This publication is a working theoretical model and therefore it is subject to revisions upon further review

The Optimal Function Neurological Paradigm

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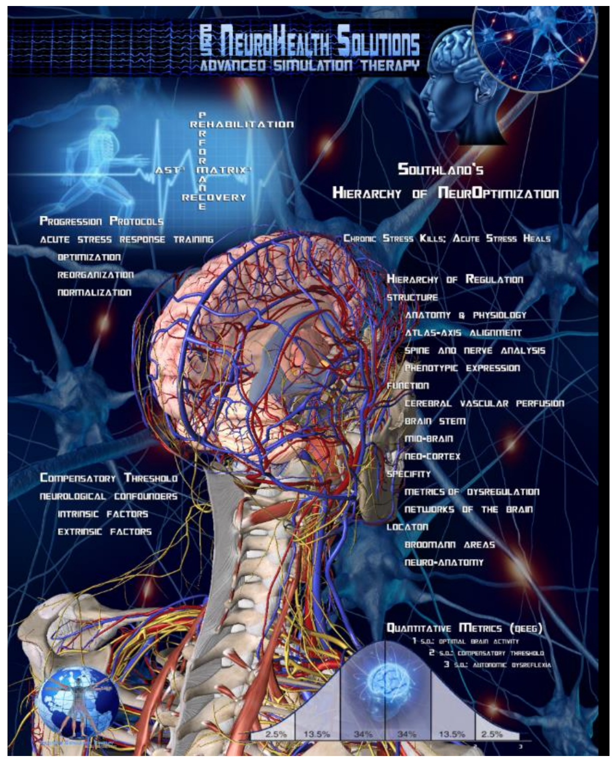
ABSTRACT

Background: It has long been accepted that the brain and nervous system are one of the earliest systems to develop in the human body during the embryonic phase. Neuroscientists acknowledge that the brain and nervous system also continue to develop throughout an individual's entire lifespan until death. [14,17] As a dynamic system which responds to stimuli, the brain can be challenged and therefore, can adapt to change. Actively tasking the brain promotes both biological and physiological responses, commonly referred to as brain morphology.

Objective: This article introduces a theoretical model which considers the true nature of the nervous system and its inherent positive responsiveness to acute stress. Southland et al. developed what is referred to as the Optimal Neurological Function Paradigm, which was conceived through quantitative and qualitative data relative to the efficacy of individual outcomes following participation in neuro/cognitive rehabilitation therapy. This paradigm presents an empirically based conceptual model that can be tested against the experience of other clinicians working in the field of restoring trauma-induced brain dysfunction. The theory embodies a progressive approach to remediate cognitive dysregulation by targeting these three principal ideas: 1) Activate the body, 2) Optimize the mind and 3) Improve and maintain quality of life to restore neural homeostasis. This theory stems from a deep understanding that the body and brain are in a constant state of flux, recovery, rehabilitation and homeostasis through life's transitions.



Conclusions: Although more research is needed to study the effects of acute stress response training, Southland et al. is finding growing evidence suggesting positive outcomes from neuro/cognitive rehabilitation. Southland et al. elucidates these outcomes of the nervous systems recovery process in this model, supported through observation of thousands of clinical acute stress response training sessions with individuals seeking an alternative, non-invasive, non-pharmacological approach to neurological health and recovery. The elements described in this model are being used within a pilot study that is currently underway looking at the effects of acute stress response training on patients with traumatic brain injuries. The hope is to redefine how traumatic brain injuries are assessed and treated, offering a new approach to neuro/cognitive recovery.

Keywords: acquired brain injury, acute stress response, autoregulation, biofeedback, brain morphology, cerebral vascular integrity, cerebral vascular perfusion, clinical quantitative electroencephalography (qEEG), compensatory threshold, concussion, extrinsic factors, homeostasis, intrinsic factors, neuro/cognitive rehabilitation therapy, neurofeedback, neuroplasticity, pulse electromagnetic frequency (pEMF), stroke, tactile feedback, trans-dermal alternating current stimulation (TDACS), traumatic brain injury (TBI), vascular dysplasia, z-score training

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INTRODUCTION

Advancing research and technology in the field of neuroscience call for the evolution of a more integrative, neuro/cognitive function recovery model. The Optimal Neurological Function Paradigm addresses and defines acute and chronic stress, neurological homeostasis, neuroplasticity and the essential therapeutic constructs to maximize recovery. The inception of this theory was bred from the ideology that “Chronic Stress Kills, Acute Stress Heals.” This ideology is supported through continual research in which acute stress has shown to significantly enhance nervous system function, while chronic stress often suppresses nervous system function. When considering the body and brain, which operate along a dynamic continuum between recovery, rehabilitation and optimal performance, the nervous system will naturally seek to reorganize until a state of homeostasis is reached under all conditions. This paradigm focuses on elevating cerebral vascular perfusion and promoting neuroplasticity, which in turn bolsters the resources required by the brain to maintain normalized function and assist in the remediation and healing of a multitude of brain function maladies. The key to achieving and maintaining normalized brain function and optimal health lies in acute stress, as is the case with most systems in the human body.

THE THEORY

Each of the subsequent components of the Optimal Neurological Function Paradigm contribute to an integrated approach to the remediation of a dysregulated brain and nervous system. By creating synergy between the body’s natural recovery processes and state of the art neuroscience technology through quantitative objective metrics and qualitative measures, a comprehensive, integrated picture of the power of the nervous system to heal itself can inescapably be painted.

1.1 ACUTE STRESS RESPONSE TRAINING

The introduction of acute stress response training for the nervous system was constructed using current neuroscience research which confirmed efficacy in brain training, specifically the prefrontal cortex, when the brain is actively engaged and challenged to multitask. During active brain tasking, a shift occurs from slow neural networks, which facilitate deliberative processing focused on “general purpose”, to fast automatic processing in the brain facilitated by task-specific processing networks.[5] Acute stress response training is used in neuro-cognitive rehabilitation settings to increase cerebral vascular perfusion and heighten one’s primary motor, sensorimotor and neocortex. Acute stress is a mechanism of action for enhancing nervous system function and yields positive physiological and biological changes. This is evidenced in research during cell proliferation in the brain, specifically in the hippocampus during astrocytic fibroblast growth factor 2 (FGF2) expression. Astrocytic fibroblast growth factor 2 is a mechanism of cell growth which induces gyrification and cortex expansion, improving functionality of the brain. Adversely, chronic stress can cause maladaptive changes to the brain, specifically to the amygdala, hippocampus and prefrontal cortex, causing memory impairment and diminished neurogenesis.[1,8,15] The belief that "Chronic Stress Kills, Acute Stress Heals" is confirmed during observation of changes to the nervous system when the body is exposed to chronic stress. Chronic stressors such as a lack of blood flow to the brain, can result in cell death and nervous system dysfunction. The brain is an organ which requires a vast amount of blood flow to efficiently activate the body and reinforce normal brain function by maintaining optimal neurovascular health.[6] The positive outcomes following acute stress response training include an overall benefit regardless of maldevelopment or disorder, delaying the effects of aging on the human brain, mitigating symptoms of neurological disorders, improving neuromuscular function, increasing neural pathway regulation, promoting neural plasticity and stimulating neurogenesis and synaptogenesis. Research suggests enhanced neurogenesis following acute stress to the body produces highly plastic, newborn neurons. Research also suggests proliferation stimulated by acute stress supports subsequent memory benefits.[8] Stimulating cerebral vascular perfusion and neuroplasticity using a multitude of modalities to optimize neural connectivity trains the brain to remediate brain function maladies, essentially preparing the brain to better handle life's inevitable intrinsic and extrinsic experiences.

1.2 MODULATION OF INTRINSIC AND EXTRINSIC FACTORS, AND NEUROLOGICAL CONFOUNDERS

Intrinsic and extrinsic factors are comprised comprised of inherent and environmental conditions under which brain and nervous system functionality adapt to or compensate for. Intrinsic factors include but are not limited to age, gender, ethnicity, genetic predisposition, brain morphology, etc. Extrinsic factors include but are not limited to physical activity, diet, environmental toxins, physical and emotional trauma, lifestyle choices, etc. Neurological confounders also influence the outcome measures of nervous system activity. These factors are inherent conditions that exist on an individual basis and affect the outcome of optimal brain and nervous system function. Confounders can be utilized to predict disease barring no other risk factors are involved. Age is an example of a strong confounder, as it is not a cause for disorder however represents a confounder because it connects the relationship between any reputed risk factor and disease.[7] The significance of intrinsic and extrinsic factors and neurological confounders becomes apparent when administering neuro/cognitive rehabilitation as they may inhibit or challenge neuroplasticity. Neuroplasticity is the nervous system's ability to respond to life's biological and environmental intrinsic and extrinsic stimuli through structural reorganization, system function, and neural connections. Neuroplasticity can conceivably be positively adaptive or negatively maladaptive. Neuroplasticity is positively adaptive when functional gains occur and negatively maladaptive when functional losses or the depth of an injury deepens.[2] Acute stress response training used in neuro/cognitive rehabilitation boosts positively adaptive neuroplasticity, modulating limitations intrinsic and extrinsic factors may pose and moves the nervous system in the direction of optimal functionality. Intrinsic and extrinsic factors and neurological confounders contribute to compensatory threshold following maladaptive modification of the nervous system. Compensatory threshold is a measure of the severity of dysregulation, manifested through compensatory behavioral development or with the onset of disease in which modification of the nervous system occurs.

1.3 REBUILD COMPENSATORY THRESHOLD RESERVE

Compensatory threshold is a measurement of dysregulation that begins to impact an individual's quality of life. Clinical quantitative Electroencephalography (qEEG) identifies metrics of dysregulation which cause quality of life changes and are observed between + or - two standard deviations of normal brain activity. Southland et al. aspire to remediate dysregulation for individuals who are beyond ideal standard deviations for optimal quality of life. Clinical qEEG is used to evaluate and measure the severity of dysregulation affecting an individual's overall brain function. Clinical qEEG is utilized to indicate a breach in maximum compensatory threshold and consequently a decreased quality of life and autonomy.

A study which examined the performance of cognitively demanding tasks, established that compensatory brain activity occurred and was evidenced by anterior frontal brain activity which was not active at baseline during primary task-related activity. The researchers found the anterior frontal brain was recruited to compensate for fatigue-induced impairments in the primary task-related network. Furthermore, over time researchers concluded that these compensatory mechanisms terminate as cognitive fatigue worsens.[18] Such research further supports the argument that the brains resiliency allows for reorganization and compensation when tasking demands are high. However, a threshold for compensatory mechanisms in the brain do exist and once this threshold is reached, the brain's ability to maintain normalized function and homeostasis is compromised at which point maladaptive symptoms become apparent in other systems of the body.

1.4 EMPLOYING QUANTITATIVE METRICS TO GUIDE THERAPY

Clinical Quantitative Electroencephalography (qEEG) is utilized to assess brain and nervous system function with objective measures supported by clinical evidence and scientific validity in reference to normative databases that indicate standards of dysregulation. The functional information gathered by using qEEG, which is a complex mathematical analysis of raw EEG recording, provides clinicians with an individualized neuro/cognitive rehabilitation approach to remediate neurophysiological and neuropsychiatric symptoms associated with nervous system dysregulation. The effectiveness of qEEG in providing empirical evidence relative to nervous system abnormalities has been heavily researched and evaluated. Supreme Court rulings dating back to the 1990's acknowledged that qEEG meets the criteria for standards for scientific methods, supporting the use of qEEG as an "admissible and clinically valid method in the evaluation of the nature and severity of neuropsychiatric disorders,".[4]

The clinical qEEG metrics are used within the neuro/cognitive rehabilitation model to recognize where brain activity dysfunction occurs. If brain activity is within one standard deviation from a normative baseline, this is an indication of normal brain activity. Brain activity within two standard deviations from a normative baseline introduces compensatory threshold which is observed during further assessment of the nervous system. When brain activity is within three standard deviations and beyond, signs of autonomic dysreflexia are observed. Using innovative neuroscience technology, neuro/cognitive rehabilitation can further advance the benefits of acute stress nervous system training and progressively transition an individual within healthier metrics below two standard deviations.

1.5 OPTIMIZE, REORGANIZE, AND NORMALIZE TO ELEVATE AND SUSTAIN NEURAL HOMEOSTASIS

The brain normalizes when neural network pathways reach homeostasis and form a consistent yet dynamic state of organization. Nervous system reorganization is constantly in a state of flux as the body adjusts reach homeostasis. Research has shown several ways in which the nervous system reorganizes when challenged with compensating for damaged or injured areas of the brain which disrupt normal function. In a study with blind subjects, researchers reported that the occipital cortex intervenes and assists during Braille reading, inferring cross-modal plasticity. Similar cross-modality reorganization occurs in the brain following injury such as stroke. Motor function restoration may be attributed to adjacent cortical areas and their acquisition of the function of the damaged areas or implementation of the use of other alternative motor pathways. These findings suggest cross-modal plasticity likely improves compensatory sensory modalities needed in nervous system reorganization.[2] Cross-modal plasticity paired with inherently built-in network redundancies created by the nervous system to compensate for neurological losses, allow the brain the most efficient neural function by modulating its response to the challenges at hand. Acute stress response training activates the brain and nervous system and initiates more efficient neural connectivity and promotion of an overall improvement in normalized function. Other such inherent factors which affect the outcome of optimal brain performance include structure, function, specificity and location.

1.7 BRAIN AND NERVOUS SYSTEM REGULATION

Understanding an individual's intrinsic and extrinsic factors as they relate to neurological structure, function, specificity and location allows for a more personalized neuro/cognitive rehabilitation plan with greater outcomes. Consideration of the functional neuroanatomy of the brain is an integral part of understanding the Optimal Neurological Function Paradigm and potential pathophysiology of the nervous system.

STRUCTURE

Structural analysis of the brain and nervous system include but are not limited to anatomy and physiology of the brain and spine, atlas and axis alignment, atlanto-occipital function and phenotypic expression. New research is suggesting that structural absolute or relative size may not be a contributor to increased function as much as other components such as neural cell types, molecular changes and broadened and elaborate patterns of neuronal connectivity.[17] These are but a few of the indicators that are considered when identifying etiology and pathophysiology of neurological debilitation which may alter a neuro/cognitive rehabilitation plan.

FUNCTION

To attain optimal brain function, cerebrovascular perfusion, brain stem health, midbrain and healthy functionality of the neocortex must be considered. Cerebral vascular perfusion is the blood flow to and from, and within the brain. Homeostatic blood flow is crucial in determining the integrity of arteries and veins which feed neural tissue. The onset of neurological dysregulation can point to a myriad of structural deficits or inadequacies in structural integrity.

The mechanism of action for information and sensory processing in the brain is largely contributed to the flow of information through specific anatomical structures, all of which can be altered after a traumatic brain injury. The hierarchy of brain morphology contributes to brain function from the inferior regions of the brain such as the brainstem responsible for automatic responses and movement, on into more complex regions of the brain such as the basal ganglia responsible for refining movement, thoughts, emotions, etc. and finally ending with the cerebral cortex, which fed by feedback and regulation from the basal ganglia, is the most superior area of the brain responsible for final execution of tasks within the human body. The hierarchy of brain morphology as it relates to function flows in and out of the cerebellum through cerebellar peduncles in order of superiority which begin in 1) Inferior brainstem areas, moving to 2) Middle areas from the cortex and ending with 3) Superior areas of the cortex during initiation. The inferior area of the nervous system, the spinal cord, relays sensory information first to the brainstem which is responsible for several functions including autonomic regulatory control of respiration, transmission of signals from the cerebrum to the medulla and sensory signals to the thalamus. The brainstem is often referred to as the "oldest" part of the brain as similar structures with related functionality are found in less evolved animals such as crocodiles. The basilar region of the brainstem assumes primary control of very basic automatic function related to "life support" such as breathing, swallowing, digestion and heartbeat. The brainstem is a contributor to motor control, acting as a processing center for information related to balance, gaze, vestibular and postural control. The brainstem essentially serves as a direct conduit for signals travelling through ascending and descending tracts to and from the spinal cord. Other brainstem function includes auditory and visual pathways which assist in ocular movement. From the brainstem signals reach the internal capsule which houses the basal ganglia, a group of deep nuclei which receive input from various structures and sends output via a looped system created by projections. The basal ganglia act as a processing center to refine various functions through a multitude of loops including the scaling of movement, provide emotional control to the limbic system and cognitive and executive function to the pre and motor cortices. While the basal ganglia are essential in carrying out crucial adjustments to previously noted functionality, the basal ganglia are not the region of the brain which initiates movement. Research in nerve cell recording shows that basal ganglia neuron activity lags that of cortical activity and therefore is an unlikely source of movement initiation.[10] The middle and superior areas of information processing and finally initiation and higher functioning occurs in the cerebral cortex. The neocortex is the somatosensory, motor and auditory area of the brain and is also involved in spatial reasoning, conscious thought and language. The motor cortex sends the signal to initiate movement through direct and indirect pathways to the spinal cord, completing the final phase of brain morphology function within the brain morphology hierarchy paradigm. The lymphatic system is a network of tissues and organs which assist the body in waste and toxin removal. Through the delivery of lymph, which is a fluid containing white blood cells specialized to fight infection, the lymphatic system plays a vital role in maintaining the body's healthy immune system. The lymphatic system can be assessed for healthy function by testing protein concentrations in cerebral fluid and by completing a complete blood count to check for infection which is detected in the lymphatic system.

SPECIFICITY

Specificity of optimizing neurological function is the normal comparison data that identify the neural metrics of dysregulation and neural networks of the brain relative to specific activities and biological and physiological function.

LOCATION

Specific areas of dysregulation can indicate actual nodes and networks of the brain which are the basis for observed dysregulation. These locations are recognized as Brodmann areas which provide a mapping of cortical function as it relates to location and neural anatomy of the brain itself. Cortical functional mapping of various regions of the brain as is found in Wilder Penfield's cortical homunculus further expands our understanding of sensory and motor cortices function in conjunction with limbs and organs of the body. The cortical homunculus is a loose projection of the body onto a region of the brain which is tasked with executing motor control or sensory functions.

The health of a person's nervous system is pertinent to the design and execution of an individualized neuro/cognitive rehabilitation plan. Without considering neuroanatomical areas and their associated function, which are largely affected by trauma, our complete understanding of normal function is lost. Nervous system structure, function specificity and location is used as a guide throughout a neuro/cognitive plan to rehabilitate and remediate dysregulation in all systems of the body

CONCLUSION

Although this Optimal Neurological Function Paradigm offers a better understanding of dynamic and power of neuro/cognitive rehabilitation and other neural optimization modalities in conjunction with optimal output and function in the brain and nervous system, there is still more to know. The importance of an integrative approach to restoring trauma induced brain dysfunction by integrating various essential therapeutic constructs such as acute stress response training and clinical qEEG, lends itself to continuous examination of an individual's deficits or advancements throughout their neuro/cognitive rehabilitation. A global approach to neuro/cognitive rehabilitation also addresses the need for a relevant spectrum of practitioners and researchers to share empirically based observations and connect them with basic science research. Neuroscience will continue to uncover more about brain morphology and with the help of cutting-edge technology, neurophysiological advancements will give rise to the most effective, non-invasive therapeutic alternatives to pharmacological solutions for brain function maladies and pathologies.

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