is not an isolated example, but rather is one of many similar case histories illustrating the profound transformations that have taken place when people have learned to self-manage their stress using these heart-based, positive emotion-focused tools. In this chapter, we describe two core tools of the HeartMath System, the Freeze-Frame and Heart Lock-In techniques, and then explore the scientific basis of their effectiveness. This discussion is built upon a conceptual framework that emphasizes the emotional component of the experience of stress and the proposition that truly transforming stress requires intervention at the emotional level. To understand how stress is generated and processed in the brain and body, we present a model of emotion, based on Pribram's theory, in which the brain functions as a complex pattern-matching system. From this perspective, it is shown that the heart is a key component of the emotional system, with the patterns of its extensive inputs to the brain making an important contribution to emotional experience. We also provide an overview of the Institute of HeartMath's research on the physiological correlates of positive emotions. This research has led to the characterization of a distinctive mode of psychophysiological functioning known as *psychophysiological coherence*. Through the use of tools and technologies that foster positive emo-

tions and psychophysiological coherence, individuals can effectively initiate a *restructuring* process, whereby habitual emotional patterns underlying stress are replaced with new, healthier patterns that establish increased emotional stability, mental acuity and physiological efficiency as a new familiar baseline or norm.

The Emotional Basis of Stress

The term "stress" has become one of the most widely exercised words in everyday vernacular. People describe themselves as "stressed" when stuck in traffic and also when experiencing the dissolution of a long-term relationship. Preparing for an examination, having difficulty communicating with a co-worker, dealing with serious illness in the family and adjusting to new living or working conditions can all be "stressful." But what is the common thread that unites these diverse experiences, making them worthy of a common descriptor? What defines the essence of the experience of "stress"?

A widely accepted model of stress involves the perception and appraisal of a stimulus as threatening, and the consequent activation of a set of physiological reactions characterized as the "stress response." Thus, stress research has traditionally been oriented toward studies examining the

cognitive processes that influence the perception of stress (a cognitive perspective) or the body's response to stress (a physiological perspective). Surprisingly, however, comparatively little attention has been given to the role of the emotional system in the stress process. From a psychophysiological perspective, emotions are central to the experience of stress; indeed, it is the *emotions* activated in response to perceiving a stimulus as threatening — *feelings* such as anxiety, irritation, frustration, lack of control or hopelessness — that are truly what we are experiencing when we describe ourselves as “stressed.” All of the above examples of “stressors,” whether minor inconveniences or major life changes, are experienced as “stressful” to the extent that they trigger emotions such as these.

While mental processes clearly play a role in stress, it is most often unmanaged emotions that provide fuel for their sustenance. It is well recognized that thoughts carrying an “emotional charge” are those that tend to perpetuate in consciousness. It is also emotions, more than thoughts alone, that activate the physiological changes comprising the “stress response.” Our own research has clearly shown that a purely mental activity, such as cognitively recalling a past situation that provoked anger, does not produce nearly as profound an impact on physiological processes as actually engaging the emotion associated with that memory; for example, actually reexperiencing the *feeling* of anger. It is the emotion that activates the autonomic nervous system and hypothalamic-pituitary-adrenal axis, leading to changes in the activity and function of the body's systems and organs. Thus, many of the deleterious effects of stress on the brain and body are, in fact, physiological repercussions of negative emotions.

In essence, stress is conceptualized here as *emotional unease*, the experience of which ranges from low-grade feelings of emotional unrest to intense emotional turmoil. It is further contended that stress arises not only in direct response to external situations or events, but also, to a large extent, the ongoing internal emotional processes and attitudes individuals perpetuate, even in the absence of any identifiable extrinsic stimulus. Re-

curring feelings of agitation, worry, anxiety, anger, judgment, resentment, discontentment, unhappiness, insecurity and self-doubt often consume a large part of our emotional energy and disrupt our feeling world even as we are engaged in the flow of everyday life and not necessarily confronted with a specific, current “stressor.” Indeed, many people do not realize the extent to which these internalized habitual emotional patterns dominate their internal landscape, diluting and limiting positive emotional experience, and eventually becoming so familiar that “stress” essentially becomes a defining part of their sense of self-identity (1, 2).

Breaking the Stress Cycle: The Power of Positive Emotions

Although most stress has an emotional source, it is interesting to observe that *most of the widely used stress management interventions do not directly focus on emotions*. For example, relaxation has long been seen as the ultimate remedy for stress; many individuals believe that if they could just learn to relax, then they would be healthier and happier. Relaxation is a helpful and beneficial process in that it temporarily draws attention away from distressing feelings and reduces physiological arousal, thereby promoting regeneration of the body. However, relaxation techniques generally do not address the unmanaged emotions that are the root cause of stress. Nor do they seek to transform the deeper, recurring emotional patterns that give rise to stress-producing feelings. Without these more fundamental changes at the emotional level, any relief from stress that is experienced is likely to be short-lived.

Other techniques commonly used to manage stress are derived from cognitive-behavioral psychotherapy. The cognitive-behavioral model operates on the theory that maladaptive thoughts drive unhealthy behaviors and that these thoughts should therefore be the focus of therapeutic intervention. Cognitive-behavioral therapy by definition excludes emotions as a primary focus for attention, and although emotions may be explored, they are seen as a consequence of maladaptive thoughts. According to the cognitive model, all emotions fol-

low a cognitive assessment of sensory input, which then leads to a behavioral response. The basic theoretical framework on which cognitive-behavioral methods are based, thus, is that if emotions always follow thought, then by changing one's thoughts, one can gain control over one's emotions.

In the last decade, however, research in the neurosciences has made it quite clear that emotional processes operate at a much higher speed than thoughts, frequently bypassing the mind's linear reasoning process entirely (3). Further, although emotions can be induced by thoughts, they may also arise from unconscious associations triggered by external or internal events. In other words, not all emotions follow thoughts; emotions often occur independently of the cognitive system and, moreover, can significantly bias or color the cognitive process and its output or decision (3, 4). For this reason, a therapeutic focus on thought processes alone may often fail to identify the fundamental cause of an emotional disturbance and thus, to resolve it. In some cases, try as one might to rectify one's thinking, one can fall short of achieving emotional relief simply because the underlying maladaptive emotional pattern may be driven largely by unconscious triggers that operate independently of the intellect.

Further insight is gained from current research in neuroscience, which is confirming that emotion and cognition can best be thought of as separate but interacting functions and systems, which communicate via bidirectional neural connections between the neocortex and emotional centers such as the amygdala. These connections allow emotion-related input to modulate cortical activity and cognitive input from the cortex to modulate emotional processing. However, research indicates that within the brain, neural connections from the emotional system to the cognitive system are stronger and more numerous than those flowing from the cognitive to the emotional system (3) (Figure 1). This provides a physiological basis for the common experience that emotional arousal can readily dominate the mental landscape, yet it is usually far more difficult to willfully "turn off" strong emotions through thought alone. Likewise, it is generally one's emotional experience, rather than solely cognitive

activity, that is the strongest motivator of attitudes, decisions and behavior.

This is why strategies that encourage "positive thinking", *without also engaging positive feeling*, may frequently provide only temporary, if any relief from emotional distress. While the individual may make a conceptual shift (which is important), the fundamental source of stress and driver of unhealthy behavior — the underlying maladaptive emotional pattern — remains largely intact. This understanding of how the cognitive and emotional systems interact has significant implications for emotion regulation interventions: It suggests that *intervening at the level of the emotional system itself* is a more direct, efficient — and powerful way to override and transform the maladaptive patterns underlying unhealthy psychological, behavioral and physiological stress responses.

More specifically, it is proposed that the *activation of positive emotions* plays a critical role in breaking the stress cycle by effectively transforming stress at its *source*. The transformative power of positive emotions is far from a new concept, having been noted for centuries by religious scholars, artists, scientists, medical practitioners and writers. However, scientific exploration of these experiences has been lacking for the most part. Overshadowed by the prevailing pathology-oriented paradigm of modern psychology, positive emotions have only recently been reexamined in a scientific light (5). It is hardly surprising, a growing body of such research is now beginning to provide objective evidence of the centrality of positive emotions to optimal functioning in nearly all spheres of human experience. Positive emotions have been demonstrated to improve health and increase longevity (6, 7). They have also been shown to affect the way we think and address challenges — increasing cognitive flexibility, creativity, receptivity and innovative problem-solving. Positive emotions further shape our behavior, promoting helpfulness, generosity and effective cooperation. In short, it is suggested that positive emotions are critical to our effective adaptation to life's challenges and to our growth and development as human beings (1, 8, 9).

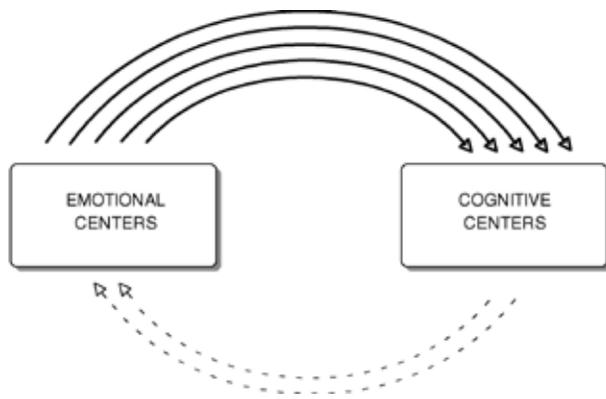


Figure 1. Simplified representation illustrating the asymmetry in the neural connections between the emotional and cognitive systems in the brain.

The neural connections that transmit information from the emotional centers to the cognitive centers in the brain are stronger and more numerous than those that convey information from the cognitive to the emotional centers. This accounts for the powerful influence of input from the emotional system on virtually all stages of cognitive processing involved in functions such as attention, perception and memory, as well as on higher-order thought processes. Conversely, the comparatively limited influence of input from the cognitive system on emotional processing helps to explain why it is so difficult to modulate our emotions through thought alone.

It is intriguing that research is now beginning to reveal some of the underlying physiological processes that may help explain *how* positive emotions improve health, enhance cognitive function and promote constructive behavior. As described in detail below, we have found that positive emotions are associated with a specific physiological state characterized by increased systemwide coherence, which in turn is associated with improved physiological functioning, emotional stability and cognitive performance.

Positive Emotion-Focused Tools and Techniques

The recent *positive psychology* movement has emphasized the importance of encouraging not only the reduction of negative emotions, but also the cultivation of positive emotions in daily life. Yet, psychology has seen a notable scarcity of interventions that focus directly and systematically on increasing positive emotional experiences. Recognizing this need many years ago, Doc Childre,

founder of the Institute of HeartMath, undertook the development of practical, heart-based positive emotion-focused tools and techniques, which are designed to facilitate the self-regulation of emotions (2, 10). Collectively known as the HeartMath System, these tools are intentionally designed as simple, easy-to-use interventions that can be adapted to virtually any culture, setting or age group. They are free of religious or cultural bias, and most people feel a positive emotional shift and experience a broadened perception the first time they use them.

Briefly, these interventions 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. We have found that appreciation is one of the most concrete and easiest of the positive emotions for individuals to self-induce and sustain for longer periods.

Here we describe two of the core HeartMath tools, the Freeze-Frame and Heart Lock-In techniques, which are the tools that were used in Chrisi case history that opened this chapter.

Freeze-Frame: A Positive Emotion Refocusing Technique

Freeze-Frame is a positive emotion refocusing exercise that enables individuals to intervene *in the moment* to greatly reduce or prevent the stress created from inappropriate or unproductive emotional triggers and reactions. The technique's name is derived from the concept that conscious perception works in a way that is analogous to watching a movie, in that each moment is perceived as an individual perceptual frame. When a scene becomes stressful, it is possible and helpful to freeze that perceptual frame and isolate it in time so it can be observed from a more detached and objective viewpoint — similar to putting a VCR on pause for the moment. We have found that the process of intentionally de-energizing and temporarily disengaging from distressing thoughts and emotions can be greatly facilitated by shifting one's attention

to the physical area around the heart (center of the chest) and self-generating a sincere positive *feeling*, such as appreciation. This process prevents or interrupts the body's normal stress response and also facilitates higher cognitive faculties that are normally compromised during stress and negative emotional states. This sharpens one's discernment abilities, increases resourcefulness and often facilitates a perceptual shift, which allows the original stressor to then be assessed and addressed from a broader, more emotionally balanced perspective.

The Freeze-Frame Technique consists of five simple steps, which can be effectively applied in real time in the midst of a stressful situation or day-to-day activities (e.g., while driving, sitting in a meeting, interacting with others, etc.). The tool can be used effectively in less than one minute.

The key elements of the technique are: *Shift* (to the area of the heart), *Activate* (a positive feeling) and *Sense* (what is the best perspective or attitude for this situation). In most training contexts, individuals are first led through several exercises

designed to aid them in identifying their deepest core values and the people, places or events they truly appreciate and care about. This helps them with Step 3, where they are asked to self-generate a feeling of appreciation or other positive emotion, which is an important aspect of the technique's effectiveness.

An important way in which Freeze-Frame is distinguished from various other stress management interventions is that it is designed to enable individuals to intercede in the moment that stress is being experienced, rather than try to recuperate "after the fact." The benefits of this cannot be overstated. Using Freeze-Frame in the "heat of the moment" saves tremendous amounts of energy that otherwise would have been drained and often prevents hours of emotionally induced wear and tear on the body and psyche. It can also reduce the time and energy spent dealing with the consequences of impulsive decisions or emotionally charged reactions, such as regret, embarrassment, guilt, accidents and damaged relationships.

The Steps of Freeze-Frame:

1. Take a time-out so that you can temporarily disengage from your thoughts and feelings, especially stressful ones.

2. Shift your focus of attention to the area around your heart. Now feel your breath coming in through your heart and going out through your solar plexus.

Practice breathing this way a few times to ease into the technique.

3. Make a sincere effort to activate a positive feeling.

Allow yourself to feel genuine appreciation or care for some person, some place or something in your life.

4. Ask yourself what would be an efficient, effective attitude or action that would balance and destress your system.

Your ability to think more clearly and objectively is enhanced based on the increased coherence you've created in steps 2 and 3. You can view the issue now from a broader, more balanced perspective. Ask yourself what you can do to help minimize future stress.

5. Quietly sense any change in perception or feeling, and sustain it as long as you can.

Heart perceptions are often subtle. They gently suggest effective solutions that would be best for you and all concerned.

One of the long-term benefits to be gained from the practice of emotion refocusing techniques such as Freeze-Frame is increased emotional awareness, a fundamental step in the process of improving emotional well-being. In addition to helping people modify their responses to stressful events in the external environment, such techniques also help individuals identify and modify more subtle internal stressors (i.e., persistent self-defeating and energy-depleting thought patterns and feelings, such as anxiety, fear, hurt, resentment, judgmentalism, perfectionism and projections about the future). As individuals practice “freezing the frame” when feeling inner emotional unrest, they gain increased awareness of the habitual mental and emotional processes that underlie their stress, and become more able to catch the onset of these feelings and patterns, thus diminishing their influence.

Heart Lock-In: An Emotion-Restructuring Technique

Heart Lock-In is an emotion-restructuring technique that is generally taught as a companion tool to Freeze-Frame. The Heart Lock-In technique fo-

cuses on building the capacity to sustain heartfelt positive emotions and their associated benefits for longer periods. This technique is generally practiced for five to fifteen minutes at a time, although longer sessions may be used as well. If desired, practice of this technique may also be facilitated by music specifically created to promote emotional balance and augment the favorable psychological and physiological effects of positive affective states (11).

The key elements of the technique are: *Focus* (in the area of the heart), *Appreciate* and *Sustain* (positive feelings). In the midst of life’s perpetual activity, the Heart Lock-In offers a simple way to cultivate and amplify heartfelt positive feelings and their nourishing effects on the body and psyche. This process is typically accompanied by feelings of deep peacefulness, harmony and a sense of inner warmth, and is often an effective means to diffuse accumulated stress and negative feelings. Also, in quieting the normal stream of mental dialogue through this process, many report the spontaneous emergence of increased intuitive clarity and insight relative to problems or troublesome issues.

The Steps of Heart Lock-In:

- 1. Gently shift your attention to the area around your heart.**
- 2. Shift your breathing so that you are breathing in through the heart and out through the solar plexus.**
- 3. Activate a genuine feeling of appreciation or care for someone or something in your life.**
- 4. Make a sincere effort to sustain feelings of appreciation or care while directing them to yourself and others.**
- 5. When you catch your mind wandering, gently focus your breathing back through the heart and solar plexus and reconnect with feelings of care or appreciation.**

After you’re finished, sincerely sustain your feelings of care and appreciation as long as you can. This will act as a cushion against recurring stress or anxiety.

Studies conducted across diverse populations in laboratory, organizational, educational and clinical settings have demonstrated that HeartMath positive emotion-focused techniques are effective in producing both immediate and sustained reductions in stress, together with improvements in many dimensions of psychosocial well-being. Moreover, these interventions have also been shown to give rise to significant improvements in key health and performance-related measures. For a review of outcome studies, see (1, 11). Collectively, results indicate that such techniques are easily learned and used, produce rapid improvements, have a high rate of compliance and are readily adaptable to a wide range of demographic groups.

The Scientific Basis of the HeartMath Techniques

We now turn to examining, from a psychophysiological perspective, the scientific basis of the positive emotion-focused tools described here. This discussion will lead us through a systems model of how emotions are generated and processed, explain the important role of the heart in the emotional system, and describe the psychophysiological changes associated with the induction of positive emotional states.

The Generation of Emotions: A Pattern-Matching Process

Recent years have seen the emergence of a new understanding of how the brain functions as well as of the brain-body dynamics involved in emotional processing. Rather than assembling thoughts and feelings from bits of data like a digital computer, the brain is an analog processor that relates whole concepts or *patterns* to one another and looks for similarities, differences and relationships between them. This new way of understanding brain processes has also challenged long-held views of how emotions are generated. Psychologists once maintained that emotions were purely mental ex-

pressions generated by the brain alone. We now know, instead, that emotions have as much to do with the body as they do with the brain: thus, the emergence of emotional experience results from the ongoing interaction between the brain, the body and the external environment.

Our research findings support a systems model of emotion that includes the heart, brain and the nervous and hormonal systems as fundamental components of a dynamic, interactive network that underlies the emergence of emotional experience (12). This model is based on the theory of emotion first proposed by Pribram (13), in which the brain functions as a complex pattern-identification and matching system. In this model, past experience builds within us a set of familiar patterns, which are instantiated in the neural architecture. Inputs to the brain from both the external and internal environments contribute to the maintenance of these patterns via a feedback process. Within the body, the patterns of activity of many processes provide constant rhythmic inputs with which the brain becomes familiar. These include the heart's rhythmic activity; digestive, respiratory and hormonal rhythms; and activation patterns of muscular tension, particularly facial expressions. These inputs are continuously monitored by the brain and help organize sensory perception, cognition, feelings and behavior.

Recurring input patterns from prior experience form a stable backdrop or *reference pattern*, against which the input patterns from present experience are compared. According to this model, current patterns that match the reference pattern are processed and experienced as "familiar," and therefore do not produce a change in emotional arousal or experience. However, when an input pattern in the present is sufficiently different from the reference pattern, a discontinuity or "*mismatch*" occurs. This mismatch, or *departure from the familiar pattern*, is what underlies the generation of feelings and emotions.

¹ HeartMath has developed a set of practical, easy-to-use positive emotion-refocusing and restructuring tools and techniques. These include Neutral, Quick Coherence, Freeze-Frame, Heart Lock-In, Attitude Breathing, Cut-Thru, etc. (Childre & Martin, 1999; Childre & Rozman, 2002, 2005; Childre, 1994).

Once a reference pattern is established, in order to maintain stability, the neural systems attempt to maintain a match between the reference pattern, current inputs and future behaviors. When the input to the brain does not match the existing reference pattern, an adjustment must be made to achieve control and return the system to stability. One way to reestablish stability is by executing an outward action. We are motivated to eat if we feel hungry, run away or fight if threatened, do something to draw attention to ourselves if feeling ignored, etc. Alternatively, we can gain control and reestablish stability by making an internal adjustment (without any overt action). For example, a confrontation at work may lead to feelings of anger, which can prompt inappropriate behavior (e.g., outward actions such as shouting, fighting, etc.). However, through intentional internal adjustments, we can *self-manage* our feelings in order to inhibit these responses, reestablish stability and maintain our job. Ultimately, when we achieve stability through our efforts, the results are feelings of satisfaction and gratification. By contrast, when there is a failure to assert control to reestablish psychophysiological stability, feelings such as anxiety, panic, annoyance, apprehension, hopelessness or depression result.

In short, since our psychophysiological systems are designed to maintain stability, returning to the familiar reference pattern gives us a sense and feeling of security, while remaining in unfamiliar territory causes unrest. Importantly, this is true even if the established reference pattern is one of chaos and confusion: *If the reference pattern becomes maladapted, the system will still strive to maintain a match to that pattern, even though it may be dysfunctional.*

In addition to processes that monitor the inputs and controls for maintaining stability (pattern matching) in the here-and-now, there are also matching processes that appraise the degree of congruity or incongruity between the past and the now and between the now and the projected future. Inputs to the neural systems are appraised and compared to memories of past outcomes associated with similar inputs or situations. These

prospective appraisals can be either optimistic or pessimistic. If the historical outcomes of similar situations are positive (resulting in the ability to maintain control and reestablish stability), an optimistic affect (e.g., interest, confidence or hope) will result.

On the other hand, if the appraisal does not result in a projected ability to return to stability, the current inputs are accompanied by pessimistic feelings about the future (e.g., annoyance, apprehension, hopelessness or depression). A pessimistic appraisal can be due to the expectation of failure to achieve stability based on outcomes of past experiences of similar situations, or to a lack of experience in the projected future situation. However, as we encounter novel situations, experience new inputs and learn new strategies to reestablish and maintain stability, we expand our repertoire of successful outcomes. The more repertoires available, the more likely a novel input will be appraised optimistically, with a high probability of success in maintaining stability. Once we learn how to handle new challenges effectively and maintain stability, the strategy (complex pattern) for dealing with the challenge also becomes familiar and part of our repertoire. It is through this process that we mature, increasing our internal self-control and management of emotions as well as our ability to respond effectively to external situations.

This model provides a psychophysiological basis for understanding why chronic stress can be so difficult to change. Through repeated experiences of stress, the brain learns to recognize the patterns of psychophysiological activity associated with “stress” as familiar, and therefore “comfortable.” To the extent that these patterns of activity become part of our baseline reference, the system then automatically strives to maintain a match with these habitual psychophysiological patterns, through a feedback process, despite their detrimental impact on health, emotional well-being and behavior. Without effective intervention, stress can become self-perpetuating and self-reinforcing.

However, because the system is in a dynamic relationship with its environment, this model also incorporates the means for change and develop-

ment. Through a *feed-forward* process, like resetting a thermostat, as new input patterns are consistently experienced and thus reinforced in the neural architecture, they become familiar to the system, and the reference pattern is thus modified and fed-forward to a new stability. Once the new reference pattern is stabilized, the system then strives to maintain a match with inputs that characterize this new baseline.

Usually this process occurs automatically and unconsciously. *However, such a feed-forward, re-patterning process can also be intentionally initiated.* This occurs as a pattern-matching operation in which the individual deliberately holds and projects a new emotional or behavioral pattern into the future as a target of achievement, in Pribram's terms (14). Holding the new pattern as a target in this way causes the psychophysiological systems to feed-forward as new patterns of input are experienced and processed. Essentially, the system makes continual adjustments in its patterns of activity until a match is achieved between the target and the current pattern of system activity. Eventually, if this process is sustained, a new baseline is created in which the new pattern is instantiated in the system as the reference pattern. It is on this principle that the HeartMath techniques and technology is based. To further understand the processes by which these techniques work, it is necessary to examine the key role of the heart in this model.

More Than a Pump: The Heart's Key Role

The model of emotion described here highlights the critical function of afferent (ascending) input from the bodily organs to the brain in contributing to the input patterns that ultimately determine emotional experience (12, 13). Although complex patterns of activity originating from many different bodily organs and systems are involved in this process, it has become clear that the heart plays a particularly important role. The heart is the primary and most consistent source of dynamic rhythmic patterns in the body. Furthermore, the afferent networks connecting the heart and car-

diovascular system with the brain are far more extensive than the afferent systems associated with other major organs. It is now established that the heart is a sophisticated information encoding and processing center, with an intrinsic nervous system sufficiently sophisticated to qualify as "little brain" in its own right. Its circuitry enables it to learn, remember and make functional decisions independent of the cranial brain, and its rhythmic input to the brain reflects these processes (15).

The heart also functions as a sensory organ, and is particularly sensitive and responsive to changes in a number of other psychophysiological systems. For example, heart-rhythm patterns are continually and rapidly modulated by changes in the activity of either branch of the ANS, and the heart's extensive intrinsic network of sensory neurons also enables it to detect and respond to variations in hormonal rhythms and patterns (15). Finally, the heart is itself an endocrine gland that manufactures and secretes multiple hormones and neurotransmitters (16).

Thus, with each beat, the heart not only pumps blood, but also continually transmits dynamic patterns of neurological, hormonal, pressure and electromagnetic information to the brain and throughout the body (16). An extensive body of research also has shown that cardiac afferent input not only exerts homeostatic effects on cardiovascular regulatory centers in the brain, but also influences the activity and function of higher brain centers involved in perceptual, cognitive and emotional processing (see (16) for a review). The multiple and continuous inputs from the heart and cardiovascular system to the brain are therefore a major contributor in establishing the familiar reference pattern against which the current input of the "now" is compared. Also, it follows from this model that *changes* in the heart's patterns of activity can have an immediate and profound impact on emotional perception and experience.

Given this connection between heart-rhythm patterns and emotion, it would be predicted that interventions that enable individuals to *intentionally* change the pattern of the heart's rhythmic ac-

tivity should modify one's emotional state. In fact, people commonly use just such an intervention when feeling stress — simply altering their breathing rhythms by taking several slow, deep breaths. Most people do not realize, however, that an important reason breathing techniques are effective in helping to shift one's emotional state is because *changing one's breathing rhythm modulates the heart's rhythmic activity*. The modulation of the heart's rhythm by respiratory activity is referred to as respiratory sinus arrhythmia.

While it can provide short-term relief from stress, cognitively directed, paced breathing is difficult for most people to maintain for more than about one minute. On the other hand, we have found that characteristic, sustained shifts in the heart's rhythmic activity can be generated through the intentional self-induction of positive emotions. As we discuss next, this process has systemwide repercussions.

The Physiology of Positive Emotions

In the early stages of our research examining how psychophysiological patterns change during stress and different emotional states, we sought to determine which physiological variables were most sensitive and responsive to changes in emotion. In analyzing many different physiological measures, we discovered that the rhythmic beating patterns of the heart were consistently the most reflective of changes in emotional states, in that they covaried with emotions in real time.

Specifically, we examined the natural fluctuations in heart rate, known as *heart rate variability* (HRV) or *heart rhythms*, which are a product of the dynamic interplay of many of the body's systems. Short-term (beat-to-beat) changes in heart rate are largely generated and amplified by the interaction between the heart and brain via the flow of neural signals flowing through the efferent and afferent pathways of the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). HRV is thus considered a measure of neurocardiac function that reflects

heart–brain interactions and ANS dynamics.

Utilizing HRV analysis, we have demonstrated that distinct heart-rhythm patterns characterize different emotional states (16, 17). In general, emotional stress, including emotions such as anger, frustration and anxiety, leads to heart-rhythm patterns that appear *incoherent* — erratic, disordered and jagged (Figure 2). Overall, compared to a neutral baseline state, this indicates less synchronization in the reciprocal action of the parasympathetic and sympathetic branches of the ANS. This desynchronization in the ANS, if sustained, taxes the nervous system and bodily organs, impeding the efficient synchronization and flow of information throughout the psychophysiological systems. Furthermore, considering that studies have shown that prefrontal cortex activity is reflected in HRV via modulation of the parasympathetic branch of the ANS, this increased disorder in heart-rhythm patterns is also likely indicative of disorder in higher brain systems.

In contrast, sustained positive emotions, such as appreciation, care, compassion and love, generate a smooth, ordered, sine wavelike pattern in the heart's rhythms. Relative to a neutral baseline, this reflects increased synchronization between the two branches of the ANS and a general shift in autonomic balance towards increased parasympathetic activity. As is visually evident (Figure 2) and also demonstrable by quantitative methods (16, 17), heart rhythms associated with positive emotions such as appreciation are clearly more *coherent* than those generated during a negative emotional experience such as frustration.

We observed that these associations appeared to hold true in studies conducted in both laboratory and natural settings, and for both spontaneous emotions and intentionally generated feelings. An important point to emphasize is that although *heart rate* or the *amount* of HRV can also covary with emotional changes, our findings showed that it is the larger-scale *pattern* of the heart's rhythmic activity that is most directly related to emotional dynamics.

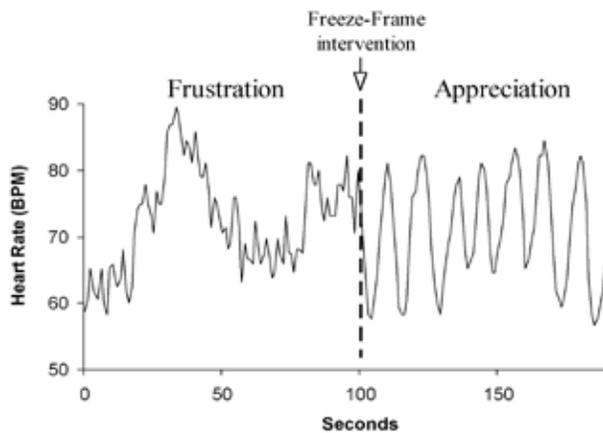


Figure 2. Emotions are reflected in heart-rhythm patterns.

The real-time heart-rate-variability (heart rhythm) pattern is shown for an individual making an intentional shift from a self-induced state of frustration to genuine feeling of appreciation by using the Freeze-Frame positive emotion-refocusing technique (at the dotted line). It is of note that when the recording is analyzed statistically, the amount of heart rate variability is found to remain virtually the same during the two different emotional states; however, the pattern of the heart rhythm changes distinctly. Note the immediate shift from an erratic, disordered (incoherent) heart-rhythm pattern associated with frustration to a smooth, harmonious, sine wavelike (coherent) pattern as the individual uses the positive emotion-refocusing technique and self-generates a heartfelt feeling of appreciation.

Taking this research further, we also observed that when positive emotional states are intentionally maintained, coherent heart-rhythm patterns can be sustained for longer periods, which also leads to increased synchronization and entrainment between the heart's rhythm and the activity of multiple bodily systems. Based on the distinctive set of physiological and psychological correlates that are consistently observed in such states across diverse subject populations, we have introduced the term *psychophysiological coherence* to describe this particular mode of functioning (16).

Psychophysiological Coherence

At the physiological level, the psychophysiological coherence mode is characterized by increased order, efficiency and harmony in the activity and interactions of the body's systems, encompassing phenomena such as autocohereance, entrainment, synchronization and resonance (1, 16). As described above, this mode is associated with increased coherence in the heart's rhythmic activity

(autocohereance), which manifests as a sine wave-like heart-rhythm pattern oscillating at a frequency of approximately 0.1 hertz. Thus, in this mode the HRV power spectrum is dominated by a narrow-band, high-amplitude peak near the center of the low-frequency range (Figure 3).

Further, during the psychophysiological coherence mode, there is increased cross-coherence or entrainment among the rhythmic patterns of activity generated by different physiological oscillatory systems. Because the heart is the body's most powerful rhythmic oscillator, generating the strongest rhythmic wave pattern, as the heart's rhythm becomes more coherent it can drive other oscillatory systems into entrainment with it. Typically, entrainment is observed between heart rhythms, respiratory rhythms and blood-pressure oscillations; however, other biological oscillators, including very low-frequency brain rhythms, craniosacral rhythms and electrical potentials measured across the skin, can also become entrained (16).

Finally, psychophysiological coherence is characterized by increased synchronization between the activity of the heart and brain. Specifically, we have found that the brain's alpha rhythms exhibit increased synchronization with the cardiac cycle during this mode (1, 16).

In terms of physiological functioning, the coherence mode confers a number of benefits to the system. These include: (i) resetting of baroreceptor sensitivity, which is related to improved short-term blood-pressure control and increased respiratory efficiency; (ii) increased vagal afferent traffic, which is involved in the inhibition of pain signals and sympathetic outflow; (iii) increased cardiac output in conjunction with increased efficiency in fluid exchange, filtration and absorption between the capillaries and tissues; (iv) increased ability of the cardiovascular system to adapt to circulatory requirements; and (v) increased temporal synchronization of cells throughout the body. This results in increased systemwide energy efficiency and conservation of metabolic energy (16). These observations support a link between positive emotions and increased physiological efficiency, which may partially explain the growing number of docu-

mented correlations between positive emotions, improved health and increased longevity. We have also shown that practicing techniques that increase physiological coherence is associated with both short-term and long-term improvement in several objective health-related measures, including enhanced humoral immunity (18) and an increased DHEA/cortisol ratio (19).

Psychophysiological coherence is similarly associated with beneficial psychological correlates, including reduced perception of stress, sustained positive affect and a high degree of mental clarity and emotional stability. We have also found that

the coherence mode is associated with significant improvement in cognitive performance (1, 16).

It is important to note that the psychophysiological coherence mode is both physiologically (as shown in Figure 3) and psychologically distinct from a state of relaxation. At the physiological level, relaxation is characterized by an overall reduction in ANS outflow and a shift in ANS balance towards increased parasympathetic activity. The coherence mode is also associated with an increase in parasympathetic activity, thus encompassing a key element of the relaxation response, but is physiologically distinct from relaxation because the system

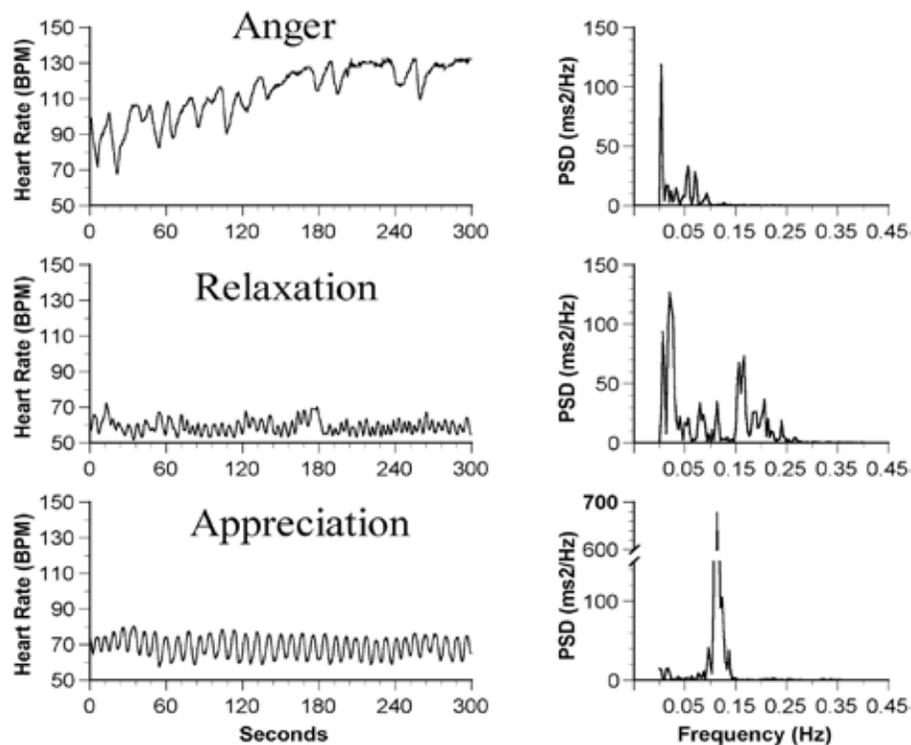


Figure 3. Heart-rhythm patterns during different psychophysiological states.

The left-hand graphs are heart-rate tachograms, which show beat-to-beat changes in heart rate. To the right are shown the heart-rate-variability power spectral density plots of the tachograms at left. Anger is characterized by a lower frequency, disordered heart-rhythm pattern and increasing heart rate. As can be seen in the corresponding power spectrum to the right, the rhythm during anger is primarily in the very low frequency band, which is associated with sympathetic nervous-system activity. Relaxation produces a higher frequency, lower-amplitude heart rhythm, indicating reduced autonomic outflow. In this case, increased power in the high frequency band of the power spectrum is observed, reflecting increased parasympathetic activity (the relaxation response). In contrast, sustained positive emotions such as appreciation are associated with a highly ordered, smooth, sine wavelike heart-rhythm pattern, indicative of the psychophysiological coherence mode. As can be seen in the corresponding power spectrum, the coherence mode is associated with an unusually high-amplitude peak (note the scale difference) in the low frequency band, centered around 0.1 hertz. This indicates systemwide resonance, increased synchronization between the sympathetic and parasympathetic branches of the nervous system, and entrainment between the heart-rhythm pattern, respiration and blood pressure rhythms. The psychophysiological coherence mode is also associated with increased parasympathetic activity, thus encompassing a key element of the relaxation response, yet it is physiologically distinct from relaxation because the system is oscillating at its natural resonant frequency (~0.1 hertz) and there is increased harmony and synchronization in nervous-system and heart-brain dynamics. In addition, the coherence.

is oscillating at its natural resonant frequency and there is increased harmony and synchronization in nervous-system and heart-brain dynamics (16). Further, unlike relaxation, the coherence mode does not necessarily involve a lowering of heart *rate* per se, or a change in the *amount* of HRV, but rather a change in heart-rhythm *pattern*.

Not only are there fundamental differences in the physiological correlates of relaxation and coherence, but the associated psychological states are also quite different. Relaxation is generally a dissociative state, conducive to rest or sleep, in which attention is primarily drawn away from cognitive and emotional processes. In contrast, coherence generally involves the active experience of positive emotions. This mode promotes a calm, balanced, yet alert and responsive state that is conducive to everyday functioning, including problem-solving, decision-making and the performance of tasks requiring mental acuity, focus, coordination and discrimination (1, 16).

Revisiting the HeartMath Techniques: A Repatterning Process

When the Freeze-Frame and Heart Lock-In techniques were first introduced in the earlier part of this chapter, we focused on a simple description of the steps the individual uses to implement the tools. Now, with an understanding of the psychophysiological processes involved in the generation of emotion, the key role of the heart in the emotional system, and the distinctive physiological changes accompanying positive emotions, we are in a position to better understand how these tools work, as well as their larger implications for health and well-being.

In essence, the significance of the HeartMath tools is that they offer the individual a systematic and reliable means by which one can intentionally feed-forward out of a state of emotional unease or stress into a “new” positive state of emotional calm and stability. This occurs as result of a process in which the individual intentionally creates a new positive emotional state as the system’s future target and activates changes in patterns of psychophysiological activity that enable the system to achieve and maintain that new state.

Intervening at the level of the emotional system, HeartMath techniques utilize the heart as a point of entry into the psychophysiological networks that underlie emotional experience. The model of emotion discussed in this chapter highlights the brain’s role as a pattern-identification and matching system, and underscores the importance of afferent bodily input in establishing the familiar patterns that are critical in determining emotional experience. As a principal and consistent source of rhythmic information patterns that impact the physiological, cognitive and emotional systems, the heart thus provides an access point from which systemwide dynamics can be quickly and profoundly affected (12, 16).

We have found that the process of coupling an intentional shift in attention to the physical area of the heart with the self-induction of a sincere heartfelt positive emotional *feeling* appears to excite the system at its resonant frequency, thus facilitating the natural emergence of the psychophysiological coherence mode (Figure 2). This shift to coherence, in turn, results in a change in the pattern of afferent cardiac signals sent to the brain, which is of significance for several reasons. First, at the physiological level, this shift serves to interrupt or prevent the triggering of the body’s normal stress response. Second, at the emotional level, the movement to a more organized pattern of cardiac afferent input that accompanies a coherent heart-rhythm pattern is one that the brain associates with feelings of security and well-being, resulting in a “pattern match” with positive emotional experience. This shift in the pattern of the heart’s input to the brain, thus, serves to *reinforce* the self-generated positive emotional shift, making it easier to sustain. Through consistent use of the HeartMath tools, the coupling between the psychophysiological coherence mode and positive emotion is further reinforced. This subsequently strengthens the ability of a positive feeling shift to initiate a beneficial physiological shift toward increased coherence, or a physiological shift to facilitate the experience of a positive emotion.

A further outcome of the shift to a state of psychophysiological coherence manifests at the

cognitive level, as a result of the change in the pattern of cardiac afferent information reaching the brain's higher cognitive centers. Our own and others' research has shown that changes in input to the brain from the cardiovascular system can modify the brain's electrophysiological activity and also lead to significant changes in perceptual and cognitive processing (for a review, see (16)). Indeed, this relationship may provide a physiological basis for research findings demonstrating a link between positive emotions and improved creativity, cognitive flexibility and innovative problem-solving — faculties that are also frequently enhanced during or following the generation of the psychophysiological coherence mode. We postulate, therefore, that the activation of positive emotions and the coherence mode leads to a state in which higher cognitive faculties are facilitated (16).

Thus, in the Freeze-Frame Technique, although attention is initially drawn away from stressful perceptions and feelings, once individuals have activated a positive emotion and a consequent shift to coherence *they then return to address the original stressor* from the vantage point afforded by this new psychophysiological state. Our experience indicates that this nearly always leads to a change in perception, feeling or attitude about the stressor, and the ability to address it from a more objective, discerning and resourceful perspective. In this way, individuals are actually able to *transform* the source of their stress in real time, replacing an automatic, emotionally draining, self-limiting, response with a proactive, creative one.

While the process of activating the psychophysiological coherence mode clearly leads to immediate benefits by helping to transform stress in the moment it is experienced, it can also contribute to long-term improvements in emotion-regulation abilities and emotional well-being that ultimately affect many aspects of one's life. This is because each time individuals intentionally arrest and override the psychophysiological and behavioral patterns associated with stress by self-generating a state of psychophysiological coherence, the "new" coherent patterns, and "new" repertoires for responding to challenge, are reinforced in the

neural architecture. With consistency of practice, these patterns become increasingly familiar to the brain. Thus, through a feed-forward process, these new, healthy patterns become established as a new baseline or reference, which the system then strives to maintain. It is in this way that HeartMath tools facilitate a *restructuring process*, whereby the maladaptive patterns that underlie the experience of stress are progressively replaced by healthier physiological, emotional, cognitive and behavioral patterns as the "automatic" or familiar way of being.

This restructuring process is greatly facilitated by use of the Heart Lock-In Technique, which is specifically designed to reinforce or "lock in" the coherent psychophysiological patterns associated with positive emotional states. By building the capacity to sustain heartfelt positive emotions and psychophysiological coherence for longer periods, consistent practice of this tool plays a critical role in the feed-forward process that helps establish coherence as a new reference pattern. Our research supports the proposition that this process promotes increased emotional stability, mental acuity and physiological efficiency as a new familiar baseline, thus diminishing the future likelihood of experiencing prolonged stress. Moreover, even when stress or emotional instability is subsequently experienced, the familiar, coherent state is more readily accessible, enabling a quicker and more enduring emotional shift.

The occurrence of such a restructuring process is supported by both physiological and psychological data. At the electrophysiological level, ambulatory recordings demonstrate a greater frequency of *spontaneous* (without conscious practice of the tools) periods of coherence in the heart-rhythm patterns of individuals practiced in the HeartMath techniques in comparison to the general population. There are also data linking the practice of HeartMath tools with favorable changes in hormonal patterns. Specifically, a significant increase in the DHEA/cortisol ratio was demonstrated in individuals who consistently used the HeartMath tools for 30 days. This finding, which has recently been independently replicated, is interpreted as evidence of a restructuring process occurring at

a fundamental level, given that there is normally little physiological variability in levels of these hormones from month to month (19).

The physiological changes observed with use of the interventions typically occur in conjunction with significant changes in psychological patterns. Reductions in measures of emotional distress, including anxiety, depression, anger, hostility, guilt and burnout, have been consistently observed in many different populations with practice of the HeartMath tools (see (1, 11) for a summary). These observations suggest that the interventions are effective in helping to modify the habitual emotional patterns that are a major source of stress.

Heart-Rhythm-Coherence Feedback Training: Facilitating Coherence

We have found that the learning and effective use of HeartMath positive emotion-focused tools can be significantly facilitated by heart-rhythm-coherence feedback training. This technology provides real-time physiological feedback that serves as a powerful aid and objective validation in the process of learning to self-generate increased psychophysiological coherence (20).

Technologies have recently been developed that enable heart-rhythm coherence, the key physiological marker of the psychophysiological coherence mode, to be objectively monitored and quantified. One such device is the emWave PC heart-rhythm-monitoring and coherence-building system (Quantum Intech, Inc., Boulder Creek, California). This interactive hardware/software system monitors and displays individuals' heart-rate-variability patterns in real time as they practice the positive emotion refocusing and emotion-restructuring techniques taught in a tutorial included with the emWave PC. Using an ear sensor to record the pulse wave, the emWave plots changes in heart rate on a beat-to-beat basis. As people 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 wavelike as they feel positive emotions. This process reinforces the natural as-

sociation between the coherence mode and positive feelings. The real-time physiological feedback helps to take 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 level, which is fed back to the user as an accumulated score or success in playing one of three games designed to reinforce the emotion-refocusing skills. This heart-rhythm coherence feedback technology is available on two platforms: a personal computer-based version (emWave PC) and the handheld version (emWave PSR).¹

Because this technology uses a fingertip pulse sensor and involves no electrode hookup, it is extremely versatile, time-efficient, and easy to use in a wide variety of settings including the workplace, home, school, etc. Heart-rhythm-coherence-feedback training and the positive emotion-focused tools discussed in this chapter have been successfully used in diverse contexts by mental health professionals, physicians, educators, law enforcement and military personnel, athletes and corporate executives. People in these and other fields have used this training and the tools for a variety of purposes: to decrease stress, anxiety, depression and fatigue; improve academic, job and sports performance; reduce physical and psychological health risk factors; and improve health and quality of life in patients with numerous clinical disorders (1, 11, 20).

Conclusions and Implications

With continually rising stress levels now a problem of global proportions, it is imperative, for both individual and societal health, that practical and effective strategies for reducing and transforming stress be made available to all people. Here we have argued that understanding and directly addressing the internal *emotional* source of stress provides an important key.

Heart-based techniques that enable the self-activation of positive emotions show promise as a simple and powerful means to modify engrained emotional patterns that contribute to the experi-

ence of stress and its debilitating effects on health and well-being. We have shown that use of such techniques gives rise to psychophysiological coherence, a highly efficient and regenerative functional mode that appears to have wide-ranging benefits. By virtue of the brain's pattern-matching function, the intentional generation of positive emotions and psychophysiological coherence enables individuals to activate a feed-forward process whereby stress-producing psychophysiological and behavioral patterns engrained through past experience are progressively replaced by new, healthier patterns of activity. Thus, through the establishment of a new reference pattern, individuals effectively create an *internal environment* that is conducive to the maintenance of physiological efficiency, mental clarity and emotional stability. This new internal environment is resilient and adaptive as we respond to life's inevitable challenges.

The use of positive emotion-based interventions to address stress and its deleterious repercussions has been shown to be effective in a wide range of contexts, including health care, business and education. Moreover, there is evidence that such an approach can provide benefits that extend beyond stress reduction. Interventions that cultivate positive emotions also appear to be effective enhancing creativity and performance in both individuals and work teams; improving organizational climate; decreasing risky behaviors and improving academic performance among students; and facilitating lasting improvements in health. Furthermore, psychotherapists have found that a positive emotion-based emotion-restructuring approach is not only an effective therapeutic tool in dealing with stress and trauma, but also significantly enhances the quality of the client's life. This has also been the experience of individual practitioners of positive emotion-focused techniques, in that many report that the use of these tools has enabled them to intentionally infuse their daily experiences with greater emotional quality, leading to lasting positive changes in their attitudes, social relationships, world view and sense of personal empowerment and fulfillment.

In short, these findings collectively suggest that positive emotions are not merely *markers* of good health and optimal functioning, but are in fact *agents* in the processes by which these states can be achieved. The correlates of the coherence mode we have identified may provide an important key to elucidating the psychophysiological basis of the effects of positive emotions on health, cognition and psychosocial functioning that have been increasingly documented by research. Further studies on the use of positive emotion-focused interventions conducted with larger samples and longer follow-up are needed to replicate and extend the findings obtained thus far. Such research will deepen scientific knowledge of the "restructuring" that can be facilitated by these interventions, including its long-term effects on the health and well-being of the individual and society.

From a broader perspective still, a new approach to addressing stress, grounded in a scientific understanding of the psychophysiological basis of emotion, may well lead us through the doorway to a new era. From our emergence more than half a million years ago, emotions have played an enormous role not only in the everyday lives of individuals but also in affecting the course of historical events of monumental importance for human civilization. But because the genesis of emotions was poorly understood, humankind has relied primarily on social regulation and constraint, and more recently pharmacological and psychotherapeutic interventions, to modulate and direct the enormous power of emotional energy. Now, with the beginnings of an understanding of how emotions are generated by specific psychophysiological processes, we are not only significantly closer to a more complete understanding of human function and behavior, but we also have effective and accessible tools, based on scientific knowledge, that individuals can use to regulate and intentionally change their inner states. Rather than remaining at the mercy of emotions and their individual and societal consequences, we can now be proactive in willfully generating positive emotional states to effect a healthier, happier and more functional life.

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