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Brain Activation Imaging in Emotional Decision Making and Mental Health: A Review Part 1

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Brain Activation Imaging in Emotional Decision Making and Mental Health: A Review Part 1

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Abstract

In Part 1 of this paper, we describe an approach and methodology that bridges two worlds: the internal, subjective experience of emotions and thoughts, and the external world of brain electrical activity. Using a novel event-related brain activation imaging method, we demonstrate that within single trials, short-term mental processes, on the order of 100 msec, can be clearly related to observed brain activation in controlled experiments. We use an ipsative assessment validation process that combines self-report with real-time EEG recordings to provide a combined picture of both the mental and the brain activity, during short-term reactions, emotions, and decisions regarding controlled information. Part 2 provides a detailed description of the emerging emotional decision-making model.

Keywords: EEG electroencephalograph; electromagnetic tomographic analysis; gamma asymmetry; response process validity; sLORETA; approach-avoidance; decision making; mental health; human performance

Introduction

The practice of mental health can benefit from brain-based models of emotional responses in a format that exposes an understanding of decision-making pathways (1,2). There is a need for models which can be used by counselors and other mental health professionals with or without the use of extra physiological monitoring or biofeedback equipment. The creation of such a model must make use of scientific methods and processes that reveal brain activity related to thoughts, feelings, and behaviors, in a global context.

From a neurological perspective, the brain is a pattern-recognition and decision-making machine that is tailored to operate in the body of a human. Even though it is a part of the human body, it has its own goals and its own means of seeking those goals. Whereas an individual may have goals that include safety, nourishment, comfort, social interactions, and other high-level goals, the brain itself has a much simpler scope. The brain's goals are better understood in terms of the mechanics of recognizing patterns, detecting danger, considering options, determining the safety of various options, and, finally, controlling the motor functions that allow the organism to operate in its environment.

Neuroscience provides a unique perspective on human behavior and mental health. By understanding the underpinnings of the brain's roles and priorities, we can better understand why an individual would think, feel, and act in a certain way. The individual may believe that he or she is in control of their life, making their own decisions and setting their own priorities. But the fact that everyone is dependent on a properly functioning brain for this to happen means that what we think is going on may be far from the facts.

We approached this problem from a conceptually high level. Given that we have tools that rely on self-report, which we have extensively analyzed using traditional statistical protocols, how can we produce corroborating measures that do not rely on the subject's own perception and ultimate reporting? We are concerned with the fundamental problem of the reliability and veracity of self-report, given the myriad of complicating factors and hidden agendas that mediate internal awareness as well as the willingness or ability to disclose.

Establishing the ground work for the role of emotions in decisions

In his book, "Descartes' Error; Emotions, Reasons, and the Human Brain", Antonio Damasio (2)(3) describes his study of people with brain damage to parts of the brain where emotions are generated, including the ventromedial sector of the frontal lobe. He determined that they appeared normal, except that they lacked the ability to experience emotions. But more importantly, he found that they all had one common deficit. Decision-making was extremely difficult for them. Many decisions have pros and cons and without the emotional component, they struggled with even the simplest tasks. The take-away from this research was that decisions have emotional components. Even before Damasio's decision-making assertions, research describing frontal lobe asymmetry and implications for emotional processing provided a theoretical basis for the role played by emotions in decisions can be traced back to 1979 (4), where they described the use of scalp-recorded EEG asymmetry and speculated possible connections to emotional processes. What followed was a plethora of studies focusing on the role of the frontal lobe approach-avoidance asymmetry related to emotional neuro-networks and related decision-making explorations (4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14). A summary of these early studies was published in 2003 (15) that proposed that a greater left-side prefrontal cortex activity appeared to be associated with approach and goal-directed action, while the right suggested avoidance-related emotions.

The role of Approach-Avoidance Frontal Asymmetry

These early studies established that (a.) emotions are crucial to decision-making and (b.) that those initiating emotions appeared to be definable as approach or avoidance asymmetry within the prefrontal lobes. While the ability to differentiate approach (reward) from avoidance (threat) is in itself noteworthy, it is important to understand the bases of this process is directly tied to emotional expressions or behaviors. In 2008 Gordon (10) defines emotions as "adaptive actions tendencies that are mobilized by signals of potential danger or reward. They involve a 'feedforward' mode of brain and body activity that is triggered automatically and without the need for conscious awareness of the triggering signal" (p. 349). They refer to this response to stimuli as a nonconscious emotional reaction, while the authors (16) define this limbic system processing prior to cognitive awareness as a precognition. As justification for this precognition label, Naccache (17) explains that the limbic networks can process threat and reward cues within 200ths of a second, thus supplying a continuous nonconscious response to every interaction we have. Being able to detect the corresponding brain activity when these precognitions occur provides a direct link to the emotions and experiences behind our decisions and exposes our thought processing before conscious thoughts or self-regulation can take place.

It is important to note that through the 1990s research examining and documenting the concept of approach-avoidance was confined to slower frequency analysis, primarily alpha asymmetry. This began to change with a series of experiments (18, 19, 20) which expanded asymmetry analysis beyond alpha to include theta, beta, and to a lesser extent, gamma (8). As a result of these studies, Davidson (8) suggested advancing this line of research by exploring frequencies other than alpha to garner additional information. This identified gap in the research, combined with the noted aspect of gamma discovered by Oakes (21), provides the basis for this focus on gamma asymmetry as a pathway to describing a model for decision-making.

A key component was established when Oakes correlated qEEG low-resolution brain electromagnetic tomography (LORETA) to regional glucose metabolism with positron emission tomography. It was shown that while alpha did show an expected asymmetry relation, the frequency band most consistently and strongly associated with glucose metabolism was gamma in the frontal lobe region. LORETA incorporates a mathematical inverse solution of surface EEG data, which can provide cortical source localization and generates three-dimensional images similar to those produced by fMRI data (22). As defined by The KEY Institute for Brain-Mind Research (23), the LORETA algorithm creates an estimate of brain activity, termed current source density (CSD), in a virtual space representing cortical structures, encompassing 2,394 coordinates, expressed as 7 mm^3 sized voxels. A new generation of the algorithm, standardized LORETA or "sLORETA" (24) advances this concept, and bases the computations on a standard such that the voxel size is 5 mm^3 for a total of 6,239 voxels. The work reported here has demonstrated that it is possible to use a novel implementation of sLORETA to both analyze and view voxel images of real-time gamma brain activity that may reflect emotional states as related to precognitive activity (16, 25).

Materials and Methods

The work reported here followed a process in which well-established methods for self-report and self-rating from the education and management field were combined with an emerging brain activation imaging technique (26,27). This offered the possibility to pursue prior work in emotional decision-making (4, 6, 7) and brain asymmetry (8,9) in the form of increased resolution in time and space. This method provides, with single-trial results, a measure of brain activation with a spatial resolution of 10's of millimeters and a temporal resolution in the range of 100 milliseconds.

The specific internally oriented method is the use of a self-rating scale to ascertain subjects' internal perception of emotional states. The external recordings consist of EEG-based estimates of real-time activation levels, with sufficient time resolution to reflect brain events at the millisecond level and with sufficient spatial resolution to identify individual Brodmann areas.

One of the first applications of this process resulted in two patents that address a validation process for ipsative assessments (26, 27). Figure 1 outlines how sLORETA imaging and the resulting gamma asymmetry can be used as response processing data that can be triangulated to help determine if an assessment respondent is cognitively processing and properly interpreting the intended purpose of the assessment items (28, 29).

Figure 1
Response Process Validation Protocol Using Neurophenomenological Gamma Asymmetry

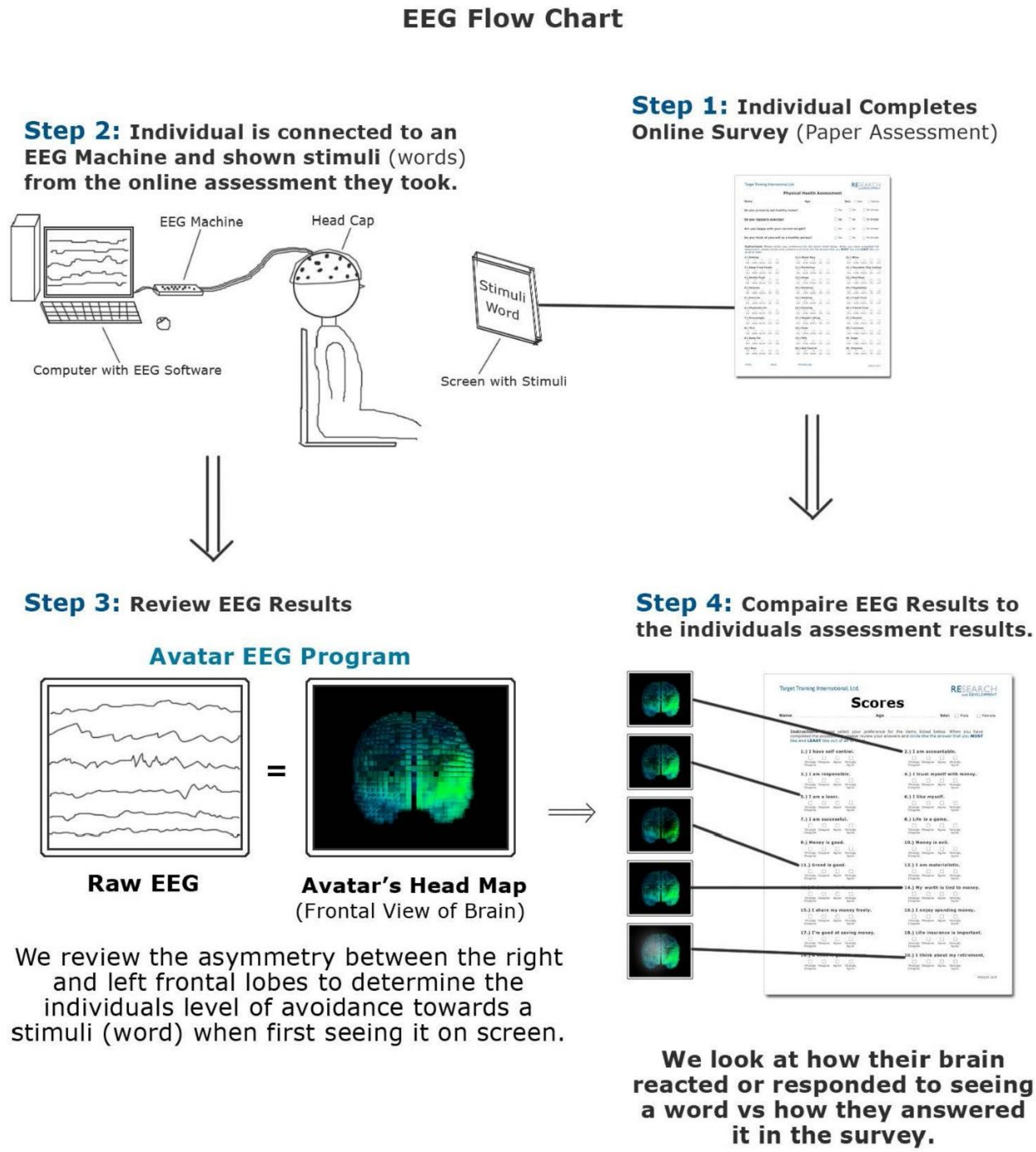


Figure 2
Frontal Lobe Gamma Asymmetry Summary

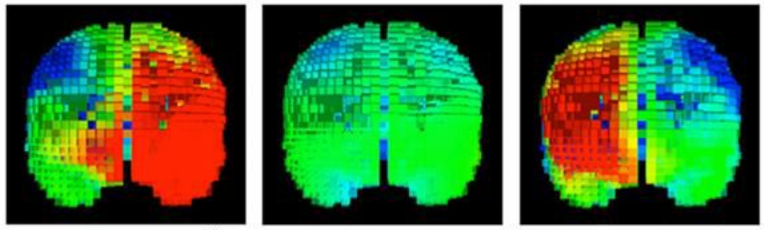


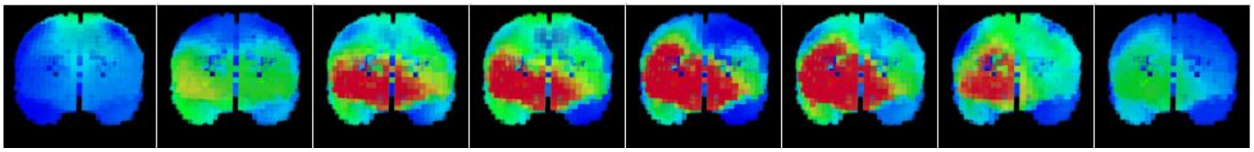
Figure 2 is an example of frontal lobe gamma asymmetry with approach, neutral, and avoidance responses. The orientation of the brain is facing forward such that the right hemisphere is on the left side of the image. Red colors (gray scale as white areas) indicate an increase in gamma activity, blue colors (darkest areas) indicate a decrease in gamma activity, and green colors (the grayest) are indicative of little or no activation, as seen in the neutral image. These represent "snapshots" of the activity at a given moment. Our work has extended these to use a rapid series of such images (8 per second), providing a time-based representation of the emotional and decision-making processes in the frontal lobes.

The use of 1/8 second, as a limit to the data variability, is based on two factors. One is the ability of the brain to produce changes at a given rate, and the other is the ability of the measuring equipment to follow these changes. The output (EEG) can be identified as comprising a series of microstates. Koenig et al. (30) defined microstates as representing building blocks of the thinking process. In a study of over 496 subjects, aged 6 to 80 years, they determined the normative microstate statistics based on surface distributions of alpha waves in subsecond epochs. The study found that the mean microstate duration was between 70 and 100 milliseconds, with a range of microstates per second of between 2.4 and 3.6. Yuan, Zotev, Phillips, Drevets, and Bodurka (31) in their review of EEG and blood-oxygenation-level dependent, (BOLD) networks, also identified microstates as having transients on the order of 100 milliseconds.

The second factor influencing the use of 1/8 second microstates is based on the ability of the data gathering system to provide rapid changes. The quantitative results are acquired by the use of a digital filtering technique that includes control of the time-constant reflected in the ability of the filters to respond. As described by Collura and Tarrant (32) this time-constant can be used to estimate the expected variability in the data across time. According to their analysis, as long as the sampling interval is on the order of the response time-constant, changes in the measured value will be captured without sudden jumps.

Based on these considerations, it was concluded that sampling the filtered sLORETA current-source density data at intervals of 125 milliseconds, producing 8 maps per second, would be sufficient to ensure that state changes would be adequately represented. This can be confirmed by visual inspection of the sequential maps, which confirms that most maps cluster into groups characterized by graded changes, even maps that look distinct from the others appear to have attributes of the neighboring instants, as observable in Figure 3.

Figure 3
One second sequence of decision making representing 1/8th second brain changes.

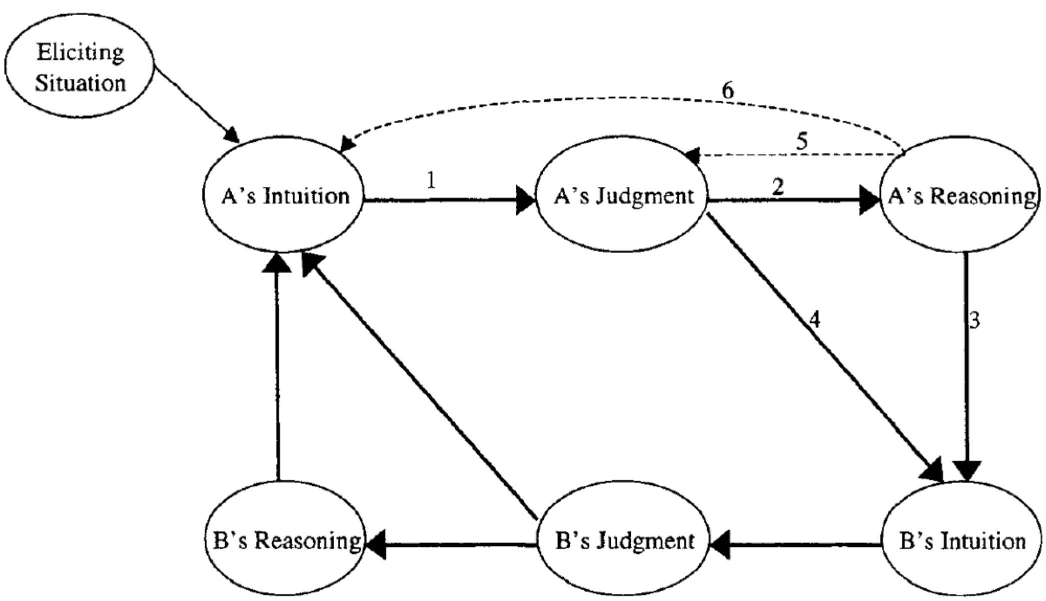


The Basic Model Initiation

Although the fields of neuroscience and mental health acknowledge the role of emotions in decision making, understanding is hampered by a need for more precise models that illuminate the neurological pathways and provide a common vocabulary among fields. By drawing from the work presented above, the authors are able to generate new insights and merge the unique contributions of both neurology and the social sciences.

The Haidt's model (33), as presented in the book "The Emotional Dog and Its Rational Tail: A Social Intuitionist Approach to Moral Judgment", advances decision models by including brain pathways and offering insights into specific decision-making brain activity. His model lays question to the previously accepted "rationalist approach" to decision-making and provides a intuitionist model that suggests that moral intuitions, including moral emotions, come first and directly cause related judgments. He refers to these intuitions as "primary emotions/sensations" and the final judgment as "secondary emotions/perceptions".
Figure 4 demonstrates how an eliciting situation triggers an intuition (emotion) which leads to a judgment, followed by reasoning. Notice that judgment occurs before reasoning. From this graphic one can conjecture that this last phase of cognitive processing is actually more of a process of rationalization and justification than a logical review of evidence.

Figure 4
Haidt's Intuitive Model



This model provides a framework for not only individual A's response to an eliciting situation but also for the interaction with another person B. In this model, persons A and B could be a client and a therapist, a couple discussing an issue, or any two individuals with a particular, definable relationship. This model is thus foundational to the authors' analysis of emotional and rational decision-making, because it applies to human interactions in general.

For example, when two people are communicating, the first person's behavior becomes the second person's experience. They then have an emotional response that leads to a judgment, followed by a form of reasoning. This cycle occurs at multiple levels, primary, secondary and then decision-making and the process loops in a cyclic manner. The dotted lines represented by 5 and 6 suggest that reasoning should influence or be a part of both the intuition and the final judgement and not be an afterthought.

Toward a Model of Decision-making

Initial thoughts that have led to this present model were first described by the authors in "Toward an Operational Model of Decision Making, Emotional Regulation, and Mental Health Impact" (16), where ground work was laid for both a Supervenience Model and an Integrative Model.

Figure 5
Emotional decision-making model showing right and left-brain processes relating to primary emotional sensations and secondary emotional perceptions.

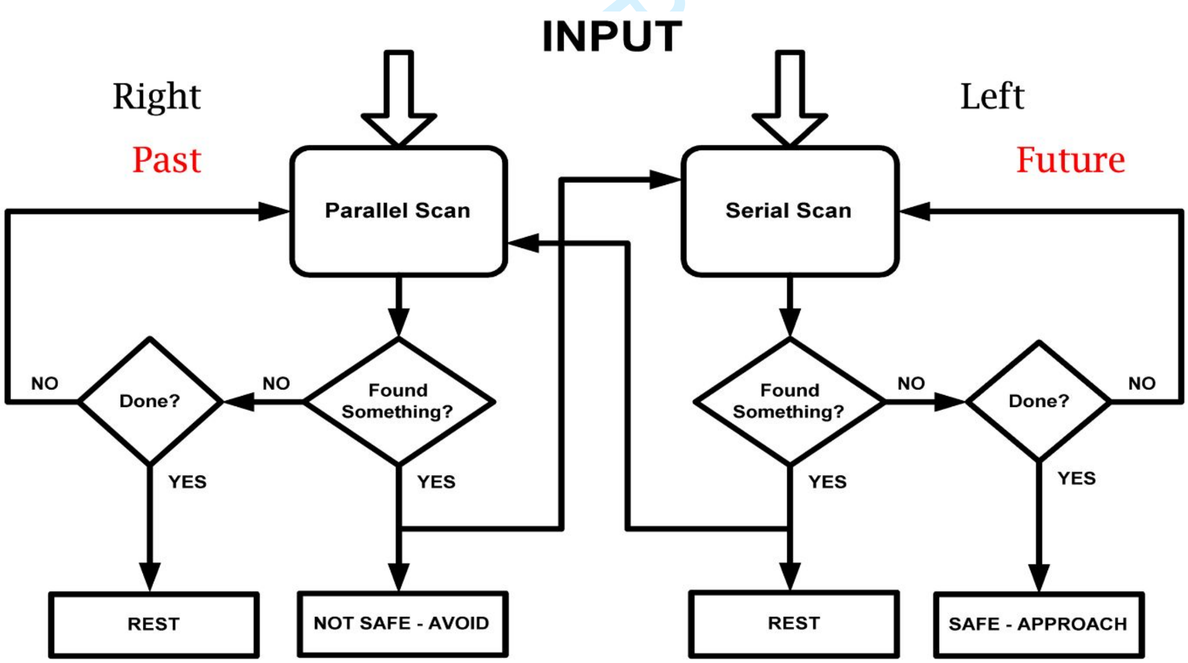


Figure 5 makes an important distinction between the left and the right decision-making processes. Whereas the right hemisphere will tend to reflect a more global, pattern-recognition parallel scan that is based on past experiences and designed to quickly detect danger, the left hemisphere process is a serial, futuristic or predictive process that uses rules and experience to determine the possible future outcomes and to identify safe options.

The supervenience model, developed by Jaegwon Kim (34, 35) of Brown University, describes the challenges associated with directly applying neuroscience principles to mental health issues. The integrative model transitions to the next level of understanding by incorporating the basic functional delineation put forth by Davidson (9) in which a difference exists in the hemispheric roles of the left and right sides of the brain. According to this model, the right hemisphere is responsible for negative emotional states and associated behaviors (e.g. withdraw), whereas the left hemisphere is responsible for positive emotional states and associated behaviors (e.g. approach). Our model builds on this by considering the different modes of processing (parallel versus sequential) as well as different levels of processing (sensation, perception) as dimensions of the model.

Results

This investigation has resulted in a series of studies that demonstrate that the proposed model provides a framework to integrate and interpret the internally focused self-report with the externally driven physiological measures. In particular, we have found that the maps and correlations that result reflect not just the individual's reactions and decisions, but how those relate to the individual's internal world and internal dialog. In order to demonstrate the general usefulness of this approach, a variety of basic experiments has been conducted, each using a particular approach to correlating the physiological measure with an internally reported response.

Pilot studies were conducted to explore a variety of possible dimensions in the emotional decision-making process (36). In one series with several subjects, individuals' responses to food and health probe words was demonstrated, reflecting the self-reported underlying sensations, judgments, and choices. In a 2016 special issue publication by the Association for Applied Psychophysiology & Biofeedback, "The Value of EEG-Based Electromagnetic Tomographic Analysis in Human Performance and Mental Health" (37), an example of a multilingual individual viewing descriptive words presented in different languages showed that the native language (Spanish) was received with positive emotional reaction, while secondary languages (French, English) were less intense but still showed acceptance, and a more foreign language (German) produced an initial mentally confused response. Bonnstetter, Hebets, and Wigton (38) studied responses from subjects who self-rated on an established scale of "soft skills" related to management, in relation to frontal gamma asymmetry data. They demonstrated that in 71% of the subjects, there was a significant positive correlation between self-report and measured gamma, while in others, the correlation was less so, or even reversed. These may reflect individual differences in how subjects viewed their opinions, and whether there were hidden or confused agendas. In addition, a reduction in gamma intensity was observed as subjects ranked their highest to lowest skills. This finding suggests that, for items rated lowest, the characteristic response is more generally one of disinterest, rather than active dislike or avoidance. In a follow up study (29) a comparison between assessment item responses and correlated brain activity yielded several insights, including: 1. Confirmation between survey responses and neurological asymmetry processing, 2. Items that may have socially acceptable or “correct” answers and that therefore fail to match brain-processing imagery, 3. Mixed brain response to confusing and reverse or double negative assessment items, and 4. Reduced gamma activation for a set of assessment items that also exhibit low statistical discrimination values.

Summary

While neuroscience and mental health professionals acknowledge the role of emotions in decision-making, application of this knowledge is hampered by the lack of a common language and a model that illustrates the potential neurological pathways. By better understanding the brain’s decision-making process and the role of emotions in those decisions, we can begin to expose the moment by moment dynamics of human behaviors and the role played by pre-cognitive thoughts. Part 2 of this paper describes a novel and comprehensible decision-making model that applies our present understanding of frontal lobe approach-avoidance asymmetry related to emotional neuro-networks. Armed with this visual model of brain-based electrical activity and combined with counseling methods, a new understanding of decision-making emerges. Evidence-based and time-tested methods such as reframing, paraphrasing, challenging, reflecting, and even listening and attending can be understood in terms of this new framework. The counselor client relationship and interactions now appear in the form of two brains, each responding and deciding each new step, based on a cyclic and evolving interaction. The client’s brain becomes an observable factor, not unlike a heart or muscle, that is preconscious and that underlies the feelings and decisions that become part of the interaction and growth of client and counselor.

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