

Combining EEG with Heart Rate Training

For Brain / Body Optimization

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There is a growing interest in combining different biofeedback modalities, in particular when EEG is involved. EEG biofeedback (“neurofeedback”) has had a tendency to develop as a separate branch of biofeedback, both rediscovering principles known in traditional biofeedback, while creating its own approaches and paradigms. When combining EEG with traditional (or “peripheral”) biofeedback, attention should be given to the unique capabilities and characteristics of each modality, in an effort to integrate them in a simple, yet effective manner.

Gevirtz (2003) provides an overview and references on HRV, which is both a powerful predictor of cardiac and other health outcomes, as well as a promising mode of biofeedback. He specifically refers to HRV resonance, which occurs when the deviations between high and low heart rates are maximized. This typically occurs at an individual breath rate of about 6 breaths per minute, which the trainee is able to find and maintain as part of the training process.

Other authors refer to HRV coherence, which occurs when the variations in heart rate are maximally sinusoidal, which means that they contain primarily one main frequency, and appear like a smooth wave. Any of a range of strategies are available for training optimal HRV. Fortunately, they are all effective, largely because any approach that restores autonomic homeostatic reflexes must ultimately restore all of the interacting processes that work together towards maximizing the rhythmic fluctuations in a healthy system that is exploring its operational boundaries.

While pursuing the combination of EEG and HRV, there is merit in returning to basics, and providing feedback that is both informative, timely, and aesthetic. When implementing a combined protocol therefore, it made sense to explore simple alpha training, in conjunction with a simple form of HRV training.

The basic design of the alpha enhancement protocol is shown below. In the interest of simplicity, a manual threshold is placed on the magnitude of the alpha wave, as measured with a third-order digital filter. The waxing and waning of the alpha is clearly evident. When alpha magnitude exceeds the preset threshold, there is a sound produced. A gentle, midrange flute note is used to indicate the presence of alpha waves.

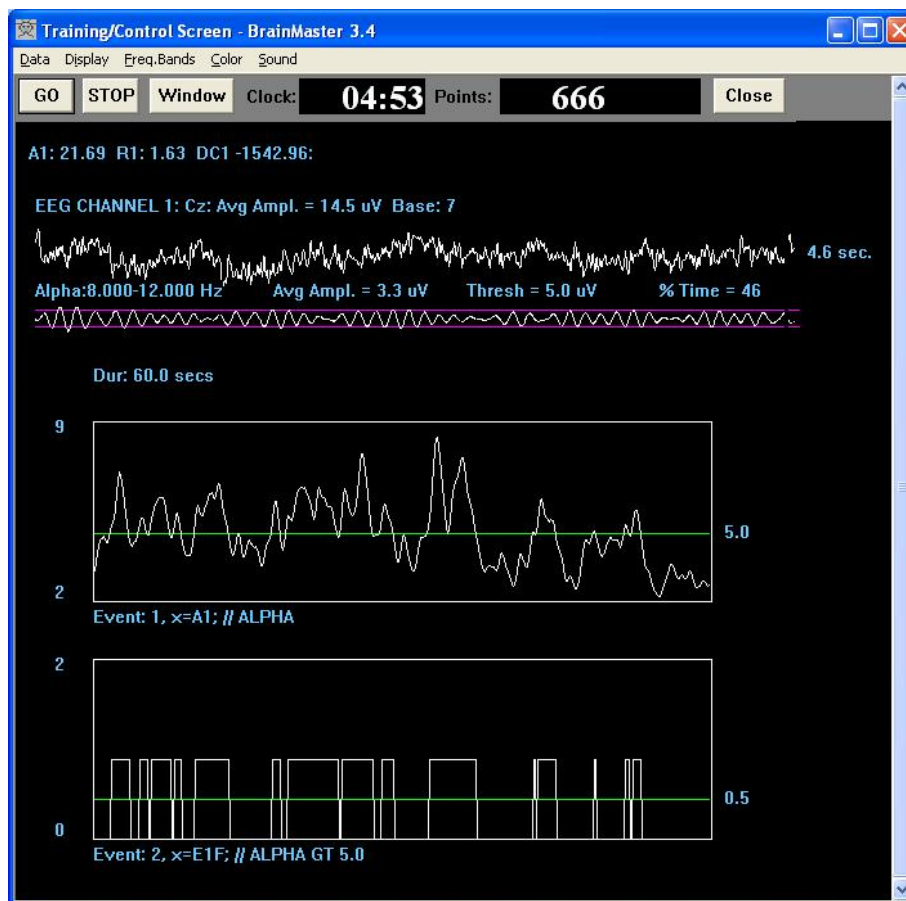


Figure 1. Design of simple alpha feedback protocol. Traces, from top to bottom: Raw EEG, Filtered Alpha Wave, Alpha Magnitude with threshold, Marker for event Alpha above threshold (high tone is produced).

Alpha waves typically wax and wane continuously, are largest when the eyes are closed, and have their own peculiar properties during feedback training. Alpha waves are maximized when the trainee relaxes, clears the mind, and essentially “gets out of the way.” Alpha waves are reduced when the trainee is anxious, thinking, or attending too intently to the sound feedback. Only by “allowing the sounds to come” does alpha training generally allow the trainee to achieve optimal increases, and the associated relaxation and reduction of stress.

In “typical” alpha training, the individual typically has eyes closed, and is passively waiting for alpha waves to occur. Strategies can include adjusting one’s internal state and attitude, letting go of ruminating thoughts, and generally looking to enter a relaxed yet attentive state. When an alpha state is achieved, the individual is generally well tuned in to both internal and external events, yet has a sense of emotional well-being, and a non-judgemental attitude.

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The basic design of the Heart Rate training protocol is shown below. The goal of the training is to reveal and allow enhancement of the phenomenon of Respiratory Sinus Arrhythmia (RSA). An individual wears a simple finger sensor that contains a photoelectric pulse oximeter of a standard type, and appropriate electronics. The sensor measures the blood flow through the finger, and can be used to find both heart rate (beats per minute) and oxygen saturation (percent). The heart rate and oxygen saturation information are converted by the hardware directly into signals that can be used for biofeedback training, simultaneously with up to 4 channels of EEG.

Rather than using metrics such as coherence or resonance, we can simply reward the heart rate variation, when it is in a sustained downward deflection, which is to occur during the exhaling phase. The trainee hears a deeper, flute sound when this occurs. The experience is similar to that from other breathing-oriented HRV devices (i.e. Wild Divine). When the trainee is able to perform a relaxing, sustained exhale that “plays” the deep tone, then the heart rate is achieving a the modulation that is sought by HRV training generally, including coherence or resonance training. The heart rate trace below shows the rhythmic, sinusoidal changes that are typical of the coherence, resonant heart rate response.

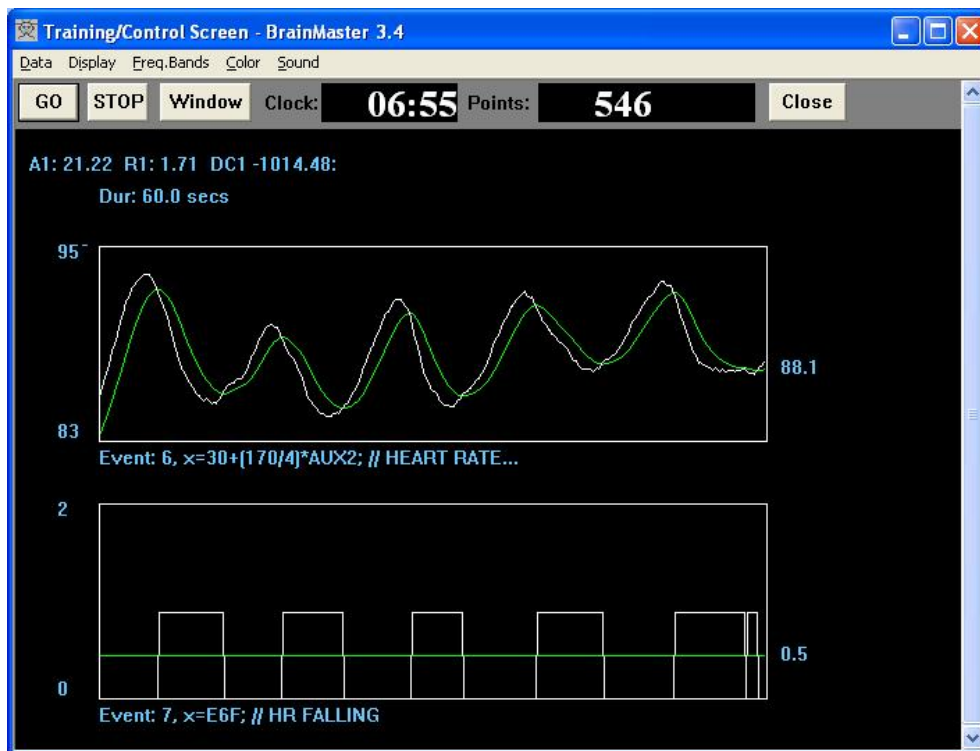
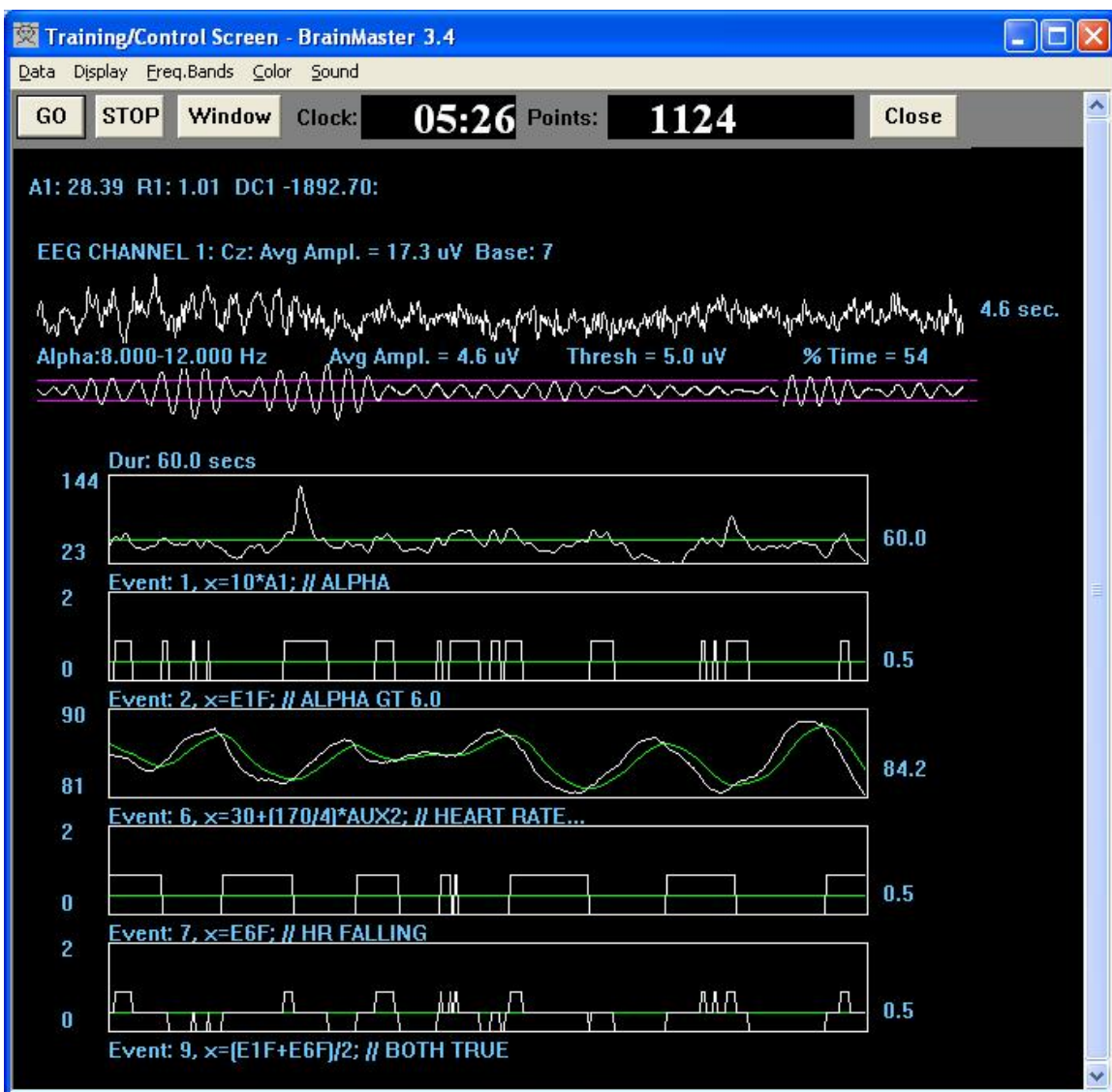


Figure 2. Design of simple Heart Rate training protocol. Top trace, Heart Rate (white) and its time-average (green). Bottom trace: Marker for Heart Rate falling (HR is below its time average). Both coherence and resonance are visibly evident, as the rising and falling of the heart rate is both maximized, and takes on a clean, sinusoidal shape.

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The HRV training protocol produces a repeating, sustained, deep tone during each successful exhale that produces a sustained drop in heart rate, as revealed by the falling phases of the RSA curve. A sustained reward criterion (500 milliseconds) is used to ensure that the trainee receives the tone only for sustained periods of falling Heart Rate. As a learning strategy, the trainee soon realizes that, in order to achieve, the long, sustained exhalations, it is necessary to first take in a large, sustained inhaled breath, so that the lungs are optimally full. Thus, even though the training is essentially only rewarded for exhaling, the trainee must produce a fully robust breathing pattern, in order to achieve sustained rewards.

The combined Alpha and Heart Rate protocol is implemented by combining the above elements, into a single design:



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Figure 3. Combined alpha enhancement and HRV protocol. Traces, from top to bottom: Raw EEG, Filtered alpha waves, Alpha magnitude, Marker for alpha above threshold (high tone is produced when marker is high), Heart Rate, Marker for Heart Rate Falling (low tone is produced when marker is high), Marker for both conditions true (bell is produced when marker peaks).

It is when both conditions are true that the trainee gets the added feedback of a bell sound, indicating that both conditions have been met for a criterion time. Bells are thus heard only during an exhale, and only when both the deep tone and the high tone are present. It is basically a special reward achieved for performing a particularly good exhale, and then relaxing into it, allowing alpha to be produced. It is also possible to easily add visual feedback such as games, videos, or other displays, based upon either or both feedback signals. Figures 4 and 5 show a form of “proportional” feedback, in which a flower cyclically opens and closes, in cadence with the achievement of the HRV changes being reinforced. The combination of a visual display with the feedback sounds is sufficient to introduce the individual to healthy, comprehensive habits of breathing and the associated internal mental states.

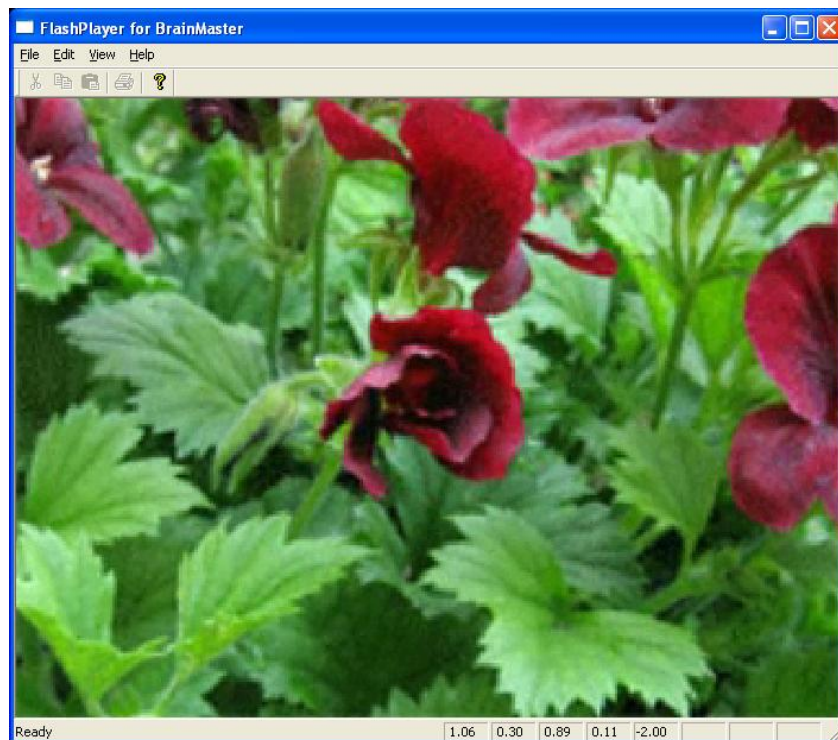


Figure 4. Geranium in closed position, typically seen during inhalation during HRV training.

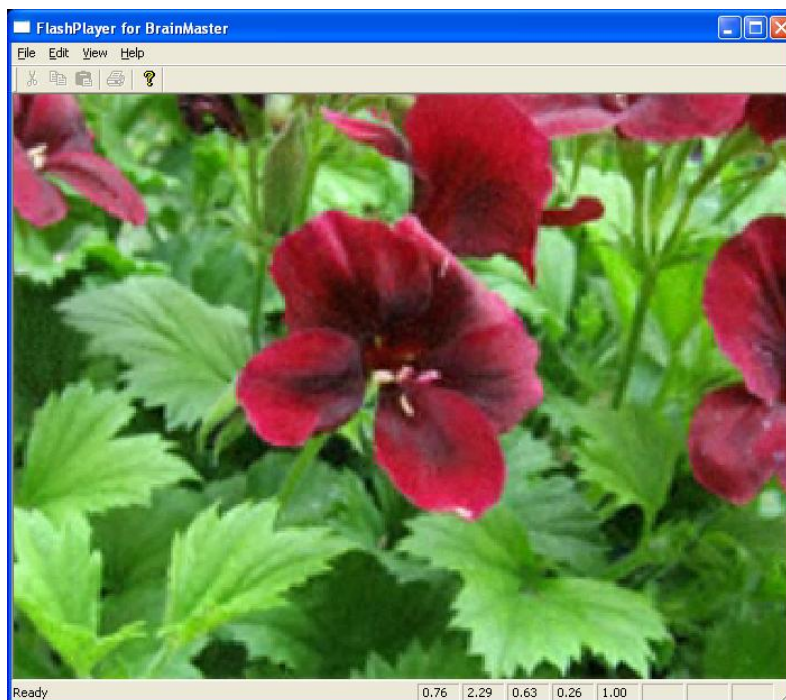


Figure 5. Geranium in open position, typically seen during exhalation during HRV training.

The trainee is able to learn a pattern of deep, rhythmic breathing, combined with the internal state associated with an alpha pattern. The subjective experience is rich and complex, despite the simplicity of the design. The breathing pattern is experienced to produce deep, sustained, soothing tones when producing an optimal exhale that is coupled to the RSA. In addition, there are the overtones reminding the trainee that alpha waves are being produced. When the trainee produces a strong, prolonged exhale, and further relaxes the brain, then one or more bell tones are produced. It is the combination of states that produces the bell, that makes it a relatively special event, among the ongoing tones that indicate the momentary changes in the state of the brain and body.

So what is produced is, in summary, a simple tone indicating optimal HRV changes, another tone indicating the presence of alpha waves, and a bell that is produced only when both the HRV and the alpha activity are present. The presence of the “total” reward sound therefore becomes a significant event, one that the trainee can achieve through relaxed, yet diligent application of simple and beneficial processes.

It is difficult to say whether this approach adds EEG to HRV, or that it adds HRV to EEG. Each modality expresses itself in its typical fashion, and each component could be effectively trained independently. But this approach seems to fill in some gaps that are left to either method when left on its own. In neurofeedback, it is not uncommon for practitioners to put emphasis on the trainee’s breathing, posture, etc., in order to ensure that they are ready for the learning processes of neurofeedback to occur. When clients are unrelaxed, fidgety, anxious, or physically agitated, it is difficult if not impossible at times, for them to “attend to the screen,” or “allow the sounds to come,” no matter how much they try. By providing a task such as HRV, the individual now has additional,

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positive things to do to move them in the desired direction. Some practitioners precede neurofeedback with time spent on an HRV system, simply to wind them down to be ready for the feedback training.

Similarly, when doing HRV training alone, it is often important to attend to the client's inner space, coach them with appropriate suggestions, visualizations, or other mental exercises, to further create a comprehensive, relaxed, positive state. By adding alpha feedback, the trainee is further instructed on a beneficial, neutral internal neuronal state, that is complementary to the systemic relaxation and flexibility inherent in HRV training.

By combining the signals, the trainee is provided with more information, in a form that can be integrated, into a more complex and comprehensive feedback task. The complexity now begins to approach more that of "riding a bicycle" rather than simply "pumping some iron." There may be a tendency for combined learning, as the individual learns a new combination of mental as well as physical skills, associated with the benefits of the entire feedback task.

By exercising voluntary control of HRV, the trainee achieves the ability to get into a state that is more conducive to global relaxation, stress reduction, and physical well-being. Strong, regular training of HRV can be expected to lead to any of the benefits associated with stress reduction. By adding the alpha training component, the individual is conditioned to simultaneously clear the mind and achieve an inner balance, that complements the body-related benefits of the HRV training.

This type of combined training is particularly relevant to the kind of concentration / relaxation cycle described by Serman and his colleagues (1994, 1995, 1996). They found that the most effective pilots exhibited an innate control of a cycle of EEG rhythms that alternated between high-frequency, low amplitude ("beta" state) and a low-frequency, high-amplitude ("alpha" state). He further found a bursting alpha phenomenon he called Post-Reinforcement Synchronization (PRS) that followed tasks.

In our combined EEG / HRV task, the individual is encouraged to cycle between states of inhalation / concentration, and states of exhalation / relaxation. The protocol is design to encourage, although not require, alpha to appear preferentially during the relaxation phases of the breathing cycle. Thus, the natural benefits found by exercising the concentration / relaxation cycle are now coupled with the breathing pattern, leading to a more comprehensive body and brain integration of this natural cycling.

References:

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