SPECIAL ISSUE

The Value of EEG-Based Electromagnetic Tomographic Analysis in Human Performance and Mental Health

Thomas F. Collura, PhD, BCN,[1,2] Nancy L. Wigton, PhD, LPC, QEEGD, BCN,[3,4] Carlos Zalaquett, PhD, LMHC,[5] SeriaShia Chatters-Smith, PhD, LMHC,[5] and Ronald J. Bonnstetter, PhD[6,7,8]

[1]BrainMaster Technologies Inc., Bedford, OH; [2]Brain Enrichment Center, Bedford, OH; [3]Grand Canyon University, Phoenix, AZ; [4]Applied Neurotherapy Center, LLC, Scottsdale, AZ; [5]Pennsylvania State University, State College, PA; [6]Center for Applied Cognitive Research, Scottsdale, AZ; [7]Target Training International, Ltd., Scottsdale, AZ; [8]University of Nebraska–Lincoln, Lincoln, NE

?1 Most work done in areas such as counseling, therapy, leadership, and coaching involves some aspect of decision making. New electroencephalographic (EEG) electromagnetic tomographic analysis (ETA) imaging techniques provide a mechanism for exploring decisions, while the individual is directly engaged in everyday choice making, by exposing our precognitive emotional responses to identified thoughts, feelings, and actions. This article discusses gamma wave activity research, at the precognitive level, and its use for describing approach-avoidance decision making. Armed with these new insights, an individual can better understand the emotional triggers that affect our daily decisions.

Introduction

There is increasing awareness of the importance of brain health and brain fitness for an individual's well-being, as well as for the strength of societies and civilizations. A significant amount of time and expense are devoted to reducing mental and emotional distresses and also to improving performance in academic, professional, sports, and related pursuits. An additional important aspect is the effect of stress or trauma on individual health and the disorders that can result from excess stress. It is clear that neuroscience holds great potential as a resource for mental health practitioners as well as human performance professionals who want to help clients at a fundamental level.

However, before assistance can be offered, identification of issues to be addressed is required. It is not hard to imagine a practitioner thinking, "If I only knew what was going on inside my client's head." Although an important component, there are limits to what can be gained from behavioral observations, self-report, and other information available to those who must evaluate and treat mental, emotional, or behavioral concerns. The value of self-report can be compromised by limitations in the client's aware-ness, honesty, confidence, and ability to express sensitive concerns (Bonnstetter, Hebets, & Wigton, 2015). Behavioral observations provide objective data but do not necessarily allow one to determine why an individual chooses (or does not choose) certain behaviors. For example, it may not be clear whether an issue is based primarily on the brain being excessively activated or driven, as opposed to having insufficient inhibitory control or a combination of these. In short, information available from traditional assessment methods has limited ability to reveal what is going on internally, and functionally, in a client's brain at any particular moment. Yet this type of information is essential, if helping professionals are to understand clients and interact with them in a meaningful and fruitful manner.

Newly available brain-imaging methods now allow for measuring real-time electroencephalographic (EEG) activity as a way to quantify neural expressions of internal processes. This imaging can be incorporated into assessment modalities, or even occur during a coaching or counseling session, to provide instantaneous colored images of brain activity. First, conventional EEG data are recorded; then, as shown in Figure 1, relevant segments are selected for analyses. Next, a mathematical inverse solution is applied to the surface quantitative EEG (QEEG) data to generate three-dimensional images, similar to those produced by functional magnetic resonance imaging (fMRI) data. These solutions, which provide the basis for brain electromagnetic tomographic analysis (ETA), include low-resolution electromagnetic tomography (LORETA), standardized LORETA (sLORETA), exact LORETA (eLORETA), and other variants such as variable resolution electromagnetic tomography. In the LORETA algorithm, a measure of brain activity, referred to as current source density, is calculated to be within a virtual space representative of cortical structures, and is made up of 2,394 three dimensional.
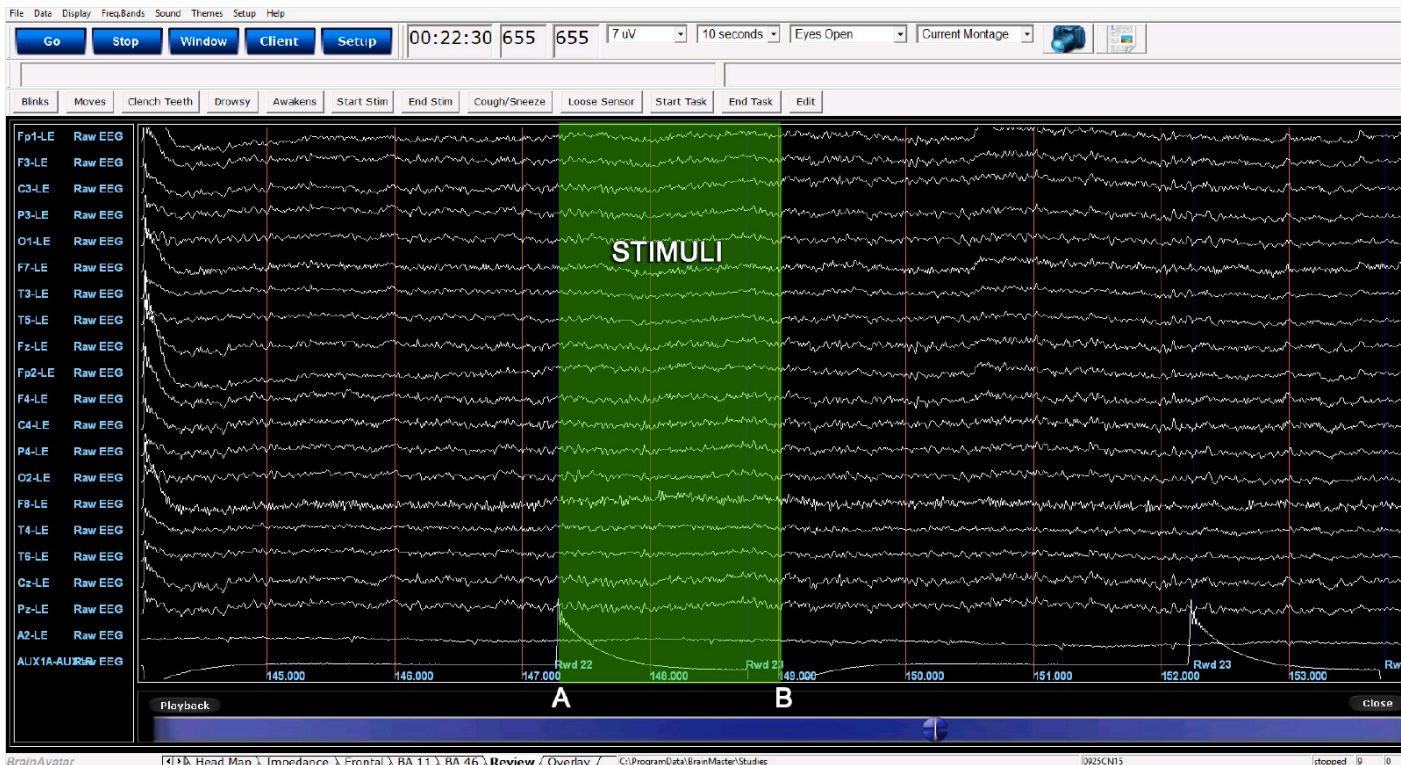
Figure 1. A typical display of an electroencephalographic recording from the scalp, along with markings that show the exact time interval that will be analyzed and imaged.

volume elements referred to as voxels (The KEY Institute for Brain-Mind Research, 2014). A higher-resolution formulation of this application, sLORETA, expands the number of voxels to 6,239, with the size of each voxel being 5 mm^3 (Pascual-Marqui, 2002).

Other imaging techniques such as computerized tomography, positron emission tomography, and fMRI are based on anatomic, metabolic, or related physical processes. Only the EEG is based solely on the electrical activity of the brain. EEG reflects the activity of the working cells in the cerebral cortex known as pyramidal cells. When these cells, which are engaged in the information processing and emotional control of the brain, are active, they produce signals that are measurable from the scalp. Therefore, these images truly reflect the activity of the brain, in ways that other methods cannot (Hüsing, Jäncke, & Tag, 2006). In addition to being based on the relevant electrical activity of the brain, EEG-based imaging has been validated in comparison with other imaging techniques and has been shown to provide a valid and accurate localization of brain activity (Ikeda & Kirino, 2004; Xiaoxiao, Towle, He, & He, 2007). Moreover, Hammond (2010) asserts QEEG data as being a culture-free approach to assessment of brain function. This position is supported by the work of Hughes

replication studies, from at least a dozen different countries, showed QEEG-based data to be free of cultural or ethnic dynamics.

Figure 2 shows an example of an ETA-generated brain activation image using sLORETA. In these images, the estimated amount of neuronal activity is represented within each voxel with the coloration applied by the software specifications. The image can be viewed, modified, and rotated by the user, providing a colored three-dimensional view of the brain that best shows important activity (or inactivity). This type of display shows selected regions of interest for brain activity, together with information related to functional processing associated with those regions, so that the data can be interpreted for research or for clinical use. Because the images are instantaneous, it is important to know the exact moment that the image reflects. This is a snapshot of brain activity that contains accurate and high-speed information about which locations in the brain are active and at which exact time.

Although this type of live neuroimaging may seem new to the human performance or mental health field, it draws on more than a century of science and clinical experience that underlie its use. The concept of localized brain function was established in the earliest years of clinical neuroscience,
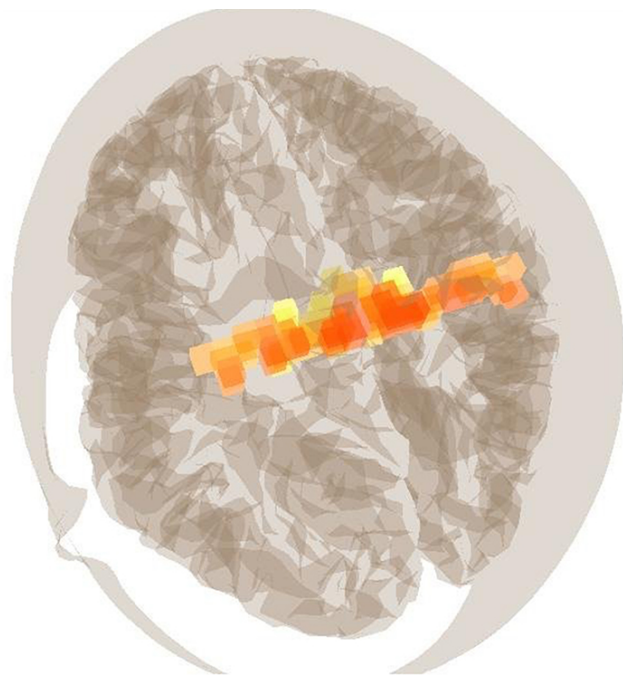
Figure 2. A typical standardized low-resolution electromagnetic tomography three-dimensional image of brain activation, showing the regions involved.

and other pioneers whose names remain fundamental in clinical and experimental neuroscience.

sLORETA Imaging and Emotional Decision Making (Approach-Avoidance Model)

The underpinnings of this model are an outgrowth primarily from the work of Davidson (1992, 2000, 2002, 2004). In discussing the approach-avoidance research, Davidson and Begley (2012) posited that all emotions, when boiled down to their most basic components, can be classified as falling within the domains of either approach or avoidance. In this model, there is activation of either the left or right frontal lobe, depending on whether an approach or avoid response is in play. In summarizing approach-avoidance research from the early 1990s to 2000s, Davidson, Pizzagalli, Nitschke, and Kalin (2003) assert that goal-directed (i.e., approach) action or responses are associated with left-side frontal activation and, conversely, withdrawal (i.e., avoidance)–oriented actions or responses with right-side frontal activation. Figure 3 shows sLORETA imaging of typical brain asymmetry patterns, in the gamma frequency (38–42 Hz), for positive (approach; left activation), negative (avoidance; right activation), or neutral responses (no asymmetrical activation). At any instant, these areas are either relatively active or not, depending on the individual's experiences, as well as personal style of responding to stimuli.

These brain regions have functions that can also be explained in terms of a model described by Collura, Zalaquett, Bonnstetter, and Chatters (2014). This model associates specific precognitive (i.e., prior to conscious awareness) decision-making functions with the left and right frontal lobes as well as the distinction between primary and secondary evaluation and response mechanisms. This model also pulls from evolutionary themes similar to those discussed by DeRidder, Verplaetse, and Vanneste (2013). When using brain activation data such as we have described, this model allows one to interpret individual thoughts, feelings, and actions, as well as the response to presented stimuli, in terms of approach versus avoidance, associated with whether the left or
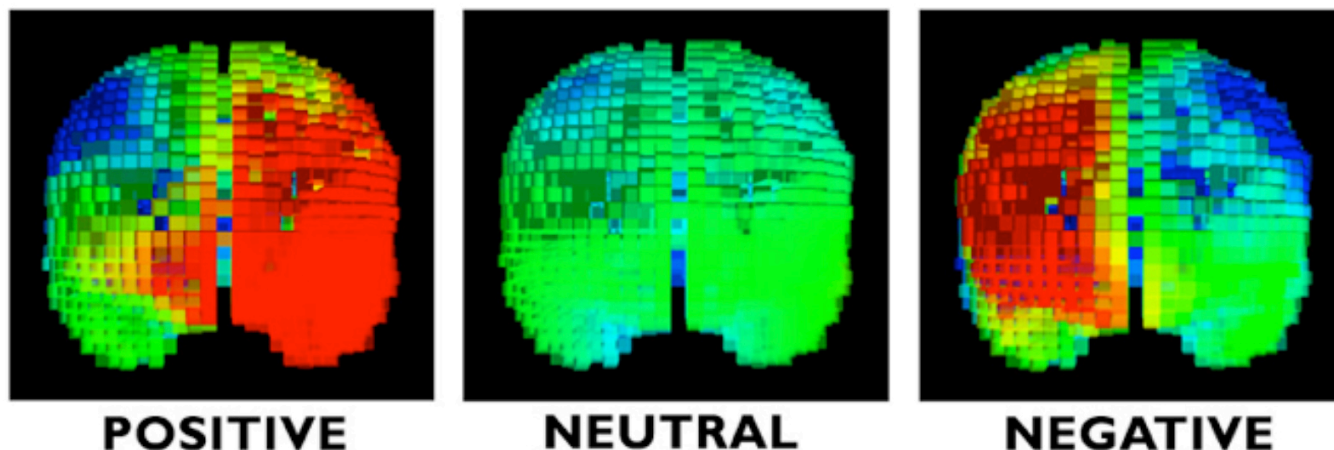

Figure 3. Example of frontal lobe gamma asymmetry with positive, neutral, and negative responses. The orientation of the brain is facing forward such that the right hemisphere is on the left side of the image. Red colors indicate an increase in gamma activity, blue colors indicate a decrease in gamma activity, and green colors are little or no activation. In gray scales, darker shading in the left hemisphere indicates a positive response and darker shading in the right hemisphere

right frontal lobes are activated at any given time. Then, this model can be applied to compare individuals' self-report perceptions of personal attributes to their precognitive response to associated stimuli words, presented while generating ETA imaging data, using the patented process of Validating Ipsative Decision-making with Electroencephalography (VIDE; U.S. Patent No. 9,060,702; 2015).

Approach-Avoidance as Applied to Language

As an example of ETA brain activation imaging, in view of this model, Figure 4 shows an individual's responses to different foreign languages, again using sLORETA. In this example, a participant was exposed to the word enthusiastic in her native language and three different secondary languages that she understood. She showed the maximum positive response (left-side activation) to her native language (Spanish), a relatively neutral (no overt activation in either hemisphere) to English, a moderately positive response (some left side activation) to French, and a strong and complex response (activation on both sides) to German. This was consistent with the fact that she was more comfortable with languages like her own and found German difficult and requiring effort to understand.

High-Speed ETA Imaging of Emotional Processing

It is also possible to collect high-speed imaging at a rate of six frames per second to record precognitive responses over a 1-second time period. Figure 5 displays images generated when an individual was presented with stimuli words relevant to a serious criminal incident. The stimuli words were meaningful to the subject and elicited specific reactions in brief intervals following the words presented. The individual evidently had very different responses to words referring to an employer, family members, or activities. By comparing these responses with the individual's verbal report, it was possible to confirm that he was providing consistent information and that there was no evidence of his attempting to deceive the investigators. Although this was not a lie detector per se, it was nevertheless a way to observe and quantify an emotional response and to correlate it with specific related information. This would appear to provide a valuable new tool for not only forensic but also applicable event-related emotional assessment and therapeutic applications, by exposing emotionally laden triggers.

Human Performance Mind-Sets in the Context of Smoking Addiction

The example illustrated in Figure 6 shows the frontal activation patterns in gamma for two individuals who were evaluated as part of a workplace wellness assessment. Prior to the brain imaging, each participant responded to a wellness survey, including questions concerning any smoking habits.

Then, while using the VIDE application to generate the sLORETA imaging, each were presented keywords or phrases from the questionnaire, and comparisons were run to see if image asymmetry matched their survey responses. In both cases, a match was found between their questionnaire responses and brain imaging. In the case of the nonsmoker, she indicated that she had never smoked and had very strong feelings about the health hazards of smoking; as seen in Figure 6, right-side activation is evident. The smoker, however, admitted on the survey to being a smoker but indicated that he was attempting to quit; as such, his imaging reveals more left-side activation.

The real value in this information is not the fact that the survey and images match but that both show emotion-laden precognitive responses to the stimuli, smoking. The left-dominate gamma reaction by the nonsmoker suggests a strong avoidance to smoking at the precognitive level, whereas the smoker reveals an acceptance response to the stimuli. In this case, it becomes apparent that until the smoker is able to adjust his approach mind-set concerning smoking, he will continue to have difficulty breaking his addiction.

What emerged during this test was an unanticipated benefit of having brain activation data in conjunction with written or verbal report. It becomes possible to determine how well a subject's own report of emotional and decision-making responses correlates with the brain activity associated with each thought, feeling, or action. This sLORETA implementation of the VIDE process provides instantaneous data related to the underlying precognitive brain activity that precedes thinking, feeling, or acting. The brain circuits that are involved with these processes, particularly in the frontal lobes, are revealed through the images that show which areas are active or at rest.

Generally, this type of example shows that ETA-based imaging displays potential to be of value in general coaching, counseling, or psychotherapeutic settings. To be clear, this technology is not intended to be any kind of a lie detector; however, it can be an emotional response indicator that provides immediate data. It is important to note that because this system responds to brain activity within 30

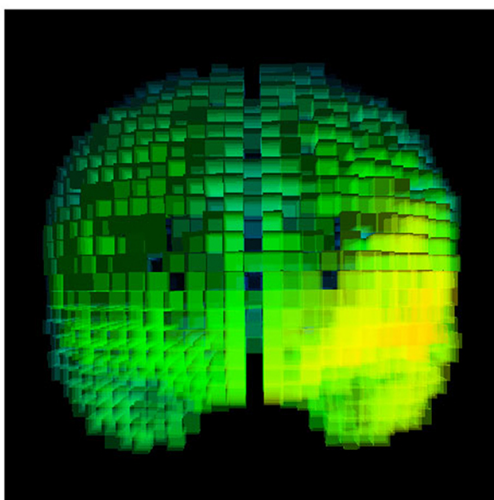# Reactions to the word Enthusiastic
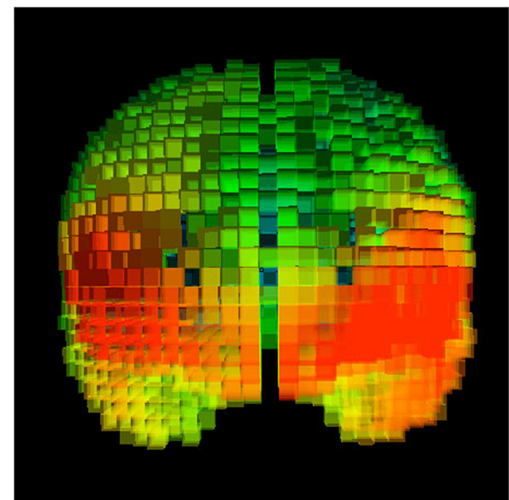
Reactions to the word Enthusiastic
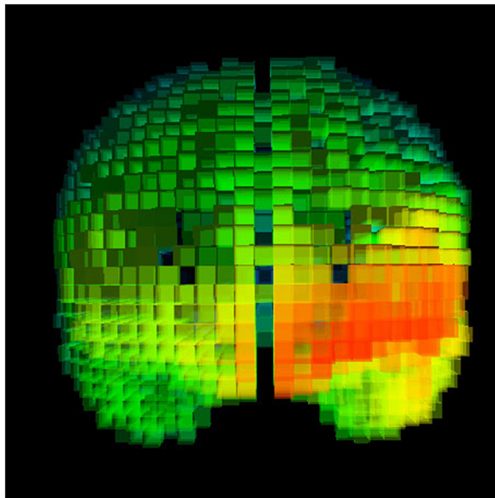
Spanish
(1st Language)
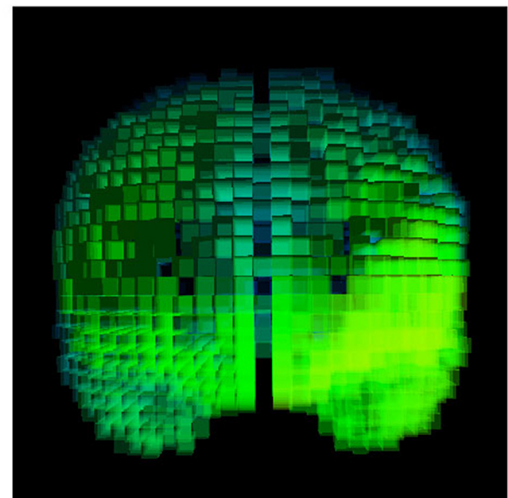
English
(2nd Language)

French
(3rd Language)

German
(4th Language)

Figure 4. Emotional reactions to the stimulus word *enthusiastic* presented in different languages. The orientation of the brain is facing forward such that the right hemisphere, is on the left side of the image. Yellow and red colors indicate an increase in gamma activity blue colors indicate a decrease in gamma activity and
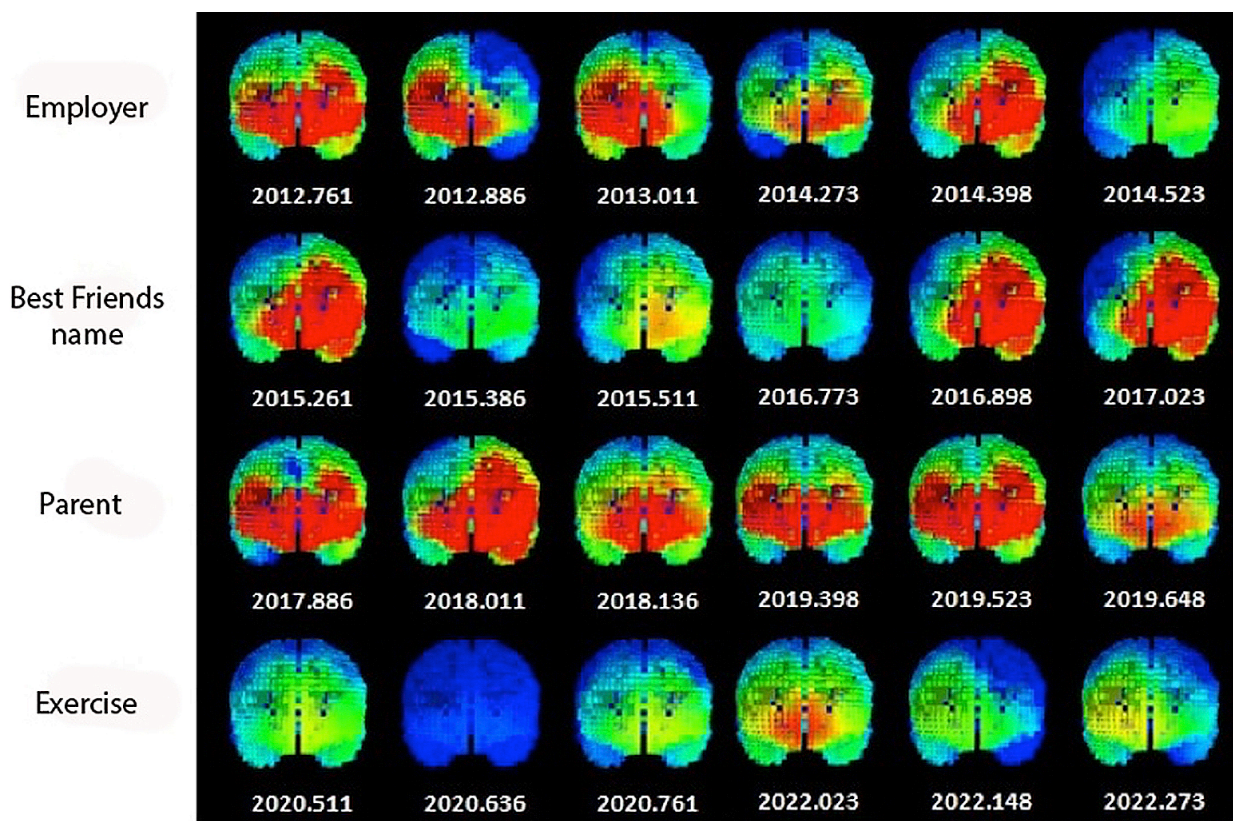
Figure 5. Event-related responses to words presented to a subject under investigation for a crime. The probe words show different sequences of emotional activity, across time. The orientation of the brain is facing forward such that the right hemisphere is on the left side of the image. Yellow and red colors indicate an increase in gamma activity, blue colors indicate a decrease in gamma activity, and green colors are little or no activation. The speed of these images is at a rate of six frames per second, which is directed by the image processing ability of BrainAvatart (Brainmaster Technologies Inc., Bedford, OH) at present.

milliseconds, the visible data precedes the individual's conscious awareness and is thus a preconscious measure.

Directions for Future Research

The capacity to observe preconscious and conscious reactions and judgments using procedures and protocols such as the ones described opens opportunities to apply ETA imaging technology to a wide variety of decision-making settings. Most of the work done in areas such as counseling, therapy, leadership, and coaching involve decision making in some form. Current brain-imaging work demonstrates the underlying mechanisms of learning, emoting, deciding, and acting, but the ETA-based applications provide a real-time mechanism for exploring the brain responses while the individual is directly engaged in everyday choice making. Access to this information gives us the capacity to explore spontaneous approach or avoidance responses to specific stimuli, situations, and/or actions, at both the personal and

interpersonal levels. Given the limitations of other forms of information gathering, the data derived from the ETA imaging applications will create opportunities to make decisions, in a number of critical areas of human performance and relationships, informed by precognitive knowledge. The decision-making model presented will allow us to assess preferences and tailor interventions to individuals' needs.

An area of specific focus in the immediate future is education. Brain wave–based research can aid in more accurate identification of potential learning barriers or negative mind-sets, thus aiding in the customization of the educational process by providing a focused approach to academic delivery and ultimately a personalized approach to education. Implications for EEG-based research in the counseling and therapy arena have similar potential. Assessment, diagnosis, and choice of intervention could be informed using ETA-based assessment and
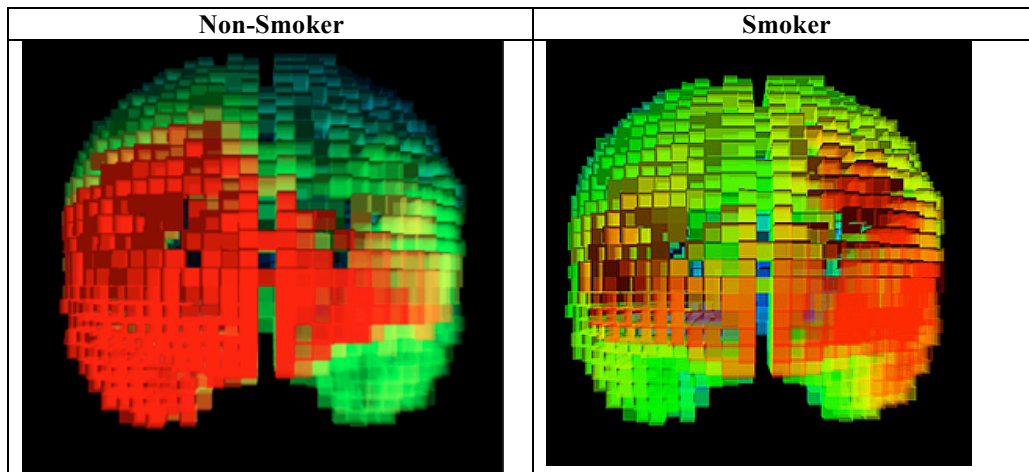
Non-Smoker	Smoker

Figure 6. The image of the nonsmoker reflects strong avoidance response to the term smoking. The image of the smoker indicates an approach response to the term smoking.

guidance by exposing hidden barriers to new goal acquisition.

It is highly predictable that different learning experiences will trigger different precognitive emotional responses based on past experience that may need to be dealt with before mastery can occur. For example, a focus on empathy, as well as sentiments toward others, may provide opportunities to positively affect interpersonal relations via empathic understanding and emotional connectedness. Enhancing tenderness could boost empathy and compassion and smooth differences between feuding partners or family members. Such procedures would be of benefit for family and couples therapists.

The implementation of new technologies in line with VIDE, using ETA imaging, has tremendous potential by opening the doors to our precognitive emotions and the impact they may have on decision making. The guided awareness and self-discovery of these precognitive functions, processes, and preferences for which we are (for the most part) not aware empowers us with a new level of self-knowledge and moves us closer to self-actualization.

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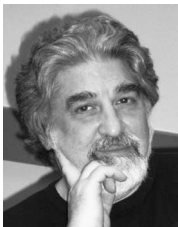
Thomas F: Collura   Nancy L: Wigton   Carlos Zalaquett   SeriaShia Chatters Smith   Ronald J: Bonnstetter

Correspondence: Ronald J. Bonnstetter, PhD, Center for Applied Cognitive Research, 17785 North Pacesetter Way, Scottsdale, AZ 85255, email: ron@ttiltd.com.