

**The Positive Subjective Experiences Related to  
Clarified Gamma Brainwave Neurofeedback  
from the Prefrontal Cortical Region of Meditators and Non-Meditators**

**Running Head (49 characters): Neurofeedback for Increasing Clarified Gamma  
Band**

Published by the Journal of Alternative and Complementary Medicine

February, 2011

by

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Key words: psychophysiology, prefrontal cortex, meditation, Transcendental  
Meditation<sup>TM</sup>, positive emotions, positive affect, positive psychology, neurofeedback,  
biofeedback, gamma band, EEG, 40 Hz, consciousness, reduced stress, altered states of  
consciousness, happiness, love

## **Abstract**

*Objective:* (1) To explore the inner experiences associated with increased production of gamma brainwaves in neurofeedback; and (2) to measure and compare neurofeedback-enhanced increased output from the prefrontal cortical region of meditators and non-meditators, using the Peak Brain Happiness Trainer™ neurofeedback system.

*Design:* Controlled pilot study; single session per subject

*Setting:* Non-profit laboratory in the United States

*Subjects:* Twelve (n=12) adults in 2 groups: six practitioners of Transcendental Meditation™; six controls

*Measures:* Self-assessed inner experiences and measurements of clarified gamma output at prefrontal cortical region

*Results:* (1) Self-assessed descriptions were comparable for both groups; (2) the associations of 16 supplied descriptors with the neurofeedback experience were comparable for both groups and showed highest scores for “happy” ( $p<0.0001$ ) and “loving” ( $p<0.0001$ ), and lowest scores for “stressed” ( $p<0.0001$ ) and “disappointed” ( $p<0.0001$ ); (3) baseline measures were comparable for both groups; (4) both groups were able to increase gamma using neurofeedback ( $p<0.01$ ); (5) meditators produced greater increases over controls ( $p=0.02$ ).

*Conclusions:* The inner experience associated with increased clarified gamma amplitude from the prefrontal cortex apparently involves positive emotions of happiness and love, along with reduced stress. Meditators achieved greater increases in gamma band from the pre-frontal cortical region during neurofeedback over controls.

## Introduction

The 40 cycle-per-second or Hertz (Hz) rhythm in the electroencephalogram (EEG) is part of the gamma band (>30 Hz) and appears to be ubiquitous throughout the brain. It originates in the reticular and intralaminar nuclei of the thalamus and repeatedly sweeps the cortex from frontal to occipital sites<sup>1</sup>. Magnetoencephalographic and EEG investigations suggest that EEG near 40 Hz may have a unique role as the “event binding rhythm”--binding together neural representations of simultaneous events into a unified whole<sup>2</sup>. Francis Crick considered the 40 Hz rhythm a “neural correlate of consciousness”.<sup>3</sup> The gamma band appears to be correlated with the brain metabolic rate, suggesting that there is probably an important purpose for such energy expenditure<sup>4</sup>.

Until recently, relatively few EEG studies on the 40 Hz rhythm have been performed because of methodological problems. Much of the gamma band signal is absorbed by the scalp and brain meninges, so that its measured amplitude on the skin appears to be very small, although EEG recordings made during brain surgeries have shown that on the cortical surface, it is much larger. Over past decades, analog EEG systems could not record fast enough above 32 Hz, but this was resolved by digital recording. A remaining problem is contamination by electromyographic signals from muscle contraction which also produces 40 Hz signal. In this study, a new computational approach, called Neureka!, a proprietary method for clarifying the 40 Hz rhythm in the EEG (signified in this paper as “clarified 40 Hz”), to eliminate most of the EMG contamination, was used both to measure the 40 Hz rhythm and for neurofeedback training<sup>5</sup>.

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The frontal lobe of the brain is thought to be associated with more conscious aspects of mental functioning, including the power of will and intention, the focus of attention, and the experience of oneness.<sup>6</sup> In certain types of yoga, meditation and related practices, there is increased activity in the frontal lobe. Studies on meditators<sup>7 8 9</sup> have shown that the 40 Hz rhythm, in some cases measured from the prefrontal cortical area, is intensified during meditation, and is apparently associated with feelings of kindness and compassion. A study on Tibetan Buddhist meditating monks showed enhanced emission of 25 to 42 Hz brainwaves from this region that correlated with heightened experiences of compassion and clarity of meditation, on a moment-to-moment basis<sup>10</sup>. The monks also produced more gamma band before, during, and after meditation than controls.

Meditation experience is correlated with increased EEG coherence<sup>11</sup> that stabilizes beyond meditation<sup>12</sup>. In many circumstances, EEG coherence may increase brain processing capacity, which may therefore improve test performance of meditators in tasks such as neurofeedback. Indeed, the observed effects of meditation practice on brain function from various studies show increased brain processing capacity and improvements in cognitive function<sup>13</sup>.

Preliminary data that we collected from a number of volunteers informed this study and contributed to its design. The data, unpublished, suggested that increased clarified amplitudes of gamma band from the prefrontal cortex in both meditators and

non-meditators is associated with feelings of satisfaction, gratitude, compassion, and love,.

In this pilot study, we investigated practitioners of Transcendental Meditation(TM)<sup>TM</sup> as taught by Maharishi Mahesh Yogi and his lineage. This is one of the most commonly practiced forms of meditation in the West, with over 600 published studies carried out at over 120 institutions since 1963. It is a mental technique that does not require any specific mental ability, such as concentration. TM utilizes a mantra, a word with phonetic qualities, to turn the mind inward toward its source.

The purpose of the present pilot study is to explore the 40 Hz rhythm from the prefrontal cortex by using neurofeedback to enhance it and learn more about its associated inner experience. This is the first study that we have identified that explores the 40 Hz rhythm in the EEG from the prefrontal cortex using neurofeedback. We posed the following research questions: (1) What is the inner experience associated with increased clarified 40 Hz enhanced by neurofeedback? (2) How do meditators and non-meditators compare in producing clarified 40 Hz from the prefrontal cortical region at baseline and under neurofeedback conditions?

We expected advanced meditators to have greater facility than nonmeditators in their awareness and description of inner states as well as being better able to engage in various states described to them, and hence, more responsive to neurofeedback. Our

purpose was not to assess 40 Hz emission during meditation, but rather, only during neurofeedback.

## **Materials and Methods**

### *Participants*

Two groups of volunteers gave informed consent. One consisted of advanced practitioners of Transcendental Meditation™ (TM) ,and the other, a control group of non-meditators. Subjects were recruited by advertisement on Craigslist.org, word-of-mouth, and by emailing two regional colleges. The following criteria were used:

- (1) Exclusion criteria for both groups: any psychiatric diagnoses; any diagnoses for any serious acute or chronic degenerative diseases including cancer, heart disease, stroke, and/or AIDS; any prescriptions for psychiatric drugs except for regular doses of hormones (birth control pills, hormone replacement therapy, thyroid hormones); use of recreational drugs; consumption of more than 10 ounces of alcoholic beverages per week; a diagnosis of Attention Deficit Disorder or Attention Deficit and Hyperactivity Disorder; complaints of “brain or mind fog”, or emotional difficulties; pregnancy; prior familiarity with the Peak Brain Happiness Trainer™ (PBHT) and more than 5 sessions of any neurofeedback training in the past.

- (2) Inclusion criteria for meditators: persons from 18 to 75 years of age in good health who have 10 to 20 years of experience practicing TM and who practice regularly at least 3 times per week.
- (3) Inclusion criteria for controls: persons from 18 to 75 years of age in good health who have either no meditation experience whatsoever, or who have meditated for less than 6 consecutive months.

The meditation group (n=6) consisted of 5 females and 1 male with an age range of 38 – 60 years old, and a mean age of 51. The control group (n=6) consisted of 4 females and 2 males with an age range of 31 - 62 years old, and a mean age of 49. The mean number of years of meditation practice for the meditation group was 15.7 years, and all meditated at least once daily. All subjects were Caucasian except for one female in the control group, who identified herself as part Native American.

### *Instruments*

The PBHT by NeuroTek was used in its single-channel feedback mode for measurement of clarified 40 Hz and neurofeedback. Three sponge-capped recording electrodes moistened with saline solution were placed on the head, including one at the FPz point (prefrontal cortical region of the brain), a reference electrode on the left ear, and a ground electrode on the left temple. The PBHT clarifies the 40 Hz rhythm from the prefrontal cortical region by filtering out signal artifact due to facial muscle tension and movement using a proprietary software algorithm—the Neureka! Protocol-- to train what

is called the Neureka! experience, which Cowan hypothesizes to be related to the processing of new learning and its reinforcement by positive feelings<sup>14</sup>. The PBHT neurofeedback device (NeuroTek, [www.peakachievement.com](http://www.peakachievement.com)) was interfaced to a Hewlett-Packard Pavilion notebook computer running Windows XP and Study Protocol 3 for clarified 40 Hz measurement and training within the Bioexplorer neurofeedback software, receiving input from a wireless data transmitter, mounted on an elastic headband (SensorBand™) on which the 3 electrodes (Sensors) were also mounted.

### *Experimental Procedure*

Participants were tested seated at the computer in the laboratory with the experimenter present in single-blinded sessions that lasted about 1.5 hours. Electrodes were connected to them through the headband configuration described above. Without divulging what type of brainwave signals were being measured, a brief explanation of the procedure was provided. Subjects were instructed to keep their facial expression constant during testing, and to notify the experimenter if they have moved their facial muscles. Subjects were asked to do the following tasks in 4 stages: (1) to explore the clarified 40 Hz neurofeedback in order to describe the associated inner experience; (2) to engage for 2 minutes in each of 16 different experiential states each represented as a descriptive word or phrase, and to decide, by comparing their momentary experience to the strength of the feedback signal, how strongly these descriptors correlated with increases in clarified 40 Hz; (3) to engage in a neutral state to measure baseline values of clarified 40 Hz; and (4) to quickly produce their maximum value of clarified 40 Hz using neurofeedback.



(1). During their 15 minutes exploration of the clarified 40 Hz neurofeedback, subjects received unlabelled feedback in the form of sound (tones that varied in pitch) and/or visual feedback (bar graphs, numerical displays of values of the signal shown in arbitrary units, and a graph of the clarified 40 Hz signal over time) provided in real-time, related to the task at hand--improving their score by changing their brainwaves. Subjects were then asked to describe, in their own words, their inner experience when neurofeedback indicated improved scores. The question posed to them was, "What words and/or phrases describe your inner experience when the sound or visual feedback indicates that you have raised your score in this neurofeedback program?"

(2). To assess the relationship, if any, between experimenter-provided descriptors of inner experience and the clarified 40 Hz neurofeedback experience, the following was done. Sixteen descriptors of various experiences were utilized in the same randomized sequence, spoken orally to each subject, who was then given up to 2 minutes to attempt to engage in the experience associated with the word, either by recalling a particular experience that elicited it, or by other means. The 16 descriptors utilized were selected from preliminary data, with the expectation that most would be positively associated with the clarified 40 Hz neurofeedback experience, and the rest either neutral or negatively associated. The 16 descriptors used were, in random order: disappointed, concentrating, loving, fully aware, alert, stressed, anticipating good, resting comfortably, aha! (as in discovery), peaceful, bored, grateful, happy, mindfully watching, satisfied, and focused. The question posed to them was, "By taking note of the moment-to-moment fluctuations

in the intensity of your inner experience of     (descriptor)     and the changes in the score, what is their relationship?” The following scale was provided to them to ascertain a score: -100 = extremely strong negative; -80, very strong negative; -60, strong negative; -40, moderate negative; -20, mild negative; zero, no relationship; +20, mild positive; +40 moderate positive; +60, strong positive; +80, very strong positive; and +100, extremely strong positive relationship. A follow-up question was given after their response to each descriptor, “How successful were you at creating the experience of     (descriptor)     in your mind?” The following scale was provided to them to ascertain a score: 0=no experience; 20=mild experience; 40=moderate experience; 60=strong experience; 80=very strong experience; and 100=extremely strong experience.

(3). Subjects were asked to produce a particular state for one-minute recording time, to obtain their clarified 40 Hz neurofeedback score in a “neutral baseline” condition, related to “neutral mind” in Tibetan Buddhist meditation<sup>15</sup>. They were not told that this was a “baseline” state. The following directions were given to them: “Please keep your eyes open and fixated. I would like you to maintain a relaxed, neutral state in which your emotional state is neither pleasant nor unpleasant. Try to be in the most ordinary state without being engaged in an active mental state such as voluntarily remembering or planning something or actively looking at an object.” The average values of clarified 40 Hz for the one-minute period were recorded along with the standard deviation.

(4). Subjects were cued to work with the clarified 40 Hz neurofeedback in attempt to produce the largest score for 3 periods of 3 seconds each, separated by 20-second rest periods. To assist them, they were told the three strongest descriptors that they perceived to be related to the neurofeedback experience. Specifically they were told, “You may wish to refer back to your trial with [descriptor x, y, or z], during this task, but you are free to do whatever will work best to produce the highest score.” The 3 values of the 3-second trial periods were recorded.

### *Data Analysis*

All data were entered into Excel spreadsheets. For (1), the subject-provided descriptions of the clarified 40 Hz feedback experience for both groups were qualitatively compared. For (2), all data for which subjects indicated they had not achieved the described state with a self-assessed score of greater than +20 were discarded from statistical analysis. Only 5 of the 192 data points were eliminated—4 of them for the adjective “bored”. Then the average scores of the two groups for each descriptor were calculated, along with standard errors, and compared using a two-tailed t-test. Since none of these between-group tests proved significant, the groups were pooled and the means for each descriptor were tested by single-tailed t-tests to determine if they were significantly different from zero. For (4), the mean of the 3 values for each subject’s enhanced clarified 40 Hz neurofeedback score was calculated. The percentage difference between the average score during clarified 40 Hz neurofeedback and the baseline measure (3) was calculated for each subject. These data were then analyzed by a 2x2

Analysis of Variance with Group (meditators vs. controls) and Test Condition (baseline vs. average highest clarified 40 Hz neurofeedback score) as factors.

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## Results

Tables 1 and 2 show the subjects' self-descriptions of the clarified 40 Hz neurofeedback experience.

--INSERT TABLE 1 FOLLOWED BY TABLE 2 HERE--

Every description of the experience featured positive feelings or spiritual experiences. Joy and love were found to be the most common themes. No subject gave a negative description of the neurofeedback experience.

The relationships of 11 of the 16 descriptors with the clarified 40 Hz neurofeedback were significantly positive. See Figure 1.

--INSERT FIGURE 1 HERE--

The results were comparable for both groups for all the descriptors (all p values >0.05). After pooling, the largest relationship quality scores were obtained for "happiness" (p<0.0001) and "loving" (p<0.0001). The associations for 2 of the descriptors, "communicating" and "focused," were insignificant for both groups (p>0.05). The

relationships for 3 of the descriptors with the clarified 40 Hz neurofeedback were significantly negative, with the largest scores for “stressed” ( $p < 0.0001$ ) and “disappointed” ( $p < 0.0001$ ), and comparable for both groups (all  $p$  levels  $> 0.05$ ). See Figure 2.

--INSERT FIGURE 2 HERE--

Baseline measurements of the clarified 40 Hz band were indistinguishable for the two groups ( $p > 0.05$ ), averaging 19.25 for the meditators and 19.85 for the controls. See Figure 3. Neureka! values plotted as the dependent variable shown in the figure refers to clarified 40 Hz.

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--INSERT FIGURE 3 HERE--

Both groups succeeded in significantly increasing clarified 40 Hz using neurofeedback in a single session ( $p < 0.002$  for Test Condition). The controls averaged a 5.6% increase after cueing by the researcher. However, meditators were much better at this task than controls ( $p = 0.02$ ), and on the average raised their scores 28.6% above baseline, which is over 500% greater than controls.

## Conclusions

The results show that the clarified 40 Hz neurofeedback from the pre-frontal cortical region appears to involve positive emotions of happiness and love, as well as reduced stress, which were discerned by both meditators and nonmeditators. They show that both advanced meditators and nonmeditators were able to perform clarified 40 Hz neurofeedback from the pre-frontal cortical region successfully in a single session, although the meditators were able to increase the amplitude of clarified 40 Hz about 5 times better than nonmeditators using the neurofeedback.

The study suggests that the clarified 40 Hz neurofeedback of the PBHT™ is able to give users instantaneous, clear information about their brainwaves associated with positive feelings.

The data from this small pilot study appear to be robust, since statistical significance was achieved with a small sample. However, this study has limitations. Future studies should increase the duration of the study and sample size. A possible confounder may be the subjects' desire to please the experimenter, who was always present during the sessions, and who may provide a positive social interaction, thus contributing to improving subjects' moods. Thus, another study should be conducted with subjects who use the clarified 40 Hz neurofeedback system by themselves with written instructions.

## **Discussion**

Unlike the results observed for Tibetan Buddhist meditators<sup>16</sup>, we did not find greater gamma power at baseline in TM meditators. However TM is a very different type of meditation technique. In addition, meditation research as reported by Alarik Arenander shows that TM is associated with “a great loss of gamma and beta power and the onset of large amplitude, highly coherent and synchronous, widely distributed alpha waves.”<sup>17</sup> If gamma is not increased during TM, then it seems paradoxical that advanced TM meditators show an enhanced ability to produce clarified 40 Hz during neurofeedback. However, the clarified gamma (Neureka!) that we measured here has not been observed in previous studies. Secondly, the greater internal awareness and self control found in advanced meditators may improve their performance on tasks in general. Moreover, because meditators enjoy positive feelings of love, compassion, empathy, joy, and equanimity as a result of their practice<sup>18</sup>, it may be that the TM meditators here were able to achieve stronger positive feelings during the task at hand, which produced higher values of clarified 40 Hz due to the correlation observed here. Meditation itself can produce increases in positive qualities such as joy and compassion<sup>19</sup>.

The results of the study suggest the possibility that brainwave signals associated with feelings of happiness, love, satisfaction, gratitude, awareness, mindfulness, peace, and the absence of stress, may be measureable in the gamma band from the prefrontal cortical region. Although this study did not go so far as to investigate whether clarified 40 Hz neurofeedback training could facilitate positive emotional feelings and/or reduce negative feelings over time, it points to this possibility. Further studies are needed to explore this. If this is found to be the case, then clarified 40 Hz neurofeedback from the

pre-frontal cortical region might prove to be important for enhancing health and wellness, because research shows that the effects of positive emotions seem to do more for health than merely counteract or cancel the effects of negative emotions<sup>20</sup>. Positive emotions have been shown to promote better health by boosting the immune system and provide greater resilience to stress. Moreover, emotions can modulate the immune system function through various neuroendocrine pathways, with negative emotions leading to inflammatory biochemical pathways that are causally linked to chronic diseases such as cardiovascular disease and cancer, and positive emotions contributing to anti-inflammatory pathways that are protective<sup>21 22</sup>.

Further work is called for to investigate whether the clarified 40 Hz neurofeedback of the Peak Brain Happiness Trainer<sup>TM</sup> can lead to long-term changes in positive emotions with concomitant improved health and well-being in various populations, including patients.

### **Acknowledgments**

We wish to thank Jonathan D. Cowan, Ph.D., for his assistance and helpful advice, as well as the study participants for volunteering their time and effort.

### **Disclosure statement**

The author received the Peak Brain Happiness Trainer from NeuroTek in consideration for performing this study. The author has no competing personal or financial interests.

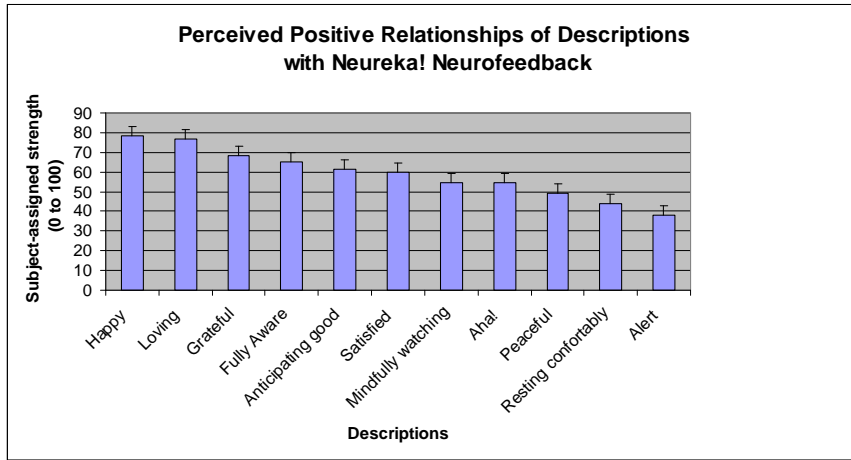
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**Figure 1: Perceived Positive Relationships of Descriptors with Neureka! Neurofeedback for all subjects**



**Figure 2: Perceived Negative Relationships of Descriptors with Neureka! Neurofeedback**

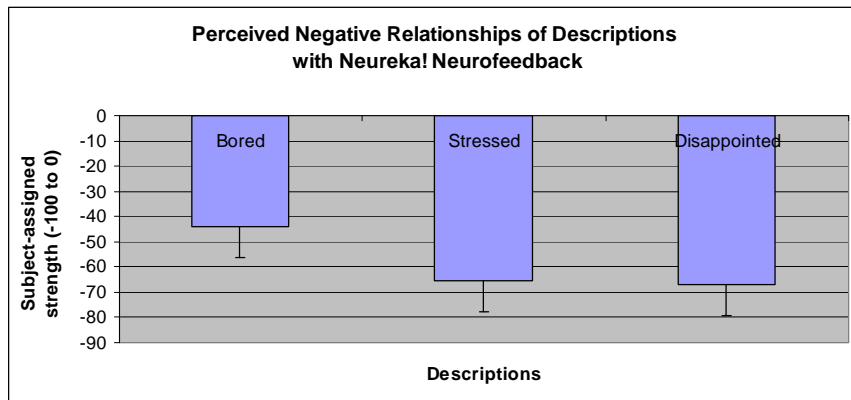


Figure 3: Comparison of Transcendental Meditators' and Controls' Neureka! Scores During Baseline and with Neurofeedback

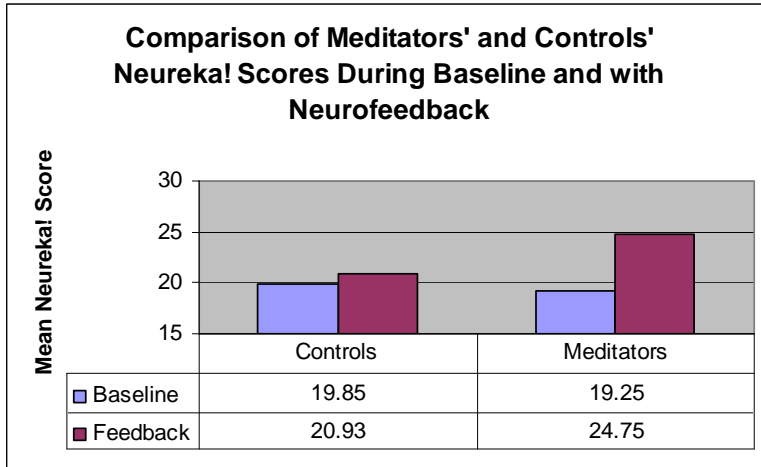


Table 1: Subject self-descriptions of Neureka! (clarified 40 Hz EEG) experience from pre-frontal cortical region of nonmeditators

<u>Detachment from myself; trust in something bigger.</u>
<u>Letting something higher come into my consciousness; not trying from the ego</u>
<u>Joy; bliss; connection with the angelic realm</u>
<u>Alert; focused on something new; being in the moment</u>
<u>Warmth from my heart chakra and the bottom of my feet; thinking of people I love, including love for those who have passed on</u>
<u>Curiosity; enthusiasm; joy; novelty of experience</u>

Table 2: Subject self-descriptions of Neureka! (clarified 40 Hz EEG) experience from pre-frontal cortical region of practitioners of Transcendental Meditation™

<u>Love; compassion; anger; surge of joy</u>
<u>Concern for others; romantic feelings; receptive to loving touch; opposite of trauma and grief</u>
<u>Relaxed; feeling good; having a good time; happy inner laughter; opposite of anxiety</u>
<u>Joy; clairvoyance; loving feeling; meditative bliss; trying doesn't get me there; preparing for the state doesn't always make it happen</u>
<u>Open heart chakra; relaxed and calm; receptive; warm fuzzy feeling; feels close to the center of the brain</u>
<u>Pure love; childlike wonder; anticipation of something new and good; thinking higher thoughts; a core connection to the Absolute; the opposite of stress</u>